Organic production systems research in blueberry and blackberry – a review of industry-driven studies

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Abstract

Organic berry production is expected to expand further in the future as consumer demand continues to increase and growers become more interested in higher-value niche markets. To help growers target these markets, long-term organic systems trials were established at Oregon State University's North Willamette Research and Extension Center (Aurora, OR, USA) for blueberry in 2006 and for blackberry in 2010. Each planting is 0.4 ha and was certified organic (Oregon Tilth) prior to the first fruit harvest. Both trials are based on industry-driven priorities and were designed through communication with an advisory group consisting of organic and conventional growers, wholesale fruit packers, and research and extension faculty. Initial challenges included finding economical weed and nutrient management tools and adapted cultivars of both crops. Cumulative yield with various production systems ranged from 21 to 60 t ha^{-1} in blueberry (2008-2013) and 13 to 26 t ha^{-1} in blackberry (2012-2013). Successful outcomes include information on differences between cultivars in ease of management in organic production; sensitivity of blueberry to high N fertilizer rates (also a problem in conventional systems); benefits of compost to blueberry nutrient management; impacts of weeds on blackberry yield; establishing plantings using drip irrigation and fertigation with fish emulsion; and the successful use of weed mat to increase yield compared to sawdust mulch in blueberry and hand-weeding in blackberry. Growers now have better management options for organic fertilization and weed management, and many have shifted to using weed mat mulch in organic and conventional plantings and are fertigating more economically with fish emulsion.

Keywords: *Vaccinium corymbosum*, *Rubus* sp., weed mat, landscape fabric, certified organic, weed control, sawdust, mulch, compost

INTRODUCTION

Approximately 10 to 15 years ago, berry growers saw opportunities for growth in organic production with strong markets for fruit, coupled with a relatively small certified organic area planted. Prices for organically grown berries have been 20 to 100% higher than for conventionally produced fruit. Often, the higher price paid for organically certified berries is considered a premium, intended to offset greater production costs associated with organic production systems. However, in most areas, organic production still fits only a small, niche market. The main challenges to rapid expansion of certified organic berry production include greater production costs or inputs (particularly for fertilization and weed management), limited options for disease or insect control (particularly in regions with pests that have a large impact on marketable production), and reduced yield of organic plantings (whether perceived or real). These production challenges may be coupled with markets where the demand and price for organic fruit are not high enough to stimulate new plantings, as growers are concerned about whether returns will be enough to more than offset the expected higher costs of organic production systems (Strik, 2014).

The western USA is considered to have advantages for organic production of berry crops, including reduced weed and disease management costs in the dry, low humidity summers common in this region, and the absence of some important disease and insect

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pests that cause losses in some other production regions (Strik, 2014; Strik and Yarborough, 2005).

There are presently three production guides for organic highbush blueberry and one for organic blackberry in North America (Carroll et al., 2011; Krewer and Walker, 2006; Kuepper and Diver, 2004; Kuepper et al., 2003). However, while these guides offer some general recommendations, these are based on anecdotal information with little research to compare methods. Furthermore, there is no information on organic production systems available for trailing blackberries specifically grown for high-value processed markets, particularly whether machine harvest can be used (as is common in conventional production) and whether such systems are profitable. Growers interested in the processed blackberry market have questions as to whether labor-saving machine harvesting technology can be used in organic systems when even “beneficial” insects could become harvest contaminants.

Our organic production systems research was initiated when the blueberry and blackberry industries in Oregon felt there was a need for targeted organic research. Key industry leaders met with B. Strik and discussed opportunities and needs. An advisory board was developed for each project, including representation from organic and conventional growers, wholesale fresh and processed packers, the nursery industry, and research and extension colleagues in Oregon, Washington, and California. The Advisory Board met initially to discuss industry priorities and questions and has since met regularly to provide useful direction on field maintenance, review project outcomes, discuss obstacles in the work, if any, help disseminate project findings throughout the grower community, and to discuss future project opportunities.

Obtaining the initial funding to establish the research trials was challenging, particularly in blackberry where the Oregon Raspberry and Blackberry Commission, a common source of funding for industry-priority research, could not fund organic research since all of the assessments (1% of gross sales) are from conventional growers. This was not a hurdle for blueberry, however, where the Oregon Blueberry Commission (growers are assessed at US$ 8.80 metric ton^{-1}) funded establishing the trial. In addition, to having growers and extension/research personnel interested in organic research trials, there have been good funding opportunities provided by the USDA-ARS federal grant programs, the Organic Farming Research Foundation, and industry groups/organizations (Strik, 2014).

Through our initial meetings with the Advisory Board, we learned that growers had many questions about organic berry production, the answers to which would help them decide if the possible benefits would outweigh the perceived risks. When we started our organic production systems research, the key questions were as follows: 1) Can blueberry and blackberry be grown in certified organic production systems, achieving sustainable, commercial yields?; 2) Do cultivars differ in adaptation to organic systems?; 3) Can production systems be refined to decrease costs, increase productivity, and ensure high-quality fruit?; 4) Is weed control critical in blackberry production, or are the plants vigorous enough to withstand some weed competition?; 5) Is weed mat a sustainable method of weed control in berry crops?; 6) How can growers ensure adequate plant nutrition in organic systems, especially when many organic fertilizers contain nutrients that may not be required?; 7) Can fertigation be used successfully in organic systems?; and 8) Do existing nutrient standards developed for conventionally-grown berries apply to organic production?

Long-term organic systems trials were established at Oregon State University’s North Willamette Research and Extension Center (NWREC; Aurora, OR, USA) for blueberry in 2006 and for blackberry in 2010. Each planting was certified organic (Oregon Tilth, Salem, OR) prior to the first fruit harvests. Here, we summarize our significant outcomes to date, and conclude with a discussion of observed changes to organic and conventional production systems documented over the last several years.

ORGANIC BLUEBERRY TRIAL

The long-term goal of our blueberry trial 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 economic benefit to growers.

In autumn 2006, we established a 0.4-ha research planting at the NWREC that was "transitional" in the establishment years, but was certified organic in the first cropping year (2008) – a typical pattern for commercial growers. The trial was designed to simultaneously evaluate the effects of planting method, fertilizers, and mulches on growth and production in two cultivars of northern highbush blueberry. Treatments were selected in consultation with the Advisory Board and were based on considerations for fertility maintenance, irrigation and soil management, and projected cost and ease of weed control within the context of an organic system. There are 48 treatments in the trial arranged in a 2×4×6 split-split plot design with five replicates. The treatments include two planting configurations (flat ground and raised beds) as main plots, four fertilizer treatments (feather meal and fish emulsion applied initially at "low" and "high" rates of 29 and 57 kg ha^{-1} N during first 2 years of establishment and then increased incrementally as the planting matured to 73 and 140 kg ha^{-1} N by 2013) as subplots, and a combination of two cultivars ('Duke' and 'Liberty') and three mulch treatments (sawdust, compost + sawdust, and weed mat) as sub-subplots. The entire planting contains 10 rows (110 m) + 2 guard rows and has a total of 240 treatment plots. The rows are centered 3.0 m apart, and sub-subplots consist of six plants spaced 0.76 m apart. The plants were pruned in January each year and were irrigated using a single line of polyethylene drip tubing (Netafim, Fresno, CA). The tubing had 2 L h^{-1} pressure-compensating, inline emitters spaced every 0.3 m. Details on planting establishment are provided elsewhere (Larco et al., 2013a). Briefly, Douglas fir sawdust and yard debris compost mulch were applied initially at planting and reapplied every 2 to 3 years. The sawdust was applied each time on top of the planting beds to a depth of approximately 9 cm, while the compost was applied 4 cm deep and covered with 5 cm of sawdust for weed control. The compost was produced from woody tree and shrub trimmings collected from urban yard maintenance. Black weed mat (porous polyethylene) was initially installed in February 2007 during the winter after planting. The weed mat was 1.5 m wide and centered over the planting beds. A 20-cm diameter hole was cut in the weed mat for each plant and covered with 5 cm of sawdust mulch. We replaced the weed mat in February 2011 with "zippered" weed mat. The new configuration allows us to "open" the weed mat and apply the feather meal fertilizer. Weeds are removed by hand-weeding from plots mulched with sawdust and weed mat (i.e., the planting hole area) and are controlled using OMRI-approved lemon grass oil in addition to hand-weeding in plots mulched with compost + sawdust. Weed control costs have been reported for the establishment years (Julian et al., 2012).

Feather meal (Nature Safe; 13N-0P-0K) and fish emulsion (Fish Agra; 4N-0.4P-0.8K) were applied by hand around the base of the plants during the first 2 years after planting (2007-2008), and were later applied along the side of the beds for the liquid fish (2009-2010) and feather (2009-present). From 2011-present, the fish emulsion has been applied through the drip system (fertigated) in approximately seven equal applications.

From the first (2008) through the seventh (2013) fruiting seasons, ripe fruit were harvested by hand four to six times per year (approximately every 7 days). The planting was sprayed with a spinosad (Entrust) weekly, starting after the 'Liberty' fruit first turned blue, to help control spotted wing drosophila (*Drosophila suzukii*). No other pesticides were required during the study period. Scare alarms (Bird Guard LLC) were used for bird control. To determine the returns per treatment, we sold the fruit to a commercial organic berry packer (fresh and processed markets).

Fruit production

Blueberry plants may be grown on flat ground or on raised beds. Raised beds improve drainage and help to reduce root rot (Bryla and Linderman, 2007; Bryla et al., 2008). They also increase machine-harvest efficiency (Strik and Buller, 2002). During the first 2 years of organic production, blueberry plants grown on raised beds produced 33% higher yields than those on flat ground (Larco et al., 2013a), warranting the added establishment costs and leading to a greater economic returns (Julian et al., 2012). Cumulative yield (2008-2013) averaged 22% greater on raised beds than on flat ground.

Cumulative yield with various production systems ranged from 21 to 60 t ha^{-1} (2008-2013). 'Liberty' has had a greater yield than 'Duke' in each fruiting season (Figure 1). Yield of 'Duke' was significantly reduced due to bird depredation in 2013. In a related study, seven other blueberry cultivars grown in certified organic production systems responded well from the second through seventh fruiting seasons, but differed in plant sensitivity to soil pH and associated challenges in nutrient uptake (Strik, in progress).

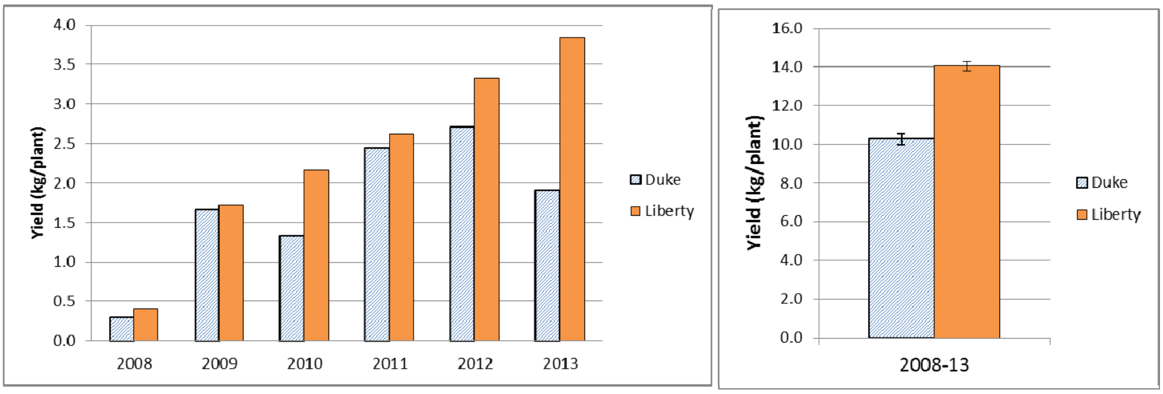

Figure 1. Effect of blueberry cultivar on average yield per plant when grown in certified organic production systems (averaged over fertilizer source and rate, mulch and raised/flat) from 2008-2013 (year 2 through 7). Cumulative yield on right.

Plants also had 33 and 17% greater yields during establishment with weed mat or compost + sawdust, respectively, than with sawdust alone (Larco et al., 2013a). Weed mat has maintained a yield advantage over sawdust, to date, by a total of 7%. However, weed mat also reduced average berry weight in 2 out of 6 years and fruit firmness in 3 out of 6 years relative to the compost treatment (data not shown); research is underway to determine the cause(s) for these measured effects.

Yield was also higher during establishment when plants were fertilized with the low rate of fish emulsion than with any other fertilizer treatment in 'Duke' but was unaffected by fertilizer source or rate in 'Liberty'. Higher yield with fish emulsion than with feather meal was due at least in part to differences in the efficiency of N delivery to the plants (Larco et al., 2013a; Valenzuela-Estrada et al., 2014). Cultivars have responded differently to fertilizer source/rate. In 'Liberty', there has been no effect of fertilizer source or rate on yield, whereas in 'Duke', fertilization with feather meal has produced the highest yield. In 'Duke', fertilization with the low rate of fish emulsion led to greater cumulative yield than with the high rate of fish. Fertilization with the high rate of fish increased berry percent soluble solids (4 of 6 years) and firmness (4 of 6 years) relative to the high rate of feather meal (data not shown); research is underway to determine the associated causal factors.

Mulches and weed control

Surface mulches generally reduce weeds and improve plant growth in blueberry (Clark, 1991; Clark and Moore, 1991; Lareau, 1989; Moore, 1979; White, 2006). Douglas fir (*Pseudotsuga menziesii*) sawdust was traditionally used for blueberry in the Pacific Northwest. In our systems trial, weed coverage and cost of weed management were greater during establishment for the compost treatment than for sawdust alone or weed mat (Larco et al., 2014). Lemon grass oil applied every 3 weeks in summer was effective on small weeds; however, hand-weeding was required in all treatments. Weed problems are a major obstacle to utilizing compost as a "stand alone" mulch in organic cropping systems and, therefore, is recommended for use in combination with sawdust or weed mat.

Weed mat has continued to reduce weed control costs (Julian et al., 2012) and improve production relative to the organic mulches. Concerns have been expressed about possible negative impacts of increased soil temperatures found under weed mat on plant growth

(Neilsen et al., 2003; Williamson et al., 2006). In our research to date, we have found increased soil temperatures, significant reductions in soil organic matter content, reduced root growth, and possibly reduced plant water use efficiency under weed mat (Larco, 2010; Larco et al., 2013b, 2014; Valenzuela-Estrada et al., 2011).

Soil and leaf nutrient concentrations

Many nutrients other than N are present in organic fertilizers and are thus applied to the planting whether or not the nutrients are required (Larco et al., 2013b). For example, we found that feather meal contained 12 times more Ca and seven times more B than fish emulsion and resulted in higher concentrations of Ca and B in the soil and B in the leaves, while fish emulsion contained three times more P, 100 times more K, and 60 times more Cu than feather meal and resulted in higher concentrations of P, K, and Cu in the soil and P and K in the leaves. We found that plant response to rate and source of organic fertilizers differed with cultivar and mulch during establishment (Larco et al., 2013a, b). Sustained use of some fertilizer sources may lead to plant and/or soil nutrient imbalances for highbush blueberry production (Larco et al., 2013b).

Compost provides a benefit to establishing blueberry plants in organic production systems (Burkhard et al., 2009; Larco et al., 2013a, b; Sullivan et al., 2014a). However, composts often contain as much total K as N. At modest compost application rates (e.g., 2.5-cm depth), a compost with 20 g kg^{-1} K in dry matter supplies about 800 kg ha^{-1} K. Potassium does not leach rapidly from soil. Our previous research demonstrated a potential long-term problem with applying too much compost K to blueberry (Costello, 2011). High soil K has been observed to induce Mg deficiency (Eck, 1988; Krewer and Ruter, 2012). High tissue K concentrations were found by us and others in blueberry when grown with various composts, which adversely affected the ability of the plants to take up other cations (i.e., Ca and Mg) (Burkhard et al., 2009; Larco et al., 2014; Sullivan et al., 2014a). Sustained compost use may thus adversely affect soil and plant health and fruit quality.

Among the three mulch treatments, compost covered with sawdust increased soil pH and organic matter and resulted in higher concentrations of soil NO_3-N, P, K, Ca, B, Cu, and Zn than sawdust alone, and increased the concentrations of leaf K and B. Weed mat, on the other hand, resulted in the lowest soil pH during establishment (Larco et al., 2013b) and the highest soil pH after 5 years (Sullivan et al., 2015). However, the soil pH in all mulch treatments was within the recommended range (4.5-5.5; Hart et al., 2006) for blueberry during the 7-year study to date. Mulch treatments did not have a strong effect on leaf nutrient concentrations during establishment (Larco et al., 2013a), but as the planting matured, compost increased leaf K concentration and reduced leaf Mg concentration. Leaf N concentrations, on the other hand, were below “target” levels in all treatments in 2012-2013, despite reaching commercially-acceptable yields of 10-12 t ha^{-1}.

Economic returns from organic blueberry production

In Oregon, the cash costs to establish a new planting of conventional blueberry can surpass \$ 30,165 ha^{-1} and result in a net loss of -\$ 9,995 ha^{-1} during the first 6 years (Julian et al., 2011a). In contrast, the cash costs required to establish a “typical” organic blueberry field is higher at \$ 32,520 ha^{-1}, but the net return through year 6 is \$ 6,930 ha^{-1} (Julian et al., 2011b). In plantings yielding 18 t ha^{-1}, the break-even price (to cover total costs) is estimated to be \$ 3.08 kg^{-1} for organic blueberries produced in Oregon (Julian et al., 2011b) and \$ 10 kg^{-1} in southern California (Takele et al., 2007). The economic analysis of our research trials to date has illustrated that returns in the first 3 years of establishment were impacted greatly by the production system used, yield, and fruit prices (Julian et al., 2012). Coupled with questions about the impact of these systems on long-term growth and yield of organic blueberry are key issues of economic sustainability. Our research findings, once the planting is mature, will be used to provide growers with the long-term costs of production of the various organic production systems to make educated management decisions.

ORGANIC BLACKBERRY TRIAL

The purpose of our blackberry trial is to investigate the effects of postharvest irrigation, training date, and cultivar on plant and soil nutrient status and nutrient accumulation and losses in trailing blackberry under three weed management strategies in order to maximize plant growth and berry yield and quality in organic production for processed markets.

The study was planted on May 26, 2010 using tissue-cultured plugs. Treatments were arranged as a split-split-split plot design with five replicates and included a row of 'Marion' and a row of 'Black Diamond' blackberry as main plots, two irrigation strategies (postharvest and no postharvest irrigation) as subplots, and a combination of three weed management strategies (weed mat (porous polyethylene), hand-hoeing, and no weeding) and two primocane training dates (August and February) as sub-subplots. Each sub-subplot consisted of four plants spaced 1.5 m apart in-row and was separated from plants in adjacent plots by 3.0 m (to provide space for clearing the machine harvester). Between row spacing was 3.0 m (2,222 plants ha^{-1}). The planting also had a plot of four border plants at the end of each row, and a border row on each side. Overall, there were 12 rows of 104 m each (0.4 ha) and a total of 120 treatment plots. Since irrigation and training treatments were not initiated until August 2012 (year 3), we report here the cumulative yield for only cultivar and weed management treatments assigned to postharvest irrigation and August training (30 plots in total). The primocanes that grew in 2010 were removed the following winter. Only primocanes grew in 2011. The first and second cropping years were 2012 and 2013, respectively. Plants were irrigated using a single lateral of drip tubing (Netafim, 1.9 L h^{-1} inline pressure-compensating emitters spaced at 0.6 m). More information on planting establishment and management is presented in Harkins et al. (2013). Fruit were harvested using an over-the-row machine harvester (Littau Harvesters Inc., Stayton, Ore.) approximately twice per week.

Fruit production

Cumulative yield for the various production systems ranged from 13 to 26 t ha^{-1} (2012-13). 'Black Diamond' has had a higher yield than 'Marion' to date, particularly when grown with weed mat as a mulch (Figure 2). While 'Marion' produced longer primocanes, 'Black Diamond' produced more canes $plant^{-1}$, more fruit $lateral^{-1}$, and larger fruit than did 'Marion' (Harkins et al., 2013). While some beneficial insects were observed in the machine-harvested fruit, these were not considered to be of economical consequence at the small levels found.

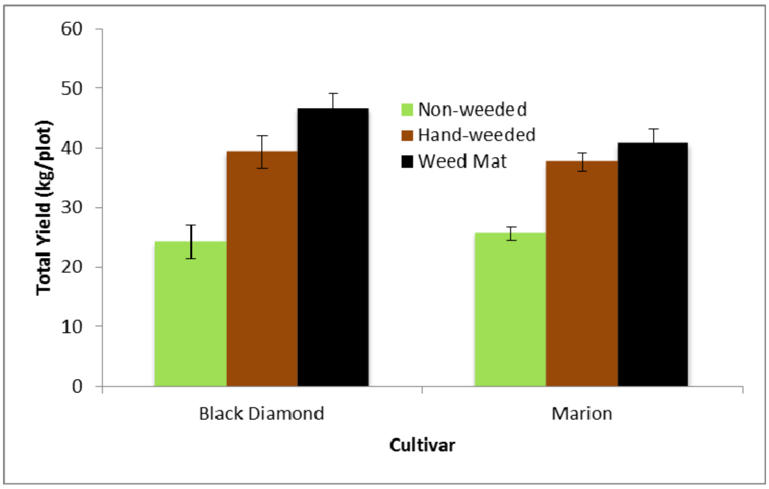

Figure 2. Effect of blackberry cultivar and weed management treatment on cumulative yield per plant when grown in a certified organic production system from 2012-2013 (first and second fruiting years) (mean ± SE).

Mulches and weed control

The presence of weeds (non-weeded treatment) reduced the number of primocanes plant^{-1} when compared with hand-weeded and weed mat plots. On average, weeds reduced cumulative yield by 54% compared to hand-weeded plots. Weed mat increased yield (14% on average) compared to hand-weeding, especially in 'Black Diamond' (Figure 2). Weeds reduced berry weight, but increased percent soluble solids (Harkins et al., 2013). Weeds reduced blackberry plant biomass and nutrient accumulation in both cultivars (Harkins et al., 2014).

Nutrient management

Fertilizers used to establish the planting (2010-11) are presented in Harkins et al. (2013). In 2012 and 2013, the planting was fertilized using OMRI-approved TRUE 402 liquid fertilizer (4N-0P-2K; True Organic Products, Inc., Spreckels, CA), 4N-2P-1K (Converted Organics, CA), and/or 5N-1P-2K (True Organic Products), all fish emulsions, depending on year. The fertilizer was diluted with 10 parts water and applied by fertigation (injection through the drip system) using a Mix-Rite TF10-002 fertilizer injector (DEMA, St. Louis, MO). Irrigation was run for 10 min prior to each injection to fully pressurize the system, and was also run for an additional hour afterwards to flush the drip lines. In 2012 and 2013, the total rate of N (56 and 90 kg ha^{-1}, respectively) was divided into four equal bi-weekly applications from late April to mid- to late-June. Plants have responded well to fertigation with this product with no adverse effects on the drip system performance. However, we have noted a 19% drop in emitter performance over a period of 2 years when fertigating with liquid sources of organic fertilizers (Fernandez-Salvador et al., 2014a).

In separate studies, we have found that trailing blackberry cultivars differ in their adaptation to organic production systems, but differ little in their response to varying sources of organic fertilizer (Fernandez-Salvador et al., 2014b, c).

SUMMARY

Organic blueberry production in the United States has increased nine-fold from an estimated 194 ha in 2003 (Strik and Yarborough, 2005) to 1,655 ha in 2011 (Strik, 2014). Presently, certified organic blueberry land accounts for about 5% of total blueberry acreage in the country. Production of organic blueberries is experiencing the greatest growth in the western United States. While this region accounted for only 26% of the total area planted to highbush blueberry in 2011, it accounted for 64% of the total US organic blueberry acreage (Strik, 2014). Organic area planted now accounts for 15% of the total area in Oregon and Washington.

The information we have shared from our organic blueberry systems trial has been used by new and experienced growers in their management decisions. Impacts of our research on commercial production practices have included an increase in use of weed mat for weed control in organic and conventional plantings from an estimated 20% in 2006 to 85% in 2012. Growers now have the confidence that planting on raised beds improves plant performance even in a good soil type. In addition, growers have been better able to manage fertility in new organic plantings using low rates of fish fertilizer or feather meal and better understand the possible benefits of compost to nutrient management. More is known about cultivar adaptation to organic production systems. While our findings to date have generated more questions that we plan to further investigate, we have made significant progress.

Blackberry production has increased worldwide from 13,960 ha in 1995 to 20,035 ha in 2005 (Strik et al., 2007). About 6,000 ha are currently produced in the United States, with more than half of this area (3,220 ha) located in Oregon. Over 90% of the production in Oregon is processed (i.e., IQF (individually quick frozen), bulk frozen, puree (with or without seeds, depending on cultivar), freeze dried, canned, or juice/concentrate). There were 2,525 ha of organic blackberry production reported in the world in 2005, but only 75 ha were in the United States (Strik et al., 2007); this increased to 200 ha in 2008, according to a recent survey (USDA, 2010), 74% of which was in the western United States.

Yields to date in our organic blackberry systems trial, for both cultivars, have been similar to what would be expected in machine-harvested conventional production, but only for the hand-weeded or weed mat treatments. It was clear from our study that weed management is critical for good blackberry yield. At present, use of weed mat in commercial blackberry fields is limited – our results may change that in the future. In our study, the planting was successfully established using only drip irrigation (not a common practice at present) and fertigation with fish emulsion/hydrolyzate. These findings are key to facilitating organic production of blackberry and may lead to an increase in organic acreage.

We successfully used drip fertigation to establish plantings and to apply fish emulsion fertilizers in our existing trials on organic blueberry and blackberry and are finding no evidence in either trial of excessive emitter plugging (Harkins et al., 2013; Valenzuela-Estrada et al., 2014).

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