Organic Blueberry Production Systems – Advances in Research and Industry

B. Strik
Department of Horticulture
Oregon State University
4017 ALS, Corvallis, OR 97331
USA

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

Abstract

Worldwide highbush blueberry area increased from 42,000 ha in 2005 to 77,290 ha in 2010. In 2010, the USA had the greatest planted area with 46% of the world total, followed by Chile (17%), Canada (12%), and Argentina, Poland, and China (with 4-5% each). The planted area of organic highbush blueberry increased four-fold from 2006 to an estimated 4,156 ha in 2011. Countries with the largest organic blueberry area in 2011 were the USA and Chile. Certified organic blueberry area in the USA increased from an estimated 194 ha in 2003 to 1,665 ha in 2011. The greatest growth has occurred in the western USA which accounted for 26% of the total planted highbush blueberry area, but 64% of the total organic area planted. Those surveyed reported similar factors that may limit the development or expansion of organic highbush blueberry area including the difficulty of managing weeds, insects, and diseases, limited markets for organic fruit and competition from fruit produced in regions where production costs are lower. In some countries, organic area has declined due to difficulty in marketing organic fruit at competitive prices. Research that may benefit organic as well as conventional blueberry growers including cultivar development, plant nutrient requirements/seasonal allocation, use of organic amendments, pest control methods, understanding pest cycles, and other general cultural practices has been done or is underway in many countries and production regions. Organic research projects (public) were reported to be underway in the USA, Chile, and Italy. Research on certified organic land has been relatively limited in blueberry. Methods of managing weeds, mulching to improve plant growth, use of composts, and fertilization in organic production systems are reviewed. It is clear that the choices available for organic blueberry production systems vary in their yield and in economic return.

INTRODUCTION

The production of highbush blueberries has increased tremendously from the late 1990s, leading to production surpassing market demand in some production regions. Efforts to improve demand for fruit included strengthening the newly emerging organic blueberry fruit market in the early 2000s. Prices for organically grown blueberries were generally 20 to 100% higher than for conventionally produced fruit, attracting growers to this new method of production. Often, the higher price paid for organically certified blueberries is considered a premium intended to offset greater production costs associated with organic production systems. Area of organic blueberry production has increased in many regions worldwide, from development of new plantings or transitioning conventional to organically certified production. Research on organic production systems was initiated in some production regions to determine the greatest challenges associated with growing this crop organically, to assist growers in developing best management systems, and to assess production costs and returns.

Colleagues and industry leaders were contacted in all blueberry productions regions of the world and asked to estimate the area of certified organic blueberry planted and provide an overview of research projects underway (see "Acknowledgements").

While this paper focuses on highbush blueberry, there has been research on organic production methods of lowbush blueberry (*V. angustifolium* L.; e.g., Smagula and Fastook, 2009; Smagula et al., 2009) and an organic production guide developed (Drummond et al., 2009).

REVIEW

Organic production in some regions of the world has become a significant part of the commercial highbush blueberry industry. However, in most areas organic production still fits only a small, niche market. The main challenges to rapid expansion of certified organic blueberry 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. These production challenges may be coupled with markets where the demand and price for organic blueberry 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. In addition, the wholesale price premium offered for organic blueberry fruit over conventional fruit ranged from 19 to 30% in 2007 and can vary by year, time of the fruiting season, and city (Granatstein et al., 2010).

Worldwide highbush blueberry area increased from about 42,000 ha in 2005 to 77,290 ha in 2010, an 84% increase (US Highbush Blueberry Council, unpublished). In 2010, the USA had the greatest planted area with 46% of the world total, followed by Chile (17%), Canada (12%), and Argentina, Poland, and China (with 4-5% each). The countries with the greatest growth in planted area from 2005 to 2010 were China (thirteen-fold increase), Mexico (nine-fold), Spain (five-fold), Chile (three-fold), Japan and Germany (doubled), and the USA, Canada, and South Africa (51 to 57% increase). Within the USA, the western region (Washington, Oregon, and California) experienced a relatively high increase (130%) in planted area compared to other regions.

The planted area of organic highbush blueberry was estimated at 4,156 ha in 2011, 5% of the world's total (Table 1). Worldwide organic blueberry area has thus increased more than four-fold from the 1,200 ha estimate in 2006 (Granatstein et al., 2010). Countries with the largest organic blueberry area in 2011 were the USA and Chile. In some countries, with a relatively small amount of blueberry production, organic area accounted for as much as 17% of the total area (e.g., Austria). Organic area in Chile accounted for 12% and in China 10% of the total area; it was difficult to obtain data on the amount of certified organic area in China. The Netherlands (8%), South Africa (7%), New Zealand and Poland (5%) had a similar proportion of organic area as the USA (5%). In some countries, certified organic area could be estimated, whereas others reported it was difficult to determine whether the organic area was certified as statistical data were not available. In the USA, certified organic area is surveyed and reported (USDA, 2010).

Certified organic blueberry area in the USA increased from an estimated 194 ha in 2003 (Strik and Yarborough, 2005) to 790 ha in 2008 (USDA, 2010) and 1,665 ha in 2011 (present survey) – an almost nine-fold increase in the last 8 years and a more than two-fold increase in the last 3 years. Organic blueberry area is experiencing the greatest growth in the western USA; while this region accounted for 26% of the total planted highbush blueberry area in the USA in 2011, it accounted for 64% of the total organic area planted. In the last 3 years, organic blueberry area has increased from 45 to 250 ha in California, 50 to 305 ha in Oregon and from 28 to 610 ha in Washington State. As a result, there is high demand for research and extension information on organic blueberry production systems in this region – the industries have identified organic research as a high priority and have supported organic research projects through funds levied by Commissions (e.g., the Oregon Blueberry Commission). Grower attendance at meetings and field days that include information on organic production has been high.

In the USA, several factors have helped increase the planted area of organic blueberry and blueberry research and extension or outreach activities including growers passionate about organic agriculture, growers interested in exploring possible high-value niche market opportunities, interested research and extension faculty, and funding provided by the USDA-ARS federal grant programs, the Organic Farming Research Foundation, and industry groups/organizations.

There are presently production guides for organic highbush blueberry production in Georgia (Krewer and Walker, 2006), New York (Carroll et al., 2011) and one developed by Kuepper and Diver (2004). The group in Oregon (Strik et al., unpublished) plans to develop a production guide based on information learned from a long-term certified organic production system research trial (e.g., Larco et al., 2012a).

While the western USA is also experiencing large growth in total blueberry area (more than a two-fold increase in 10 years), the relatively large growth in organic area is likely due to certain advantages offered in this region for blueberry production. Weed management is considered one of the most difficult aspects of organic production in most production regions; however, the relative lack of summer rain and low humidity in the western USA reduces weed presence compared to the more humid, wet summers in the eastern and southern USA. Diseases promoted by humid conditions during the growing season including anthracnose (*Colletotrichum acutatum* sexual: *Glomerella acutata*) and alternaria (*Alternaria tenuissima*) fruit rots and rusts (*Pucciniastrum vaccinii*) are less prevalent or not found in this region. In addition, some insect pests that cause losses in some production regions (Strik and Yarborough, 2005), including the blueberry maggot (*Rhagoletis mendax*), cranberry fruitworm (*Acrobasis vaccinii*), cherry fruitworm (*Grapholita packardi*), and Japanese beetle (*Popillia japonica*), are difficult to control using organic methods, but are not found in this region.

Many who were surveyed reported similar factors that may limit the development or expansion of organic highbush blueberry area including the difficulty of managing weeds, insects, and diseases, limited markets for organic fruit and competition from fruit produced in regions where production costs are lower. In some countries, organic area has declined due to difficulty in marketing organic fruit at competitive prices (e.g., France, Poland).

Particular pests mentioned as very difficult to control in organic systems were mummy berry (*Monilinia vaccinii-corymbosi*) a common disease problem in many regions of North America and the Spotted wing drosophila (SWD; *Drosophila suzukii*) a relatively new insect pest to many blueberry production regions. Organically-approved methods of control for mummy berry are mechanical or chemical (lime sulfur) damage of the fruiting bodies (apothecia) in spring and choosing cultivars that offer more resistance to this pest; organically-approved pesticides have been relatively ineffective compared to options available to conventional growers (e.g., McGovern et al., 2012; Scherm and Krewer, 2008).

Soil borne-pathogens may be reduced in organic production systems. In a greenhouse study, fertilization with organic products reduced the incidence of Fusarium wilt and increased soil biota activity and mycorrhizal colonization relative to fertilization with conventional products (Montalba et al., 2010). Mycorrhizal infection levels were found to be higher in organic farms than in conventional farms in Michigan suggesting colonization is enhanced by organic management (Sadowsky et al., 2012).

New research on controlling SWD in blueberry fields is underway in many production regions (e.g., www.spottedwing.com). Organic growers of blueberry in the western USA have been monitoring SWD populations using traps and have used preventative pesticide applications when populations of SWD may threaten marketable fruit; in this region, growers use organically-approved applications of Entrust® Naturalyte® Insect Control and Entust SC® (a spinosad) and Pyganic® (pyrethrum) to protect fruit from the egg-laying adults, per label recommendations. In some regions, there is less grower interest in starting organic production in blueberry since SWD was identified. Similar products have been found to be an effective part of an organic management program for the blueberry maggot (Barry et al., 2005) and the Japanese beetle (Grieshop et al., 2012).

Research that may benefit organic as well as conventional blueberry growers including cultivar development (e.g., tolerance to insect, virus, and disease pests), plant nutrient requirements/seasonal allocation, use of organic amendments (before planting and as mulches), pest control methods (IPM, biological control, testing organically-approved products), understanding pest cycles, and other general cultural practices has been done or is underway in many countries and production regions. Organic research projects (public) were reported to be underway in the USA (Michigan, New York, North Carolina, Oregon, and Washington), Chile, and Italy. Research on certified organic land has been relatively limited in blueberry.

Weed management is critical for economic production in blueberry (Pritts and Hancock, 1992; Strik et al., 1993). Pre-emergent and contact herbicides are commonly used in conventional production systems, but in organic systems, chemical options are limited. Directed applications of acetic acid (vinegar) at a concentration of 20% and lemongrass oil have been effective at controlling young weeds in an established organic blueberry planting (Larco, 2010; Julian et al., 2012). Organic burn-down herbicides performed poorly on established grasses, the dominating weeds in southern Georgia (Tertuliano et al., 2012). Propane flaming may be an option to control smaller weeds (Julian et al., 2012; Larco, 2010), but may damage the crop plant (Granatstein and Mullinix, 2008) or be a fire hazard in plantings mulched with organic materials such as sawdust. Weed management at the interface between the in-row mulch (e.g., sawdust or perforated landscape fabric or weed mat) has been limited to hand weeding in Georgia (Tertuliano et al., 2012) whereas concentrated acetic acid as a directed spray (Julian et al., 2012; Larco, 2010) and a power string trimmer held at an angle (Julian et al., 2011b) were successfully used in Oregon.

Organic mulches are commonly used in organic blueberry to help control weeds (Burkhard et al., 2009, 2010; Grieshop et al., 2012; Krewer et al., 2009; Sciarappa et al., 2008). Mulches also improve plant growth and yield (Clark and Moore, 1991; Goulart et al., 1997; Karp et al., 2006; Kozinski, 2006; Krewer et al., 2009; Savage, 1942; White, 2006), root distribution (Spiers, 2000), the number of shoots and whips (Kozinski, 2006; White, 2006), and water-holding capacity, and minimize temperature fluctuations (Cox, 2009; White, 2006), as compared to bare ground plantings.

Use of sawdust mulch is common in many production regions, but it can be an expensive input (e.g., Julian et al., 2011a) and, with a high carbon (C) to nitrogen (N) ratio, immobilizes N applied from fertilizers (White, 2006). Burkhard et al. (2010) found no evidence of immobilization of N when mulches of pine-needles (C:N, 72:1) or manure-sawdust compost (48:1) were used for two years. When blueberry were planted into sawdust beds, it was difficult to supply sufficient N when using only organic sources in a 2-year study in New Zealand (Miller et al., 2006).

Composts when used as a pre-plant amendment or as a mulch may be of benefit to blueberry. As compost decomposes, it releases mineral N, with 3 to 10% of compost total N being converted to mineral N for several years after application (Gale et al., 2006; Sikora and Szmidt, 2001). High rate applications of organic materials can build soil N mineralization rates for 7 or more years after application, suggesting that soils may mineralize sufficient N for blueberries for many years if high rates of compost are applied periodically (Cogger et al., 2001; Sullivan et al., 2003). Composts may also provide a more favorable soil microbial environment or improved soil water relations for blueberry.

Yard debris compost is readily available in many production regions and may be suitable for commercial blueberry production. Many composts made from yard-debris are high in potassium (K) leading to potential problems with applying too much K from compost to blueberry (Costello, 2011). High soil K has been observed to induce magnesium (Mg) deficiency (Eck, 1988; Krewer and Ruter, 2012) and high leaf K and very low leaf Mg in blueberry is associated with poor plant performance following compost application in the field (Temple et al., 2011) and the greenhouse (Costello, 2011).

When composts derived from on-farm and municipal organic feedstocks were evaluated as soil amendments in potted blueberry, plant growth was limited when composts having a pH above 7.5 and an EC >4 $mS \cdot cm^{-1}$ were incorporated into soil (Costello, 2011). Grieshop et al. (2012) reported on preliminary results of a dairy-based compost providing sufficient nutrients for blueberry establishment, but commented on how this type of compost may increase soil pH and require additional applications of sulfur to maintain pH in the desired range for blueberry. Acidification of composts with elemental sulfur, prior to their use in the field (Costello et al., 2011), shows promise for development of a compost more suitable for long-term use in blueberry production systems. In Switzerland, blueberries can be successfully grown on alkaline soils for organic production using pre-plant amendments of acidified pine sawdust (Suter et al., 2010).

Rabbiteye blueberry plants fertilized with worm castings had more growth and higher yield than those fertilized with inorganic products (Panicker et al., 2009). In their study, surface soils had higher concentrations of nitrate-N and phosphorus when treated with organic manures, but sub-surface soil layers had higher concentrations when fertilized with inorganic products. Burkhard et al. (2009) found good growth and yield of highbush blueberry when using seafood compost and manure-sawdust compost. The addition of yard-debris compost to sawdust mulch increased total plant dry weight at the end of the first growing season in organic highbush blueberry, but had no impact on plant growth by the end of the second growing season (Larco et al., 2012a). After two years, compost maintained soil pH in the optimum range for blueberry, provided plant-available cations, increased soil organic matter, and increased plant yield, relative to sawdust alone (Larco et al., 2012b). The longer-term effects of compost mulch on plant and soil nutrient status need to be assessed as yard-debris composts are relatively common and thus a highly-desired source of organic matter and nutrients for organic blueberry farmers.

Composts, when used as part of a mulching program have increased weed presence and weed management costs (Burkhard et al., 2010; Julian et al., 2012; Larco, 2010; Larco et al., 2012a). In contrast, weed mat (perforated landscape fabric) has been shown to be an effective mulch for weed control, although weeds appear in the area cut for the planting hole, and removal by hand may be required in blueberry farms. Sciarappa et al. (2008) and Larco et al. (2012a) reported almost complete control of weeds when using weed mat plus a mulch of coffee grinds or sawdust around the planting area in organic blueberry in New Jersey and Oregon, respectively. In Oregon, plants established with weed mat had improved plant growth and early production relative to sawdust mulch (Larco et al., 2012a) and the labor savings related to weed management improved economic returns (Julian et al., 2012). In Georgia, rabbiteye blueberry (*V. virgatum* Ait.) established with organic mulches had a similar yield to those with weed mat in the first 2 years of establishment, but greater yield in years 3-5 (Krewer et al., 2009); net returns were estimated to be higher for organic than conventional rabbiteye production over a 6-year period despite a lower yield for organic plots (Tertuliano et al., 2012).

Concerns have been expressed about possible negative impacts of increasing soil temperature under weed mat on plant growth (Larco, 2010; Neilsen et al., 2003; Williamson et al., 2006). Magee and Spiers (1995) found that white-on-black plastic polyethylene based mulches produced greater plant growth and yield than black plastic or black woven fabric mulches in southern highbush cultivars, due to decreased soil temperature under the more reflective mulches. Blueberry plants grown with weed mat had a lower root to shoot ratio than those mulched with sawdust or compost topped with sawdust in the first 2 years of establishment (Larco et al., 2012a).

In general, highbush blueberry requires nitrogen (N) fertilizer at a rate of approximately 25-100 $kg \cdot ha^{-1}$ N per year for optimum growth and production (Bañados et al., 2012; Chandler and Mason, 1942; Eck, 1988; Griggs and Rollins, 1947; Hanson, 2006; Hart et al., 2006). Uptake of N fertilizer is most rapid from bloom to harvest (Bañados, 2006; Throop and Hanson, 1997) but continues through the remainder of the growing season (Bañados, 2006; Bañados et al., 2012).

Organic blueberry farmers in the USA commonly use OMRI-approved (Organic

Materials Review Institute) fish emulsion, as a direct liquid application or injected through the drip irrigation system, and granular feather meal as N fertilizer sources. Specialty fertilizers (fish meal, feather meal, or seed meals) decompose rapidly (>50% decomposition in 1 month) and release plant-available N rapidly (Gale et al., 2006). Fertilization with fish emulsion improved blueberry plant growth relative to feather meal in the establishment year, but not in the second growing season when feather meal was applied earlier improving N availability. In addition, plants allocated more biomass to root and crown tissue and less to wood and leaves when fertilized with feather meal than when fertilized with fish emulsion (Larco et al., 2012a). Similar to what has been observed in conventional production systems (Bañados et al., 2012; Cummings, 1978; White, 2006), allocation of biomass to roots decreased with higher fertilizer rates and there was a threshold for optimal fertilizer rates for establishing blueberry plants in organic production systems (Larco et al., 2012a).

Use of weed mat has become very common in organic as well as conventional blueberry production systems in the western USA (e.g., Julian et al., 2011b). In these plantings, drip irrigation lines are placed under the weed mat and fertilization is commonly done through the drip irrigation system. Organic growers can effectively use fish emulsion to fertilize through the drip irrigation system (Valenzuela-Estrada et al., unpublished). However, when plants would benefit from applications of granular fertilizer products (e.g., boron) or addition of composted fertilizer sources, application in weed mat mulched systems can be problematic. To address these issues, growers in the western USA have developed a "zippered" weed mat system where two overlapping sections of weed mat are held in place with staples that can be removed to fold back the weed mat and apply products in the row (Julian et al., 2011b).

It is clear that the choices available for organic blueberry production systems vary in their yield and returns. For example, Julian et al. (2012) found that when establishing northern highbush blueberries, the highest yielding treatment combinations (growing on raised beds mulched with compost and sawdust and fertilized with fish emulsion) improved cumulative net returns as much as $ 19,333/ha over 3 years.

When testing 10 highbush blueberry cultivars for 5 years in an organic production system, Strik et al. (unpublished) found all cultivars were well adapted to organic fertilization and weed management systems. Southern highbush blueberry fruit from plants fertilized with 11 different organic fertilizer treatments within the same field showed little difference in postharvest fruit quality parameters as compared to unfertilized and conventionally fertilized plants (Echeverría et al., 2009). In contrast, 'Bluecrop' fruit harvested from different organic blueberry farms had higher soluble solids, malic acid, total phenolics, total anthocyanins, and antioxidant activity (ORAC) than fruit from conventionally managed farms (Wang et al., 2008). In rabbiteye blueberry, while there were cultivar differences in total phenolics, anthocyanins, and ORAC values, there was no consistent difference between organic and conventional production systems (You et al., 2011).

SUMMARY

The planted area of organic highbush blueberry was estimated at 4,156 ha in 2011, 5% of the world's total. Several factors have helped increase the planted area of organic blueberry and public programs supporting organic blueberry including growers passionate about organic agriculture, growers interested in exploring possible high-value niche market opportunities, interested research and extension faculty, and funding provided by the USDA-ARS federal grant programs, the Organic Farming Research Foundation, and industry groups/organizations in the USA. Many who were surveyed reported that difficulty of managing weeds, insects, and diseases, limited markets for organic fruit, and competition from fruit produced in regions where production costs are lower may limit the development or expansion of organic highbush blueberry area. Organic mulches help improve blueberry plant growth and yield and reduce incidence of weeds as compared to bare soil; however, in organic production systems weeds are difficult to control with

burn-down chemicals. Composts help improve soil and plant nutrient status, but increase weed presence. Many organic growers are using perforated landscape fabric to manage weeds; the long term impact of weed mat on blueberry plant growth still needs to be determined. Feather meal and fish emulsion, along with judicious use of yard-debris composts have been effective fertilizer products at rates similar to those used in conventional systems. It is clear that the choices available for organic blueberry production systems vary in their yield and returns.

ACKNOWLEDGEMENTS

The author appreciates the information provided by academic and industry colleagues throughout the world. USA: Tom Avinelis (California), Peter Andersen, Jeff Williamson (Florida), Gerard Krewer (Georgia), David Yarborough (Maine), Eric Hanson (Michigan), Gary Pavlis (New Jersey), Marvin Pritts (New York), Bill Cline (North Carolina), Eric Pond (Oregon), Kathy Demchak (Pennsylvania), David Granatstein, Tom Walters, and Alan Schreiber (Washington), Cort Brazelton and US Highbush Blueberry Council; elsewhere: Gary Wright (Australia), Astrid Forneck (Austria), Mark Sweeney (Canada), Pilar Bañados (Chile), Marketing Division of Wallen Agriculture (Qingdao) LLC (China), Stephen Taylor (France), Gunhild Muster (Germany), Lara Giongo (Italy), John Bal, Maria Buitenkamp (The Netherlands), Geoff Langford (New Zealand), Nina Opstad (Norway), Bohdan Koziński, Stephen Taylor (Poland), Pedro Oliveira (Portugal), Trevor McKenzie (South Africa), Marta Ciordia (Spain), and Rex Brennan, Stephen Taylor (UK).

Literature Cited

Bañados, M.P. 2006. Dry weight and ^{15}N-nitrogen and partitioning, growth, and development of young and mature blueberry plants. Ph.D. thesis, Oregon State University, 172p.

Bañados, M.P., Strik, B.C., Bryla, D.R. and Righetti, T.L. 2012. Response of highbush blueberry to nitrogen fertilizer during field establishment. I. Accumulation and allocation of fertilizer nitrogen and biomass. HortScience 47:648-655.

Barry, J.D., Sciarappa, W.J., Teixeira, LA.F. and Polavarapu, S. 2005. Comparative effectiveness of different insecticides for organic management of blueberry maggot (*Diptera*: *Tephritidae*). J. Econ. Ent. 98:1236-1241.

Burkhard, N., Lynch, D. and Percival, D. 2010. Effects of pine-needle and compost mulches and weeds on nitrogen dynamics in an organically-managed highbush blueberry field. Acta Hort. 873:253-259.

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.

Carroll, J., Pritts, M. and Heidenreich, C. (eds.). 2011. Production guide for organic blueberries. NYS IPM Pub No. 225 v2, Cornell Univ. Coop. Ext.

Chandler, R.B. and Mason, E.C. 1942. The effect of mulches on soil moisture, soil temperature, and growth of blueberry plants. Proc. Amer. Soc. Hort. Sci. 40:335-337.

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

Cogger, C.G., Bary, A.I., Fransen, S.C. and Sullivan, D.M. 2001. Seven years of biosolids vs. inorganic nitrogen applications to tall fescue. J. Environ. Qual. 30:2188-2194.

Costello, R.C. 2011. Compost acidification increases growth and nutrient uptake of highbush blueberry under a low N fertilizer regime. M.S. Thesis, Ore. St. Univ., Corvallis, OR. http://hdl.handle.net/1957/26590.

Costello, R.C., Sullivan, D.M., Bryla, D.R., Strik, B.C. and Owen, J. 2011. Highbush blueberry response to compost and sulfur. Western Nutrient Mgt. Conf. Proc. 9:67-72.

Cox, J. 2009. Comparison of plastic weedmat and woodchip mulch on low chill blueberry soil in New South Wales, Australia. Acta Hort. 810:475-482.

Cummings, G.A. 1978. Plant and soil effects of fertilizer and lime applied to highbush

blueberries. J. Amer. Soc. Hort. Sci. 103:302-305.
Drummond, F., Smagula, J., Annis, S. and Yarborough, D. 2009. Organic wild blueberry production. Maine Agric. Forest Expt. Stn., Univ. Maine, Bulletin 852.
Echeverría, V.G., Cañumir, J.V. and Serri, H.G. 2009. Postharvest behavior of highbush blueberry fruits cv. O'Neal cultivated with different organic fertilization treatments. Chilean J. Agr. Res. 69:391-399.
Eck, P. 1988. Blueberry Science. Rutgers Univ. Press, New Brunswick, N.J. p.135-169.
Fausey, J.C. 2003. Controlling liverwort and moss now and in the future. HortTechnology 13:35-38.
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. J. Environ. Qual. 35:2321-2332.
Goulart, B.L., Demchak, K. and Yang, W.Q. 1997. Effect of cultural practices on field grown 'Bluecrop' highbush blueberries, with emphasis on mycorrhizal infection levels. Acta Hort. 446:271-278.
Granatstein, D. and Mullinix, K. 2008. Mulching options for northwest organic and conventional orchards. HortScience 43:45-50.
Granatstein, D., Kirby, E. and Willer, H. 2010. Current world status of organic temperate fruits. Acta Hort. 873:19-35.
Grieshop, M.J., Hanson, E., Schilder, A., Isaacs, R., Mutch, D., Garcia-Salazar, C., Longstroth, M. and Sadowsky, J. 2012. Status update on organic blueberries in Michigan. Int. J. Fruit Sci. 12:232-245.
Griggs, W.H. and Rollins, H.A. 1947. The effect of planting treatment and soil management systems on the production of cultivated blueberries. Proc. Amer. Soc. Hort. Sci. 49:213-218.
Hanson, E.J. 2006. Nitrogen nutrition of highbush blueberry. Acta Hort. 715:347-351.
Hart, J., Strik, B., White, L. and Yang, W. 2006. Nutrient management for blueberries in Oregon. Oregon State Univ. Ext. Ser. Pub., EM 8918., 22p.
Julian, J., Strik, B. and Yang, W. 2011a. Blueberry economics: the costs of establishing and producing blueberries in the Willamette Valley, Oregon. AEB 0022, 25p. http://arec.oregonstate.edu/oaeb/files/pdf/AEB0022.pdf.
Julian, J., Strik, B., Pond, E. and Yang, W. 2011b. Blueberry economics: the costs of establishing and producing organic blueberries in the Willamette Valley, Oregon. Oregon State Univ. Pub. AEB 0023, 25p. http://arec.oregonstate.edu/oaeb/files/pdf/AEB0023.pdf.
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 47:1-8.
Karp, K., Noormets, M., Starast, M. and Paal, T. 2006. The influence of mulching on nutrition and yield of 'Northblue' blueberry. Acta Hort. 715:301-305.
Kozinski, B. 2006. Influence of mulching and nitrogen fertilization rate on growth and yield of highbush blueberry. Acta Hort. 715:231-235.
Krewer, G. and Ruter, J. 2012. Fertilizing bushes three years and older. p.5. In: Fertilizing Highbush Blueberries in Pine Bark Beds. Univ. Ga. Coop. Ext. Bull. 1291.
Krewer, G. and Walker, R. 2006. Suggestions for organic blueberry production in Georgia. Univ. Georgia Ext. Fruit Pub. 00-1 http://www.smallfruits.org/Blueberries/production/06organicblues.pdf.
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 Hort. 810:483-488.
Kuepper, G.L. and Diver, S. 2004. Blueberries: Organic production. ATTRA. www.attra.ncat.org.
Larco, H.O. 2010. Effect of planting method, weed management, and fertilizer on plant growth and yield of newly established organic highbush blueberries. MS thesis, Oregon State Univ., Corvallis http://ir.library.oregonstate.edu/xmlui/handle/

1957/18065.
Larco, H.O., Strik, B.C., Bryla, D.B. and Sullivan, D.M. 2012a. Mulch and fertilizer management practices for organic production of highbush blueberry. I: Plant growth and allocation of biomass. HortScience (submitted).
Larco, H., Sullivan, D.M., Strik, B. and Bryla, D. 2012b. Mulch effects on highbush blueberry under organic management. Acta Hort. (in press).
Magee, J.B. and Spiers, J.M. 1995. Influence of mulching systems on yield and quality of southern highbush blueberries. In: R.E. Gough and R.F. Korcak (ed.), Blueberries: a Century of Research. Haworth Press, Inc., 10 Alice St., Binghamton, NY. 13904.
McGovern, K.B., Annis, S.L. and Yarborough, D.E. 2012. Efficacy of organically acceptable materials for control of mummy berry disease on lowbush blueberries in Maine. Int. J. Fruit Sci. 12:188-204.
Miller, S.A., Patel, N., Muller, A., Edwards, C.M. and Solomona, S.T. 2006. A comparison of organic and conventional nutrient management protocols for young blueberry nursery stock. Acta Hort. 715:427-432.
Montalba, R., Arriagada, C., Alvear, M. and Zúñiga, G.E. 2010. Effects of conventional and organic nitrogen fertilizer on soil microbial activity, mycorrhizal colonization, leaf anitioxidant content, and *Fusarium* wilt in highbush blueberry (*Vaccinium corymbosum* L.). Sci. Hort. 125:775-778.
Neilsen, G.H., Houge, E.J., Forge, T. and Neilsen, D. 2003. Mulches and biosolids affect vigor, yield, and leaf nutrition of fertigated high density apple. HortScience 38:41-45.
Panicker, G.K., Sims, C.A., Spiers, J.M., Silva, J.L. and Matta, F.B. 2009. Effect of worm castings, cow manure, and forest waste on yield and fruit quality of organic blueberries grown on a heavy soil. Acta Hort. 841:581-584.
Pritts, M.P. and Hancock, J.F. 1992. Highbush Blueberry Production Guide. NRAES-55, Ithaca, NY, 200p.
Sadowsky, J.J., Hanson, E.J. and Schilder, A.M.C. 2012. Root colonization by ericoid mycorrhizae and dark septate endophytes in organic and conventional blueberry fields in Michigan. Int. J. Fruit Sci. 12:169-187.
Savage, E.F. 1942. Growth responses of blueberries under clean cultivation and various kinds of mulch materials. Proc. Amer. Soc. Hort. Sci. 40:335-337.
Scherm, H. and Krewer, G. 2008. Disease management in organic rabbiteye blueberries. Intl. J. Fruit Sci. 8:1-2.
Sciarappa, W., Polavarapu, S., Barry, J., Oudemans, P., Ehlenfeldt, M., Pavlis, G., Polk, D. and Holdcraft, R. 2008. Developing an organic production system for highbush blueberry. HortScience 43:51-57.
Sikora, L.J. and Szmidt, R.A.K. 2001. Nitrogen sources, mineralization rates, and nitrogen nutrition benefits to plants from composts. p.287-305. In: P.J. Stofella and B.A. Kahn (eds.), Compost Utilization in Horticultural Cropping Systems. CRC Press, Boca Raton, FL.
Smagula, J.M. and Fastook, I. 2009. Lowbush blueberry response to several organic fertilizers. Acta Hort. 810:741-746.
Smagula, J.M., Yarborough, D.E., Drummond, F. and Annis, S. 2009. Organic production of wild blueberries. II. Fertility and weed management. Acta Hort. 810:673-684.
Spiers, J.M. 2000. Influence of cultural practices on root distribution of ‘Gulfcoast’ blueberry. Acta Hort. 513:247-252.
Strik, B. and Yarborough, D. 2005. Blueberry production trends in North America, 1992 to 2003 and predictions for growth. HortTech. 15:391-398.
Strik, B., Brun, C., Ahmedullah, M., Antonelli, A., Askam, L., Barney, D., Bristow, P., Fisher, G., Hart, J., Havens, D., Ingham, R., Haufman, D., Penhallegon, R., Psheidt, J., Scheer, B., Shanks, C. and Williams, R. 1993. Highbush blueberry production. Pacific Northwest Extension Bulletin 215. Oregon State University, Corvallis, Ore.
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. 11:265-275.

Suter, F., Schmid, A., Daniel, C., Weibel, F.P. and Jenny, M. 2010. Organic highbush blueberries (*Vaccinium corymbosum* L.) production: long-term effect of cultivation system and pH regulation on plant growth, yield and root distribution and biomass in two cultivars. Acta Hort. 873:261-267.
Temple, W., Forge, T. and Bohmke, A. 2011. Final Project Reports to B.C. Blueberry Council. p.75-76. In: Alternative Mulch Effects upon Highbush Blueberry Root Health & Nutrient Management BMPs.
Tertuliano, M., Krewer, G., Smith, J.E., Plattner, K., Clark, J., Jacobs, J., Andrews, E., Stanaland, A.D., Andersen, P., Liburd, O., Fonsah, E.G. and Scherm, H. 2012. Growing organic rabbiteye blueberries in Georgia, USA: results of two multi-year field studies. Inter. J. Fruit Sci. 12:205-215.
Throop, P.A. and Hanson, E.J. 1997. Effect of application date on absorption of ^{15}N by highbush blueberry. J. Amer. Soc. Hort. Sci. 122:422-426.
USDA. 2010. Organic production survey (2008). Vol. 3. Special studies, part 2. 2007 Census of Agr. Updated July 2010.
Wang, S.Y., Chen, C.-T., Sciarappa, W., Wang, C.Y. and Camp, M.J. 2008. Fruit quality, antioxidant capacity, and flavonoid content of organically and conventionally grown blueberries. J. Agric. Food Chem. 56:5788-5794.
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 Univ., Corvallis.
Williamson, J., Krewer, G., Pavlis, G. and Mainland, C.M. 2006. Blueberry soil management, nutrition and irrigation. In: N.F. Childers and P.M. Lyrene (ed.), Blueberries for Growers, Gardeners and Promoters. E.O. Gainesville, Fl. 263p.
You, Q., Wang, B., Chen, F., Huang, Z., Wang, X. and Luo, P.G. 2011. Comparison of anthocyanins and phenolics in organically and conventionally grown blueberries in selected cultivars. Food Chem. 125:201-208.

Tables

Table 1. Survey results for total and organic highbush blueberry area planted worldwide, 2010-2011.

Country	Highbush blueberry area	
	Organic (ha)	Total (ha)
USA	1665	34819
Chile	1580	13051
China	350	3499
Poland	150	3157
Canada	125	9138
Spain	100	1052
Italy	33	275
South Africa	32	453
Netherlands	45	535
New Zealand	30	587
Portugal	14	194
Japan	10	902
Austria	9	51
UK	7	271
Australia	5	619
Norway	0.5	23
Argentina	0	3845
France	0	360
Germany	na	2145
Total	4156	74976

[z] Survey results; see “Acknowledgements”.
[y] Courtesy of the US Highbush Blueberry Council, 2010 data.
[x] Not available.
[w] Total reflects world estimated total organic area and total blueberry area for countries that reported organic area. Countries with no reported organic area were not included in table.