International Journal of Fruit Science

ISSN: 1553-8362 (Print) 1553-8621 (Online) Journal homepage: http://www.tandfonline.com/loi/wsfr20

# Organic Lowbush Blueberry Research and Extension in Maine

Frank Drummond , John M. Smagula , David Yarborough & Seanna Annis

**To cite this article:** Frank Drummond , John M. Smagula , David Yarborough & Seanna Annis (2012) Organic Lowbush Blueberry Research and Extension in Maine, International Journal of Fruit Science, 12:1-3, 216-231, DOI: 10.1080/15538362.2011.619132

**To link to this article:** http://dx.doi.org/10.1080/15538362.2011.619132

*International Journal of Fruit Science*, 12:216–231, 2012

ISSN: 1553-8362 print/1553-8621 online
DOI: 10.1080/15538362.2011.619132

# Organic Lowbush Blueberry Research and Extension in Maine

FRANK DRUMMOND[1], JOHN M. SMAGULA[2],
DAVID YARBOROUGH[2], and SEANNA ANNIS[1]
[1]*School of Biology and Ecology, University of Maine, Orono, Maine, USA*
[2]*Department of Plant, Soil, and Environmental Sciences,*
*University of Maine, Orono, Maine, USA*

*A six-year organic systems research project was conducted in Maine from 2004 to 2009. The project had several components: (1) a large replicated interdisciplinary multifactor (fertility, weed, insect, and pathogen) experiment over three cropping cycles (6 years), (2) single disciplinary experiments designed to develop organic management tools for pest management, (3) an economic analysis of current organic production, (4) a survey of organic growers for the purpose of deriving a descriptive profile and the development of grower case studies, and (5) organic Extension workshops and field meetings and production of an organic wild blueberry grower's guide. This article highlights some of the outcomes of this project including: ecological interactions among pests and fertility, novel management tactics, niche-market diversity, and economic viability.*

*KEYWORDS organic, wild, lowbush blueberry,* Vaccinium angustifolium*, economics, Extension*

## INTRODUCTION

Management and harvest of wild blueberry was first practiced by eastern woodland indigenous Native Americans. They periodically cleared swaths of forest and burned fields to maintain production (Yarborough, 2009). In the early 1800s, the European settlers gathered berries as a public privilege on

---

Address correspondence to Frank Drummond, School of Biology and Ecology, University of Maine, 305 Deering Hall, Orono, ME 04469, USA. E-mail: frank_drummond@umit.maine.edu

the blueberry barrens of Washington County, Maine (Yarborough, 2009). Blueberries were canned and shipped to the Union troops during the Civil War in the 1860s (Drummond, 2000). Organic farming of lowbush blueberry in Maine was the traditional method of production up until the end of the 19th century (Drummond, 2000). After the civil war, public access was limited and production was improved by more frequent pruning (Yarborough, 2009). The 20th century brought the use of insecticides, herbicides, fungicides, and synthetic fertilizers and amendments to be incorporated as production practices in the lowbush blueberry landscape (Drummond, 2000). Management intensity and production has increased over the years. Maine is the largest producer of wild blueberries in the world. Maine produces 15% of all blueberries in North America, including wild and cultivated production. Twenty percent of the total crop is produced in the Canadian provinces of Nova Scotia, Québec, New Brunswick, Prince Edward Island, and Newfoundland (Yarborough, 2009). The remaining 65% of the crop are cultivated highbush blueberries produced in Michigan, New Jersey, British Columbia, Washington, Oregon, Georgia, Arkansas, and in other states (Childers and Lyrene, 2006). Currently, 99d% of the Maine crop is frozen and most is used as a food ingredient, less than 1% of the blueberry crop is sold fresh (Yarborough, 2009).

During the past decade, there has been an increase in farmers producing organic blueberries in Maine. Prior to 2004 less than 200 acres were under organic production but by 2009 more than 400 acres were in organic production by more than 40 farmers (Files et al., 2008b; Drummond et al., 2009b). In order to better serve these farmers and address the knowledge gaps in organic production practices, we initiated a USDA funded research and extension project in 2004. The original project was conceptualized for 4 years or two production cycles (Drummond et al., 2009a), but additional funding resulted in two more years or an additional production cycle to the research part of the project. In this article, we report on this multifaceted research and extension project over the entire 6-year period. A further continuation of this project began in the spring of 2010 and will focus on research and Extension in organic production for the next 4 years, making our project 10 years in duration. This may be one of the longest research time series for small fruit in the U.S. (Whalon et al., 2007).

## METHODS

The Maine organic wild blueberry research and Extension project was comprised of five components: (1) a large-scale interdisciplinary systems project that was designed to elucidate the interactions between pruning method (mowing or burning), soil pH amendment (sulfur addition or not), and three levels of fertilizer; (2) ancillary experiments that were focused on single disciplinary studies; (3) an economic analysis of organic production derived from the large-scale systems project; (4) a socio/economic study of blueberry growers was conducted by grower surveys and case studies; and (5) Extension outreach involving annual progress reports, grower field days, and publication of management bulletins and fact sheets.

## Interdisciplinary Systems Project

A replicated field experiment was conducted from 2004 to 2009 to assess the main and interactive effects of pruning method, sulfur application, and fertilization on fertility and weeds in an organic lowbush blueberry field managed for three 2-year production cycles in Amherst, Maine. Within each of the split-plots of pruning (burning or mowing) and sulfur (at 1,120 kg S/ha only once in 2004), an organic fertilizer Pro-Holly, (4-6-4) was applied pre-emergent at 0, 22, or 45 kg N/ha to 2 m × 15 m treatment plots in 2004, 2006, and 2008. Effects of treatments on soil and leaf nutrient concentrations and stem characteristics were determined. In 2004, 2006, and 2008, weeds were cut using a motorized weed cutter once a month in June, July, and August. Grass, broadleaf, and woody weed and blueberry cover were assessed each time prior to the sites being cut. Berry yield was determined by mechanically harvesting a 0.6-m-wide strip down the middle of each plot in August 2005, 2007, and 2009. Smagula et al. (2009), Drummond et al. (2009a), and Yarborough et al. (2009) present detailed methods for the first two cycles of this study. Based upon these data, a systems analysis for the entire 6 years of the study (2004–2009, three production cycles) was conducted for the purpose of elucidating the ecological interactions that result from organic management of wild blueberries. Structural equation modeling (Pugesek et al., 2003) and mixed linear modeling (McLean et al., 1991) were used to model the variance/covariance structure so that we could develop and test hypothetical models to explain the relationships between yield, management practices, pests, beneficial organisms, soil characteristics, and leaf nutrient composition over the three cycles.

## Ancillary Experiments

Three previously unpublished projects are highlighted in this article, although several ancillary experiments have been conducted during the duration of the overall project. For example, organic management solutions were found for all significant insect pests associated with producing Maine lowbush blueberry (Drummond et al., 2009a) and studies to find organically acceptable materials for mummy berry disease control were conducted during and after this project (McGovern et al., this issue).

An experiment on weed management was conducted in Stockton Springs, Maine during the 2007 summer to determine the frequency of cutting necessary to control weedy trees and if they could be controlled in one growing season. Twenty patches each of white birch (*Betula papyrifera*) and willow (*Salix* spp.) were located and assigned to four treatments in a completely randomized design. Five patches of each species were cut to the ground with hand-clippers as one of four treatments: no cut or control, cut once at the end of June, two sequential cuts in June and July, or three sequential cuts at the end of June, July, and August. The initial numbers of stems and heights of stems were recorded prior to each treatment and 1 year after the first cut. Data was analyzed as completely randomized design ANOVA for each species and each plant growth measure (stem height and stem number) independently.

Another experiment was conducted in 2004 where four organic fertilizers were evaluated in a commercial lowbush blueberry field with a history of N and P deficiency in Penobscot Co., Maine. A replicate block (RCB) design with 1.8 m × 15 m plots was used. In non-organic production, di-ammonium phosphate (DAP) is the standard fertilizer for correcting N and P deficiency. At a rate of 67 kg N/ha for each, Renaisance (8-2-6) (Renaissance Fertilizer, Inc., Minnetonka, MN, USA), Pro-Holly (4-6-4) (North Country Organics, Bradford, VT, USA), Pro-Grow (5-3-4) (North Country Organics, Bradford, VT, USA), Nutri-Wave (4-1-2) (Envirem Technologies, Inc., Fredericton, NB, USA), or DAP (18-46-0) was applied pre-emergent to the treatment plots. Leaf N and P were deficient ($<1.6$ and 0.125%, for N and P, respectively) in the unfertilized plots that served as controls. Analysis of variance (RCB) was used to test the effect of fertilizer.

A third experiment was designed to assess field perimeter applications of sticky tape for blueberry maggot fly (BMF) control. This study was conducted for 2 years, 2008 and 2009. The sites were established in six (three per year), fruit-bearing blueberry fields in Washington Co., Maine. At each site, Hopperfinder$^{\text{TM}}$ barrier tape was hung from wooden lathes placed 5 ft apart so that the bottom of the tape was even with the top of the blueberry canopy. The enclosed area was 33 m × 33 m with at least one side of the square along a field edge close to a wooded area from which BMF were most likely to colonize each field. Ammonium acetate superchargers were hung from each support post to enhance the attractiveness of the sticky barrier to adult BMF. An adjacent area of each field was left unprotected as an untreated control. Flies were monitored by deploying three baited Pherocon$^{\text{TM}}$ AMF traps in each plot in each field. Adult trap capture was recorded twice a week for the duration of the study (month of July). Maggot infestation was assessed by taking four random 1 L samples of berries in each of the plots in each field. The berries were setup over sand and emerging maggots were counted for each liter of berries. A two-way RCB MANOVA (flies and maggots used as repeated measures) was used to test for the effectiveness of the hopper barrier tape. The main factors were presence of barrier tape and year.

## Economic Analysis

In 2007, enterprise budgets were developed for the 12 management practice combinations outlined in the large-scale systems project (pruning practices × soil amendments for pH adjustment × fertilizer levels). Yield and costs of labor and materials from the large-scale research project were used to parameterize the budgets (Files et al., 2008a). Economic risk analysis (Kay, 1986) using Monte Carlo simulations were conducted to assess the variability in returns due to market price fluctuations, and geographic and annual weather fluctuations for the fixed set of management practices that we implemented in our experimental design (see methods above). This provided a range of total and net returns that growers might expect to see if they followed any of the management practices.

## Socio/Economic Descriptive Profile

In 2006, a survey was mailed to all known commercial organic lowbush blueberry growers ($n = 42$) in December, a time when the most growers would have time to answer the survey (Pennings et al., 2002). The survey was constructed according to the Dillman Method (Dillman, 1978). Thirty-five surveys were returned, but only 32 were complete enough for analysis. Summary of arithmetic means and graphical presentation of the data were used to develop a profile of Maine organic lowbush blueberry growers. In 2007, five organic growers were selected as a representative sample of the grower profile developed from the 2006 survey. These five growers were visited and interviewed about their operations. Management, marketing, and obstacles to production of an organic crop were documented as case studies (Files et al., 2008a).

## Extension/Outreach

Organic grower needs had been addressed by the University of Maine Cooperative Extension prior to the initiation of this project in 2004 (Yarborough, 1994a, 1994b, 1998). However, this project provided a more formal and cohesive effort for the development of specific organic grower field meetings, blueberry schools, and management publications. The outcomes are summarized below.

## RESULTS AND DISCUSSION

### Interdisciplinary Systems Project

Many of the results of the first 4 years (two production cycles) have been reported in three publications (Drummond et al., 2009a; Smagula et al., 2009; Yarborough et al., 2009). However, these results are presented herein from three disciplinary perspectives: soil fertility and plant nutrition, pest management, and food quality. A view of the major dynamics are presented here as a quantitative model of blueberry ecology under organic production (Fig. 1). The model suggests that nutrients in the soil strongly influence leaf nutrients and these in turn influence yield. We also found that fertilizer treatments and the addition of sulfur affect soil nutrient levels, but we found no direct effects of fertilizer treatments on yield (a non-Bonferoni corrected analysis of just the 2009 yield data suggested a sulfur × fertilizer interaction ($F_{(2,56)} = 3.08$, $P = 0.054$) where the plots with sulfur addition and the highest rate of fertilizer (40 Kg N) had significantly higher yields than the non-sulfur treatments. This could be interpreted as a weak cumulative effect of three cycles

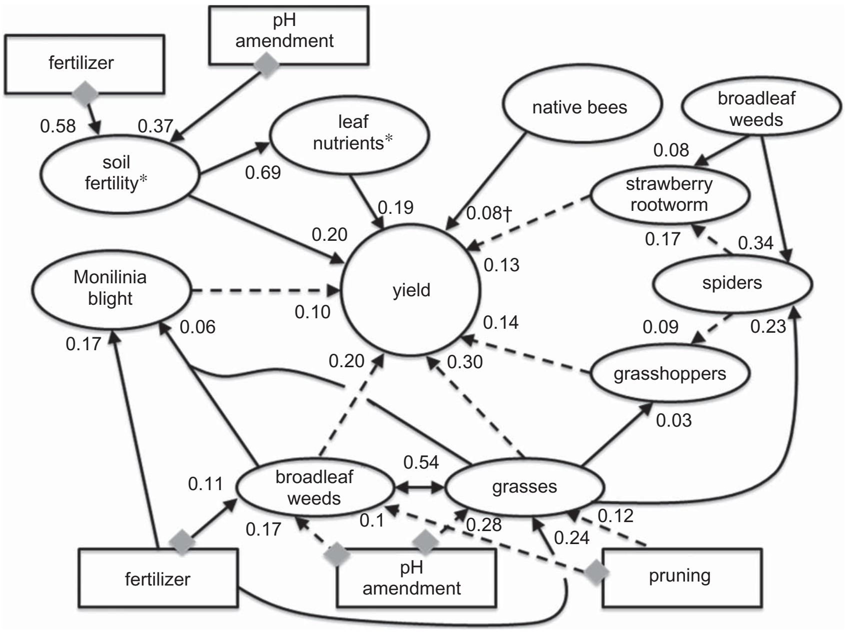

**FIGURE 1** A path-systems model of organic lowbush blueberry production system. Arrows with a single head represent causal effects, double-headed arrows represent correlations. Solid lines are positive relationships and dashed lines are negative or inverse relationships. Gray diamonds represent a significant year × factor interaction present. Path coefficients are displayed at arrow heads (coefficients estimated using SPSS–AMOS$^{TM}$ software). Footnotes: † = significant at $P \leq 0.10$ (all other relationships are significant at $P < 0.05$), * = analysis performed on first axis of PC ordination.

of fertilizer applications. The general lack of a fertilizer response in yields is most likely due to the strong effects of weeds in the system. Both broadleaf weeds and grasses respond well to pruning, sulfur application, and fertilization (albeit with year × factor interactions), but to the detriment of yield as weeds compete for space and nutrients with blueberry plants. This competitive interaction apparently is strong enough that a direct fertility response in yield to fertilization is not realized. In other words, any nutritional benefit to the blueberry plant is offset by the growth response and resulting competitive effect by the weeds. Therefore, when a mixed model ANOVA is conducted on yield as a function of pruning, sulfur addition, and fertility it is the indirect effects on yield through management practices that suppress weed growth that are seen (i.e., burning and sulfur addition result in the highest yields and also the most suppression of weeds). The effects of sulfur and pruning on yield are shown in Fig. 2A ($F_{(1,14)} = 5.311$, $P = 0.037$). Weeds tend to drive many of the ecological interactions in the lowbush blueberry production system.

Figure 1 shows that weeds also affect *Monilinia* blight and both insect pests and their natural enemies. All of these relationships have positive slopes, suggesting that weeds positively synergize with the lowbush blueberry pest complexes, while at the same time suppressing yield. The only positive effect of fertilizers, other than the effect of increasing soil fertility and leaf nutrients, on yield is on increasing *Monilinia* blight disease of blueberry ($F_{(2,200.9)} = 4.046$, $P = 0.019$; Fig. 2B). Native bees are the only positive effect on yield other than that of fertilization. The positive effect of native bees on yield is weak, but this may be due to the design of our experiment that included supplemental pollination with bumble bees and honey bees.

## Ancillary Experiments

Weed management can be obtained in part by soil pH management as shown in the preceding systems analysis. However, this is not effective for perennial woody weed species. Our study on sequential cutting found that although the number of stems increased with the first two cuts in 2007, the height of the stems declined with each sequential cut ($F_{(3,16)} = 12.23$, $P < 0.001$ and $F_{(3,16)} = 8.59$, $P = 0.001$; birch and willow, respectively, Fig. 3). Ratings in the following year (2008) found that birch was completely controlled and willows had less than one stem surviving per patch. Cutting woody weeds two or three times in one growing season effectively controlled birch and also reduced the height of willows to below that of blueberry (Fig. 3), which greatly reduces competition and detrimental effects on yield. Therefore, cutting is an effective strategy for controlling woody perennial weeds, but only if it is performed three times within a year.

The rates of N, P, and K and concentrations of the major N constituents varied among the fertilizers (Table 1). Our fertilizer study showed

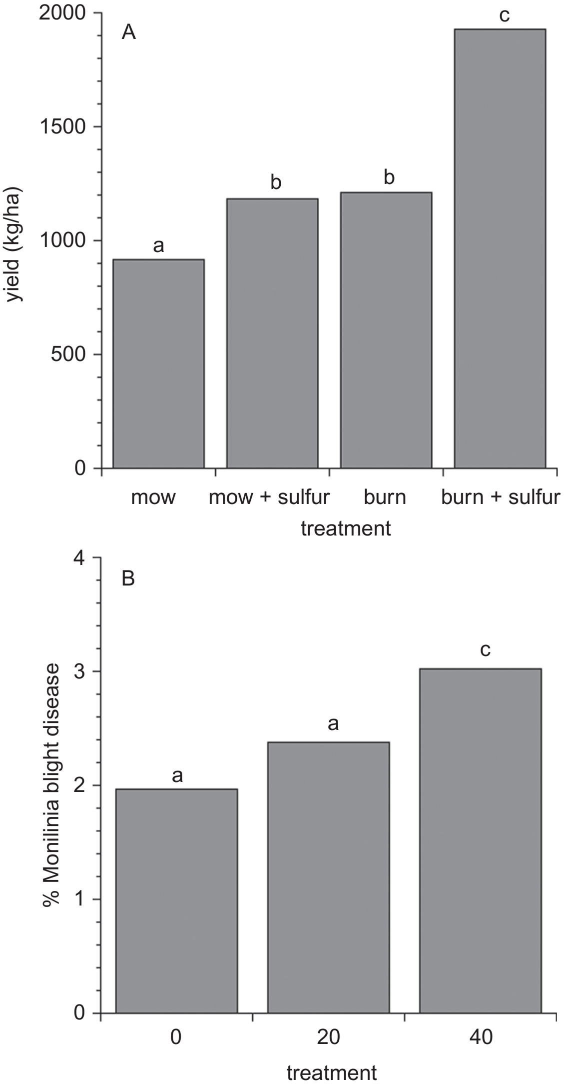

**FIGURE 2** Results of the long-term organic systems research project. Response of wild blueberry yield to the interaction of pruning and sulfur addition over three production cycles (A). There was no year * pruning * sulfur interaction, $F_{(2,172)} = 1.604$, $P > 0.05$. The response of Monilinia blight disease incidence in lowbush blueberry to fertilizer level (Kg N/Ha) over 3 years (B). There was no year × fertilizer interaction, $F_{(4,168)} = 0.609$, $P > 0.05$.

that Pro-Holly was as effective as DAP in supplying N and P. Although K was not deficient, Pro-Holly raised leaf K concentrations and could be useful in fields where this nutrient is deficient. Correcting the N and P deficiency resulted in more growth and increased stem branching, and flower bud formation. Pro-Holly was the only organic fertilizer that resulted in higher yields

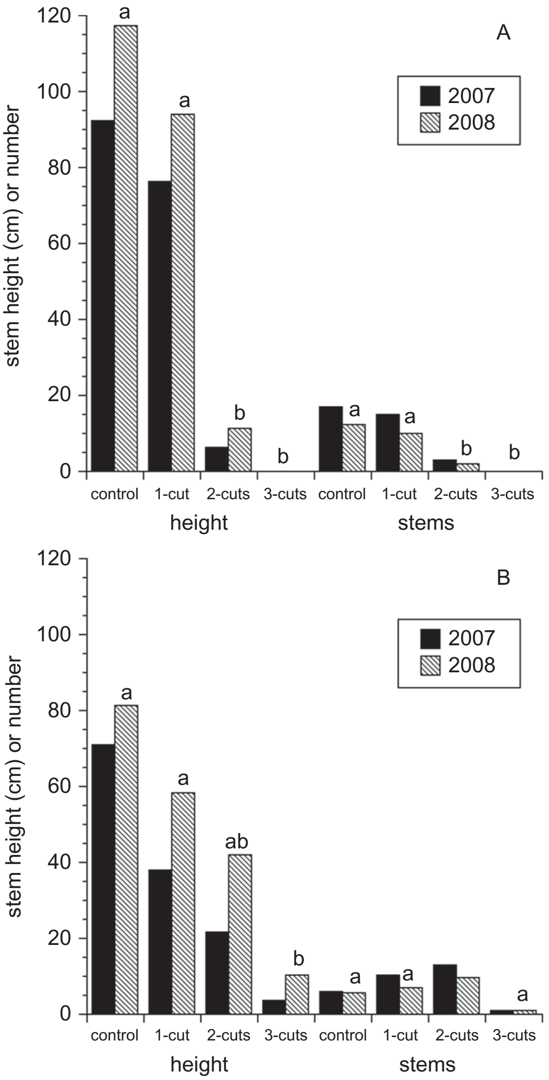

**FIGURE 3** Average height (in cm) and number of white birch stems (A) and willow (B) per patch in June 2007 and 2008 following manual cutting treatments in the summer of 2007. Cutting regimes followed by the same letter are not different (Tukey-test).

than the controls and was equivalent to treatment with DAP ($F_{(5,35)} = 21.21$, $P < 0.001$).

Insect control is not a top priority for most organic wild blueberry growers in Maine, although blueberry maggot was a concern for 37.5% of them (Files et al., 2008b). The organically approved (OMRI) insecticide, Naturalyte (GF-120), is recommended for control of the blueberry maggot (Drummond et al., 2009b). While GF-120 has consistently reduced fly trap captures in

**TABLE 1** Analysis and Rates of Four Organic Fertilizers and the Industry Standard (DAP)

| | Analysis | | | Application rates | | |
|---|---|---|---|---|---|---|
| Fertilizer | Total N$^z$ (%) | $NH_4$-N$^z$ (%) | $NO_3$-N$^z$ (%) | N (kg/ha) | P (kg/ha) | K (kg/ha) |
| Renaisance 8-2-6 | 8.63 | $<0.01$ | 0.0003 | 67 | 8 | 41 |
| Pro-Holly 4-6-4 | 4.41 | $<0.01$ | 1.39 | 67 | 44 | 56 |
| Pro-Grow 5-3-4 | 1.04 | 0.27 | 0.64 | 67 | 18 | 45 |
| Nutri-Wave 4-1-2 | 3.26 | 0.20 | 0.0024 | 67 | 8 | 28 |
| DAP 18-46-0 | 16.8 | 15.4 | 0.0002 | 67 | 74 | 0 |

$^z$Total N, $NH_4$-N, $NO_3$-N from analysis of each fertilizer product by the Maine Agriculture and Forestry Experiment Station Analytical Laboratory.

treated fields compared to a non-sprayed control in 7 years of field trials, it has been less reliable (3 of 7 years) in terms of significantly reducing maggot infestation (Drummond, unpublished data). Therefore, we decided to test a continuous sticky tape deployed around the perimeter of a field plot. Our results provided evidence that over the 2-year-period, 2008–2009, the blueberry maggot fly was significantly reduced in plots surrounded by a perimeter of barrier tape compared to an unprotected control plot (MANOVA, $F_{(1, 6)} = 6.305$, $P = 0.046$; Fig. 4). There was no evidence for a treatment × year interaction ($P > 0.05$). However, we had much better results in 2008 compared to 2009 (Fig. 4), despite there being greater pest pressure.

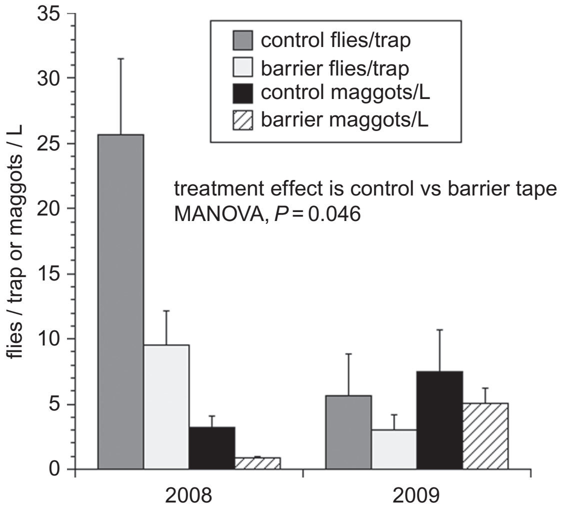

**FIGURE 4** Measures of blueberry fly infestation (flies or maggot infested fruit) for non-protected versus barrier tape protected fields in 2008 and 2009.

## Economic Analysis

A detailed discussion of our economic analysis can be found in a technical bulletin (Files et al., 2008a). The analysis was conducted only on the first two production cycles. The most important findings were as follows. Fertilization does not increase yields and is not a profitable management practice for organic blueberry production (this is mainly due to the resulting increased weed biomass). The best total revenue (based upon fresh-pack prices) resulted from the management practices that included burning and adding sulfur as a soil amendment ($8,919/acre) and the practices of mowing and not using a pH adjusting soil amendment resulted in the lowest total revenue ($3,997/acre). Variable labor and materials costs were highest for the burn-sulfur practices, but despite this the highest net income was found to be associated with the burn-sulfur practice ($6,268/acre). The mow-no sulfur practice resulted in the lowest net income ($2,640/acre). The variation in yield within suites of management practices suggested that site effects can have a large effect on the projected income of these management practices and that externalities may play a more important role in grower selection of management practices (e.g., wild fires and the safety of burning).

In addition, our economic analysis was confined to the geographic variation in yield at a single farm in Amherst (although our blocks were laid out over varied hilly topography) and annual variation over just a 4-year-period (2009 did represent the wettest Maine growing season in recorded history, but was not included in the economic risk analysis). We state this to acknowledge that the range in yield variation in what organic growers might expect for the two practices of pruning and soil amendments for pH management could be much greater than our estimates used in our simulations (Files et al., 2008a). In addition, there is great variation in organic blueberry management practices both from a performance and cost perspective (see below) and so we believe that our economic analyses provide more of a schematic of the economic landscape of organic blueberry production in Maine than a business plan.

## Socio/Economic Descriptive Profile

Maine organic wild blueberry growers are rapidly growing in numbers. In the 2010 summer organic grower field day about 1/6 of the attending growers (ca. 30) were new growers (Drummond, personal observation). The organic wild blueberry grower community is very diverse as are their practices. A detailed summary of our findings is reported in Files et al. (2008b). Growers range in age from 25 to 74 (mean of 54 yrs) and farms range in size from 0–2 ha to more than 12 ha, but are generally quite small (mode is ca. 2 ha). Practices are highly diverse also. For example, 63% of the growers mow instead of burn for pruning. However, of those that mow, 23% use a garden lawn mower, 34% use a tractor pulled flail mower, 25% use a tractor-pulled rotary mower, and 18% use some other tactic such as a scythe (Files et al., 2008b).

A particular relationship that has not been published and was not initially expected was the uneven deployment of honey bee or bumble bee pollination capital. There is an inverse relationship ($F_{(1,12)} = 6.561$, $P = 0.025$, $\beta = -0.146$) between farm size and stocking density of bumble bees or honey bees (Fig. 5). Hive stocking density recommendations for lowbush blueberry are the same for hives of honey bees and hives (not quads) of bumble bees (Drummond, 2002; Stubbs et al., 2001). Since the measure of pollination investment surveyed was hives/acre, one might expect a flat response (slope of zero) or possibly a positive slope suggesting that more profitable larger farms (linear relationship between farm size and percent of income from blueberries, $F_{(1,26)}$, $P = 0.091$, $\beta = 0.007$) invest more heavily in pollination. One explanation is that most Maine organic lowbush blueberry growers sell fresh fruit directly to the public (Files et al., 2008b). Because of this, it is common that the entire field is not harvested (69.4% ± 40.9%; mean ± SD, respectively). Therefore, there may be a reluctance to invest heavily in pollination if harvest is not necessarily a function of field size. Another

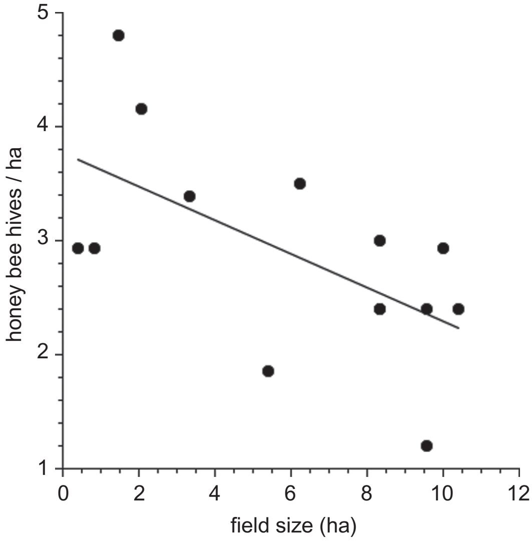

**FIGURE 5** The inverse relationship between organic lowbush blueberry field size and stocking density of honey bees and bumble bees on a per acre basis. Data derived from a Maine grower survey conducted in December 2006.

explanation is that only 30% of the growers surveyed invested in commercial bees for pollination and several relied solely on native bees, and so it is possible larger farms are managed by growers that are intentionally conserve native pollinators (Drummond and Stubbs, 2003).

Case studies are valuable for providing a detailed vertical investigation of farm-level structure, capital investment strategies, and philosophies (Gerring, 2007). Our study of five growers provided insight into the operation of five very different blueberry farms. The growers included: (1) a grower that didn't own his own land, but cooperatively managed and harvested other peoples' land; (2) a couple that specialized in making jams, jellies, and fruit juice; (3) a couple that specialized in making blueberry tea, but also sold fresh market and frozen berries; (4) a couple that specialized in blueberry dog biscuits, but also sold fresh market berries; and (5) a couple that sells frozen blueberries bulk, but also specialized in making blueberry "leather" and selling this product to retail stores. These growers represent the diversity that constitutes the Maine organic lowbush blueberry community. Despite this diversity, several common themes emerged among the growers. There is a high degree of innovation in acquisition of labor and in management practices and a high level of marketing "value-added" products. In addition, while economics is a very important consideration in the daily operations of their farms, stewardship of the land and a concern for the environment and healthy food are major factors in the decision making process.

## Extension/Outreach

The Maine organic research/Extension project has enabled the University of Maine research and Extension faculty a conduit to a rapidly growing sector of the wild blueberry production system. Most growers have only been growing blueberries for 5 years or less (Files et al., 2008b). This project has enabled us to develop Extension publications on production practices (Drummond et al., 2009), economics (Files et al., 2008a), socio/economic profile (Files et al., 2008b), and to initiate a new Fact Sheet series on beneficial insects (Choate et al., 2009). Our outreach has also been focused on grower field days. We have approached this as a team and we schedule these annual spring or summer field days at an organic grower's farm and select a different farm in a different area of the state each year. So far we have held six of these field days. The first field day was held in 2005 in Cherryfield, Maine, then successive field days were held between 2006 and 2010 in Washington, Waldo, Hancock, and Penobscot Counties. The growers have responded very favorably to these field days and attendance is generally between 25 and 40. Much brainstorming and exchange of ideas occurs among growers and growers and researchers. We have also held several spring organic meetings where we have reported the results of our previous year's research prior to the start of the growing season. These meetings have been held at a central location in Ellsworth, Maine.

## CONCLUSIONS

We have initiated a long-term research and Extension project of the Maine organic lowbush blueberry production system. After 6 years, we have learned much about the ecology of the blueberry production system and the grower community. The ecology appears to be driven by the weed community that in turn is greatly affected by fertilizer applications. These fertilizer applications also appear to directly affect grasshopper pests (probably directly acting as an optimal food source) and *Monilinia* blight disease (either indirectly by affecting blueberry plant susceptibility or indirectly by affecting the weed community, which in turn may affect the microclimate influence on infection success). Burning and the addition of sulfur enhance yield greatly by reducing weed growth and potentially enhancing the uptake of nutrients in the soil by blueberry plants. These practices can increase grower net revenues by 2.4 times on average. Ancillary research projects conducted over this time suggest that woody perennial weeds can be managed by hand cutting, but only if the frequency of cutting is three times per year or more. In addition, birch is reduced more by cutting than is willow. Field perimeter sticky tape deployment was also shown to have potential for reducing blueberry maggot infestation as does the application of the OMRI approved GF-120 NF Naturalyte$^{TM}$. Organic growers of wild blueberries in Maine are highly diverse in terms of their practices and markets and they are middle aged on average, but a large proportion are young with less than 5 years of experience on farm fields that are 2 ha or less in size.

## ACKNOWLEDGMENTS

We would like to acknowledge Judith Collins, Kristen McGovern, Kerry Lough-Guissepe, Sarah Hoffmann, Beth Choate, Wind Fastook, and Jennifer D'Appollonio for technical help with the research portion of this project. Many undergraduate research assistants also helped with data collection in this study over the 6 years, and we appreciate their careful work. We would also like to thank Kathleen Frost for assisting in writing the technical bulletin on organic management practices and Andrew Files for conducting interviews and economic surveys of organic growers. The dozen or so cooperating organic farmers that helped shape the research objectives were invaluable participants in this endeavor. We would also like to thank the numerous blueberry landowners and managers who allowed us to use their fields for experiments. This project was funded by a USDA/Organic Transitions

Grant. Additional funding was obtained from the Maine Organic Farmer's and Grower's Association, and the Maine Wild Blueberry Commission. We would especially like to thank David K. Bell. This is journal number 3256 of the Maine Agricultural and Forestry Experiment Station.

## LITERATURE CITED

Childers, N.F. and P.M. Lyrene (eds.). 2006. Blueberries for growers, gardeners, promoters. Dr. Norman F. Childers Hort. Publ., Gainesville, FL, 266 p.

Choate, B., F. Drummond, and D. Yarborough. 2009. Beneficial insect series 1: The Allegheny mound ant. Fact Sheet 195, University of Maine Cooperative Extension, Orono, ME. 6 February 2012. <http://extension.umaine.edu/blueberries/factsheets/insects/195-allegheny-mound-ant>.

Dillman, D.A. 1978. Mail and telephone surveys—The total design method. John Wiley & Sons, New York, NY, 341 p.

Drummond, F.A. 2000. History of insect pest management for lowbush blueberries in Maine. Trends Entomol. 3:23–32.

Drummond, F.A. 2002. Honeybees and blueberry pollination. University of Maine Cooperative Extension Wild Blueberry Bulletin No. 629, Orono.

Drummond, F.A. and C.S. Stubbs. 2003. Wild bee conservation for wild blueberry fields. University of Maine Cooperative Extension Fact Sheet 630, Orono, 12 p.

Drummond, F., S. Annis, J.M. Smagula, and D.E. Yarborough. 2009a. Organic production of wild blueberries. I. Insects and disease. Acta Hort. 810:275–286.

Drummond, F., S. Annis, J.M. Smagula, and D.E. Yarborough. 2009b. Organic wild blueberry production. Maine Agric. For. Exp. Stn., University of Maine, Orono. Tech. Bull. 852, 43 p.

Files, A., D. Yarborough, and F. Drummond. 2008a. Economic analysis of organic pest management strategies for wild blueberries using enterprise budgeting. Maine Agric. For. Exp. Stn., University of Maine, Orono. Tech. Bull. 198, 12 p.

Files, A., D. Yarborough, and F. Drummond. 2008b. Grower survey of organic pest management strategies for wild blueberries in Maine with case studies. Maine Agric. For. Exp. Stn., University of Maine, Orono. Tech. Bull. 759, 33 p.

Gerring, J. 2007. Case study research: Principles and practice. Cambridge Univ. Press, Cambridge, UK, 271 p.

Kay, R.D. 1986. Farm management: Planning, control, and implementation, Second Edition. McGraw-Hill, Inc., New York, NY, pp. 65–82.

McGovern, K.B., S.L. Annis, and D. Yarborough. 2012. Efficacy of organically acceptable materials for control of mummy berry disease in lowbush blueberries in Maine. Intl. J. Fruit Sci. 12:188–204.

McLean, R.A., W.L. Sanders, and W.W. Stroup. 1991. A unified approach to mixed linear models. Amer. Stat. 45:54–64.

Pennings, J.M.E., S.H. Irwin, and D.L. Good. 2002. Surveying farmers: A case study. Appl. Econ. Persp. and Policy 24(1):266–277.

Pugesek, B.H., A. Tomer, and A. von Eye. 2003. Structural equation modeling: Applications in ecological and evolutionary biology. Cambridge Univ. Press, Cambrideg, UK, 409 p.

Smagula, J.M., D.E. Yarborough, F.A. Drummond, and S. Annis. 2009. Organic production of wild blueberries II. Fertility and weed management. Acta Hort. 810:673–684.

Stubbs, C.S., F.A. Drummond, and D. Yarborough. 2001. Commercial bumble bee, *Bombus impatiens*, management for lowbush blueberry. University of Maine Cooperative Extension Wild blueberry fact sheet No. 302, Orono, 4 p.

Whalon, M., G. Bird, D. Birmingham, K. Delate, A. Puvalowski, and J. Wilson (eds.). 2007. Proceedings 4th International Organic Tree Fruit Research Symposium, March 3–6, 2007, Michigan State University, East Lansing, Michigan, 41 p.

Yarborough, D. 1994a. Cultural management for weeds in wild blueberries. University of Maine Cooperative Extension Fact Sheet No. 252, Orono.

Yarborough, D. 1994b. Cultural management for insects and diseases in wild blueberries. Fact Sheet no. 253, Univ. Maine Coop. Extension, Orono (updated in 2004).

Yarborough, D. 1998. Cultural management pH. Fact Sheet no. 254, University of Maine Cooperative Extension, Orono (updated in 2008).

Yarborough, D. 2009. Wild blueberry culture in Maine. Fact Sheet No. 220, University of Maine Cooperative Extension, Orono.

Yarborough, D.E., J.M. Smagula, F.A. Drummond, and S. Annis. 2009. Organic production of wild blueberries III. Fruit quality. Acta Hort. 810:847–852.