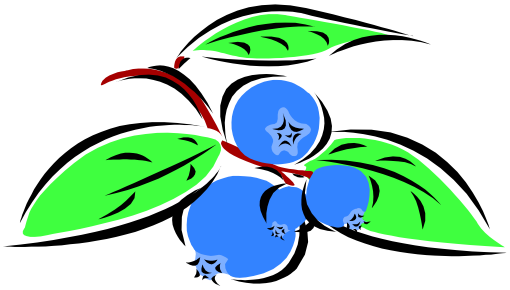
PROCEEDINGS

10th North American Blueberry Research & Extension Workers' Conference



June 4-8, 2006
Tifton, Georgia

1785
The University of Georgia
College of Agricultural & Environmental Sciences

10th North American Blueberry Research & Extension Workers' Conference June 4-8, 2006

at the
University of Georgia Tifton Campus Conference Center
Tifton, GA

Hosted by

D. Scott NeSmith, Editor

Forward and Acknowledgements

The 10th North American Blueberry Research & Extension Workers' Conference was held at The University of Georgia's Tifton Campus Conference Center on June 4-8, 2006. The first half of the Conference consisted of oral and poster paper presentations by scientists from around North America and abroad, while the last two days was a tour of the Georgia blueberry industry and an overnight trip to St. Simons Island. Conference organizers were Dr. Gerard Krewer and Dr. D. Scott NeSmith, faculty members in the Department of Horticulture at The University of Georgia.

The Conference organizers would like to thank the following sponsors for funds received in support of the 10th North American Blueberry Research & Extension Workers' Conference.

Driscoll's

Georgia Blueberry Growers' Association

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Michigan Blueberry Growers Association

Southern Region Small Fruit Consortium

SunnyRidge Farm, Inc.

U.S. Highbush Blueberry Council

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10th North American Blueberry Research & Extension Workers' Conference

Scheduled Program

SUNDAY, JUNE 4, 2006

3:00-6:00 pm	**Registration at Agrirama (State Museum of Agriculture) Exit 63B then go west, I-75, Tifton, Ga.**

MONDAY, JUNE 5, 2006

8:00-8:30 am	**Registration at UGA Tifton Campus Conference Center Exit 64 then go west, I-75, Tifton, Ga.**
8:30 am	**ORAL PAPER SESSION I**
8:30 am	**Welcome**
8:40 am	**U.S. Highbush Blueberry Council - How It Works, What It Does** Dave Brazelton, Fall Creek Nursery, Lowell, OR
9:00 am	**Sensitivity Profitability Analysis for Growing Rabbiteye Blueberries in Georgia** Greg Fonsah, Univ. of Georgia
9:20 am	**Stirring the Pot; The Role Of Interspecific & Sectional Hybridization in the N. C. State Program** Jim Ballington, North Carolina State Univ.
9:40 am	**Seasonal & Varietal Variation in Hardiness of Blueberry Flower Buds** Eric Hansone, Michigan State Univ.
10:00 am	**Refreshment Break**
10:40 am	**Soil Characteristics Associated with Wild Huckleberry and Bilberry Colonies in the Northwestern U.S.** Danny Barney, Univ. of Idaho
11:00 am	**Evaluation of Two Organic Fertilizer Blends for Blueberry Production** Wei Yang, Oregon State Univ.

11:20 am	**Nutrient Assessment Technologies for Wild Blueberry Production** David Percival, Nova Scotia Agricultural College
11:40 am	**Comparison of Irrigation Methods for Establishing Highbush Blueberry** David Bryla, USDA-ARS, Corvallis, OR
12 noon – 1:30 pm	**Lunch Break** (included in full conference registration)
1:40 pm	**Environmental Losses of Soil Applied Nitrogen in Wild Blueberry Production** Gloria Thyssen, Nova Scotia Agricultural College
2:00 pm	**Effects of Raising Leaf Cu Concentration Growth & Field of Lowbush Blueberry** John Smagula, Univ. of Maine
2:20 pm	**Reducing Soil pH To Control Weeds in Wild Blueberries** David Yarborough, Univ. of Maine
2:40 pm	**Parthenocarpic Fruit Development in Highbush Blueberry (*Vaccinium corymbosum* L.)** Mark Ehlenfeldt, USDA-ARS, Chatsworth, NJ
3:00 pm	**Refreshment Break**
3:30 pm	**POSTER SESSION I** (authors present at posters)

Poster Number

1.	**Blueberry Production Increasing in Clinch County** Elvin Andrews, Univ. of Georgia
2.	**Improved Methods of Replanting Blueberries in Established Fields** Elvin Andrews, Univ. of Georgia
3.	**Phytotoxicity of CPPU on Southern Highbush Blueberry in North Carolina** Bill Cline, North Carolina State Univ.
4.	**Nutsedge Control in Newly Planted Blueberries** Mark Czarnota, Univ. of Georgia

5. **Cost Benefit Analysis of Rabbiteye Blueberry Production in Georgia**
Greg Fonsah, Univ. of Georgia

6. **The New Michigan State University Highbush Blueberry Varieties**
Jim Hancock, Michigan State Univ.

7. **Horizontal Wells: What Are They, How Do They Work, and How Would They Benefit Us**
Gary Hawkins, Univ. of Georgia

8. **New Southern Highbush Blueberry Varieties from The University of Georgia**
D. Scott NeSmith, Univ. of Georgia

9. **Response of 'Reveille' Southern Highbush Blueberry to Various Amounts of Pinebark in a Typical Flatwoods Georgia Soil**
Gerard Krewer, Univ. of Georgia

5:30-8:30 pm **Tour of UGA Alapaha Blueberry Research Station and Pig / Vegetable Roast** (included in full conference registration or daily registration with dinner)

TUESDAY, JUNE 6, 2006

8:00-8:30 am **Registration at UGA Tifton Campus Conference Center**

8:30 am **ORAL PAPER SESSION II**

8:30 am **Welcome**

8:40 am **Georgia's Native *Vaccinium* Species**
Wendy Zomlefer, Univ. of Georgia

9:00 am **Factors Influencing the Long Term Storage of Blueberries**
Jim Hancock, Michigan State Univ.

9:20 am **Impact of Management Practices on Blueberry Shoot Growth**
Bernadine Strik, Oregon State Univ.

9:40 am **Use of Phosphite Fungicides for Control of Blueberry Diseases in Georgia**
Phil Brannen, Univ. of Georgia

10:00 am	**Refreshment Break**
10:40 am	**Implementation of a Reduced-risk IPM Program for Control of Blueberry Insect Pests** Rufus Isaacs, Michigan State Univ.
11:00 am	**Studies on Transmissibility of Stem Canker via Cuttings from Infected Plants** Bill Cline, North Carolina State Univ.
11:20 am	**Effects of Cultural Practices on Severity of Blueberry Root Rot** Barbara Smith, USDA-ARS, Poplarville, MS
11:40 am	**Screening for Sources of Aphid Resistance in Vaccinium spp., Advanced Selections & Cultivars** Christopher Ranger, Rutgers Univ.
12 noon – 1:30 pm	**Lunch Break** (included in full conference registration)
1:40 pm	**Mummy Berry Disease of Southern Blueberries: What Have We Learned During the Past Ten Years** Harald Scherm, Univ. of Georgia
2:00 pm	**Reducing Microbial Contamination of Blueberry Fruit** Annemiek Schilder, Michigan State Univ.
2:20 pm	**Commercial Propagation & Delivery of the Orchard Mason Bee for Cultivated Blueberry Pollination** Blair Sampson, USDA-ARS, Poplarville, MS
2:40 pm	**A Recent History of Pesticide Use in New Jersey Blueberry Prodution** Dean Polk, Rutgers Univ.
3:00 pm	**Refreshment Break**
3:30 pm	**POSTER SESSION II** (authors present at posters)

Poster Number

1.	**Pruning and Mechanical Harvesting Southern Highbush and Rabbiteye Blueberries** Elvin Andrews, Univ. of Georgia

2. **Natural Enemies in Blueberry**
Rufus Isaacs, Michigan State Univ.

3. **Fiber Content of Two Rabbiteye and Two Southern Highbush Cultivars**
Donna Marshall, USDA-ARS, Poplarville, MS

4. **Development and Implementation of Reduced-risk Pest Management Programs for Blueberries in New Jersey**
Cesar Rodriguez-Saona, Rutgers Univ.

5. **Fungicides and Fungicide Timing for Control of Blueberry Diseases**
Annemiek Schilder, Michigan State Univ.

6. **Recent and Pending Blueberry Cultivar Releases**
Steve Stringer, USDA-ARS, Poplarville, MS

7. **Evaluation of Southern Highbush Blueberry Cultivars for Forcing Culture in Japan**
Takato Tamada, Japan

8. **Evaluating New Pre and Post Herbicides for Weed Control in Wild Blueberries**
David Yarborough, Univ. of Maine

9. **New Rabbiteye Blueberry Varieties from The University of Georgia**
D. Scott NeSmith, Univ. of Georgia

5:30 pm-8:30 pm **Quail and Chicken Supper at UGA Blackshank Lake and Picnic Shelter** (included in full conference registration or daily registration with dinner)

WEDNESDAY, JUNE 7, 2006

7:30 am Depart Post-conference Tour from Tifton Hotels

THURSDAY, JUNE 8, 2006

7:00 pm Return from Post-conference Tour to Tifton Hotels

Table of Contents

Sensitivity Profitability Analysis for Growing Rabbiteye Blueberries in Georgia

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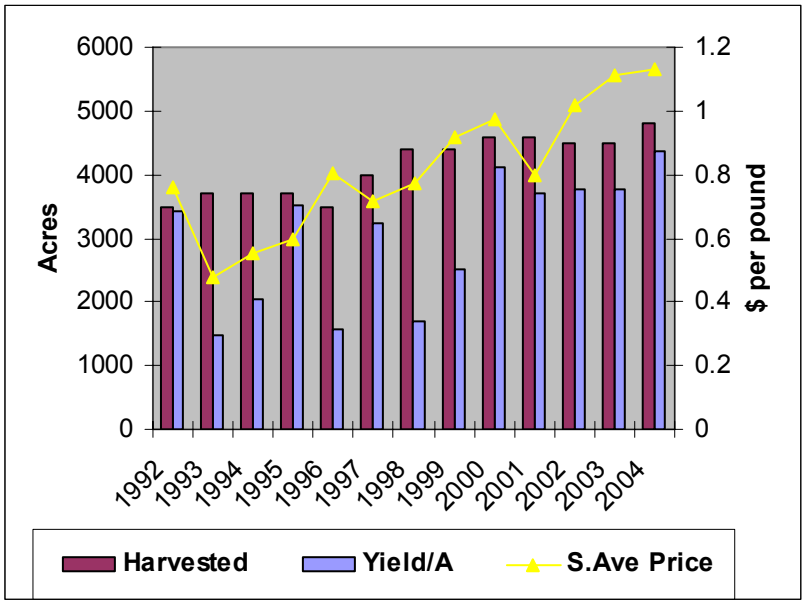
Introduction

Rabbiteye blueberry (Vaccinium *ashei*) is the most important type of blueberry grown in Georgia. This species is classified as a highbush blueberry type, but is distinctively different from highbush (*Vaccinium corymbosum*) in its ability to withstand high temperatures and lower organic matter soils (Krewer and NeSmith, 2002). Rabbiteye blueberries are relatively high yielding with well tended field commercial yields in the range of 5,000 to 8,000 pounds per acre typical on well maintained fields. Occasionally optimistic yields in excess of 10,000 to 12,000 pounds per acre are reported once in eight years. Fields may remain productive for thirty years or more even though only 20 years was used in calculating the compounded establishment cost in this study (Fonsah et al, 2005; Krewer et al, 2003; Westberry et al. 1995).

Since there are several current economic analysis and budgets for rabbiteye blueberries, and the fact that cultivation techniques, cost of production, quality and prices obtained are different between growers, thus, no single budget can capture the exact profitability margin, the focus of this study was to determining the sensitivity of profit margin using a risk-rated analysis.

Blueberry has become an important economic crop in the state of Georgia. Since 2004 Georgia blueberry industry surpassed peach and became number two most important fruit in the state by generating 21.4% of total farm gate value that year. Yield trend has been inconsistent increasing from 1992 to 2004. The best yields were in 2000 and 2004 and it is expected to increase through 2006 as the growers adopt new technologies and good agricultural practices (Fig. 1). Harvested area has been rising since 1992. The lowest season average price of 47 cents/lb was in 1993 and since then, prices have been rising. In 2005 the price per lb rose to $1.50 and it is expected to rise to $1.65/lb in 2006 (Fig 1).

Figure 1. Georgia Blueberry Harvested, Yield and Seasonal Average Price, 1992-2004.



Source: Georgia Farm Report Volumes 06-Number 03, Vol. 05-Number 11, 2005.
Also see: http://www.nass.usda.gov/ga/

Cost Breakdown Analysis

The figures in Table 1 were extracted from a comprehensive study entitled "the estimated cost and economics for rabbiteye blueberries in Georgia, 2005" in which the costs of cultivating rabbiteye blueberries were calculated. The study showed that expected yield for years two through four were 500 lbs, 1,300 lbs and 4,500 pounds respectively. Total establishment costs were $5,022, $2,223, $3,488 and $4,671 in years 1 through 4 respectively (Fonsah et al. 2005; Fonsah et al. 2004; Lisec and Strik; 1995; Westberry et al. 1995).

Table 1: Selected Cost Breakdown of Producing Rabbiteye Blueberries in Georgia, 2006.

Measure and Product Type	Year 1	Year 2	Year 3	Year 4
Yield/Acre (lbs)	0	500	1,300	4,500
Gross Receipts ($)	0	725	1,866	4,388
Pest & Disease Control ($)	97	97	175	405
Est. Cost/Acre of Drip Irrigation (25 acres)	373	373	373	373
Total Variable Cost ($)	3,620	561	659	1,248
Total Harvesting & Marketing Costs ($)	0	719	1,871	2,377
Total Fixed Cost ($)	1,402	943	958	1,046
Total Establishment Costs ($)	5,022	2,223	3,488	4,671
Total Est. Costs after Returns from Receipts ($)	5,022	1,498	1,621	284
Recaptured Annual Est. Cost/acre/year ($)	2,736	2,736	2,736	2,736

Total variable or operating costs were $3,620, $561, $659 and $1,248 in years 1 through 4 respectively. The major cost components in year one were land preparation and planting which included but not limited to stumping, pushing, burning, ditching and drainage, chopping, milled pine bark, plants, and labor (Fonsah et al. 2005, Fonsah et al. 2004; Lisec and Strik, 1995; Westberry et al. 1995).

According to a recent study, the expected return or yield per acre for rabbiteye blueberry in Georgia was 5,000 pounds. With an expected price is $1.45 per pound, the total return was $7,250 per acre if sold 100% fresh. However, if only 50% was sold fresh and the remainder 50% is sold as frozen at the price of $0.05 per pound, then the total expected return would be $4,875 (Fonsah et al, 2005; Fonsah et al. 2004; Lisec and Strik, 1995).

Sensitivity Profitability Analysis

An economic risk-rated sensitivity analysis over total costs of producing and selling rabbiteye blueberries was conducted to determine the riskiness and profitability margin under five different price and yield levels respectively. Two price levels: (1) selling 100% fresh and/or (2) selling 50% fresh and 50% processed were analyzed to determined which combination provide optimum financial benefit to the rabbiteye blueberry growers (Table 2). The pessimistic yields used for this analysis were 3000 lbs/acre and 4000 lbs/acre while the optimistic yields were 8000 lbs/acre and 12,000 lbs/acre respectively.

There were five different sensitivity prices used for selling rabbiteye blueberries 100% fresh thus: $1.10, $1.25, $1.45, $1.85 and $2.10. The combined average prices for selling 50% fresh and 50% processed were $0.68, $0.80, $0.98, $1.25 and $1.43 respectively. Table 2 shows that if a pessimistic yield of 4000 lbs/acre were produced and sold all fresh at $1.85/lb the grower will obtain a positive return of $247/acre whereas, he/she would obtain a negative return of $-765/acre if the crop was sold at an average combined 50% fresh and 50% processed price of $1.25/lb. With an optimistic yield of 8000 lbs/acre, a positive return of $4538/acre would be achieved if sold all fresh at a reduced price of $1.10/lb or a return of $2421/acre if sold at an average combined price of $0.68/lb for 50% fresh and 50% processed.

Table 2: Sensitivity analysis and economic risk-rated returns for price and yield over total costs of producing and selling fresh and frozen rabbiteye blueberries in Georgia, 2006.

Price/lb fresh & frozen	Pessimistic yield/acre	Pessimistic yield/acre	Exp yield/acre	Optimistic yield/acre	Optimistic yield/acre	Base budgeted net revenue[3]	Chances for profit[4]
	3000 lbs	4000 lbs	5000 lbs	8000 lbs	12,000 lbs		
($)	($)	($)	($)	($)	($)	($)	(%)
1.10[1]	-2184	-1105	-56	4538	6280	-1381	50
0.68[2]	-3280	-2489	-938	2421	4084	-3481	23
1.25	-1946	-765	259	5154	6932	-631	64
0.80	-2871	-1995	-686	3126	4811	-2881	30
1.45	-1698	-377	679	5937	7772	369	77
0.98	-2417	-1419	-308	4013	5730	-1981	43
1.85	-1369	247	1519	7466	9461	2369	86
1.25	-1946	-765	259	5154	6932	-631	64
2.10	-1245	565	2044	8432	10555	3619	88
1.43	-1720	-413	637	5860	7689	269	76

[1] The top row is the price/lb for rabbiteye blueberries sold 100% fresh.
[2] The bottom row is the average price/lb for rabbiteye blueberries sold 50% fresh and 50% processed.
[3] The percentage chances for profit was calculated based on the expected yield of 5000 lbs/acre and the given price.
[4] The base budgeted net revenue was calculated based on the expected yield of 5000 lbs/acre and the going price.

Conclusion

The annual recapture establishment cost was $2,736/acre. The annual fixed and variable cost of drip irrigation/acre was estimated at $373/acre and included, pipe and fittings, sprinklers, six inch well that can handle 300 gals/min pump, motor, installation and miscellaneous. The total establishment costs/acre for years 1, 2, 3 and 4 were $$5,022, $2,223, $3,488 and $4,671 respectively. Harvesting and marketing costs were $719, $1,871, and $2,377/acre for years 2 through four respectively. Total fixed costs were $1402, $943, $958 and $1,046/acre for years 1 through 4 respectively.

An economic risk-rated sensitivity analysis over total costs of producing and selling rabbiteye blueberries was conducted to determine the riskiness and profitability margin under five different price and yield levels. The results showed that if a pessimistic yield of 4000 lbs/acre were produced and sold all fresh at $1.85/lb then growers will obtain a positive return of $247/acre whereas, he/she would obtain a negative return of $-765/acre if the crop was sold at an average combined 50% fresh and 50% processed price of $1.25/lb. Whereas with an optimistic yield of 8000 lbs/acre, a positive return of $4538/acre would be achieved if sold all fresh at a reduced price of $1.10/lb or a return of $2421/acre if sold at an averaged combined price of $0.68/lb for 50% fresh and 50% processed.

Literature Cited

Fonsah, E.G., G. Krewer, K. Harrison and D. Stanaland (2005). "Estimated Cost and Economics for Rabbiteye Blueberries in Georgia". AGECON 05 108, Department of Agricultural and Applied Economics, College of Agricultural and Environmental Sciences, University of Georgia.

Fonsah, E.G., G. Krewer, K. Harrison and M. Bruorton (2004). "Economic Analysis of Producing Southern Highbush Blueberries in Soil in Georgia". AGECON 04 93, Department of Agricultural and Applied Economics, College of Agricultural and Environmental Sciences, University of Georgia.

Krewer, G. and D.S. NeSmith. 2002. "The Georgia Blueberry Industry: Its History, Present State, and Potential for Development in the Next Decade", Acta Hort. 574:101-106.

Krewer, G., D.S. NeSmith, P. Brannen, B. Boland, D. Stanaland and M. Bruorton. 2003. "Establishing High bush and Rabbiteye Blueberries in Georgia" (Unpublished manuscript).

Lisec, B. T Cross and B Strik. 1995. "Blueberry Economics: The Costs of Establishing and Producing Blueberries in the Willamette Valley", Oregon State University Extension Service, EM 8526.

Westberry, G.O., W.O. Mizelle, D. Stanaland and G. Krewer. 1995. Economic Analysis of Producing Commercial Blueberries, The Cooperative Extension Service, The University of Georgia, College of Agricultural and Environmental Sciences, Ag Econ 95-040.

The Role of Interspecific Hybridization in the North Carolina State University Blueberry Breeding Program

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Introduction

Interspecific hybridization has played a significant role in blueberry improvement from the very beginning with Coville (1937). It was expanded by Darrow and his associates (Darrow and Camp, 1945; Darrow et al., 1952; Darrow et al., 1954), and by Johnston (1946), Brightwell et al., (1949), Sharpe (1966), Jelenkovic and Draper (1973), Draper (1977), Ballington (1980; 1990), Vorsa (1983), Lyrene (1988; 1990), and Luby (1991), and continues to be important in a number of programs today. The majority of named blueberry cultivars today that involve interspecific hybridization in their backgrounds are backcrosses as opposed to F_1 generation hybrids. The species that have been most important in improvement of tetraploid highbush blueberry (*Vaccinium corymbosum* L.) (2n=4x=48) "types" through interspecific hybridization are *V. angustifolium* Ait. (lowbush blueberry) (2n=4x=48), *V. darrowii* Camp (Darrow's evergreen blueberry) (2n=2x=24), and rabbiteye blueberry [*V. virgatum* Ait. (syn. *V. ashei* Reade)] (2n=6x=72). *Vaccinium angustifolium* backcross derivatives to *V. corymbosum* have been important in improvement of both standard or "northern highbush" and "halfhigh" cultivars. *Vaccinium darrowii* and *V. virgatum* backcross derivatives have been important in improvement of "southern highbush" cultivars. The contributions of the diploid species *V. darrowii* result from the production of viable unreduced gametes making it possible to produce tetraploid progeny in crosses with tetraploid *V. corymbosum*, which were then backcrossed to relatively unrelated cultivated *V. corymbosum* genotypes. The contributions of *V. virgatum* have primarily resulted from backcrossing partially fertile *V. virgatum x V. darrowii* pentaploid hybrids (again involving viable unreduced gametes from the latter species) to northern highbush cultivars for several generations to restore full fertility and genomic balance. In addition, backcross derivatives from one partially fertile *V. virgatum x V. tenellum* Ait. (2n=2x=24) pentaploid hybrid are also often involved in the parentage of this latter group. Only one other species has been important in improvement of rabbiteye blueberry up to this time. This is *V constablaeii* Gray (2n=6x=72), and although promising hybrids have been developed (Ballington et al.,1986a), few cultivars involving this species and *V. virgatum* have been named. Several other possibilities for

improvement of rabbiteye blueberry through interspecific hybridization now appear feasible. Even though not used as extensively up to this point as with tetraploid southern highbush, Vorsa (1983) demonstrated the feasibility of backcrossing partially fertile *V. corymbosum x V. virgatum* pentaploids to *V. virgatum* as a bridge to introgress desirable fruit quality traits from tetraploids into hexaploids. Ehlenfeldt and Vorsa (1993) produced a hexaploid and near hexaploid "southern highbush" (based on parentage) progeny from crossing two slightly fertile triploids, which were then successfully crossed with rabbiteye blueberry.

This report summarizes the use of interspecific hybridization by the blueberry breeding program at North Carolina State University in blueberry improvement from the beginning of the Ballington era in 1977. In the interest of brevity it will not include interspecific hybridization efforts among diploid species.

Materials and Methods

All blueberry improvement programs have traditionally built upon the success of cooperating programs, and this has certainly been the case with the North Carolina program. This includes the diverse germplasm being maintained throughout the North Carolina program, and the great breadth of germplasm available for use from cooperating programs at several USDA stations, and the University of Florida and the University of Georgia. Formal cooperation with the USDA breeding program at Beltsville, MD, was the rule until Beltsville was assigned to the northeast region of the US. Up through 1987, all blueberry cultivar releases from North Carolina were joint releases with the USDA. Fortunately most of the work reported in this report took place when free exchange and utilization of germplasm was the rule.

The other resources that made the interspecific hybridization reported herein possible were the diverse germplasm resources available as a result of germplasm collecting expeditions in North America from the late 1960s up through the mid 1990s. The extensive collections made by Galletta (1975) in eastern and central North America in the late 1960s, and Ballington et al., (1980; 1982; 1986b) in southeastern North America formed the core of the species germplasm used in interspecific hybridizations.

Standard published methodologies were used to make crosses, germinate and grow seedling progenies, establish, maintain and grow seedlings to maturity, and evaluate progenies in the field (Galletta,1975).

Results and Discussion

Tetraploids. Using cultivated northern highbush as a basis for comparison, a total of 128 elite *V. corymbosum* genotypes were identified. These included 36 that were selected primarily because of cultivar potential; 38 that were selected primarily for resistance to stem blight [*Botryosphaeria dothidea* (Mouq. ex Fr.) Ces & de Not]; 27

that were selected primarily for resistance to stem canker [*B. corticis* (Demaree & Wilcox) Arx & Muller]; and 17 wild by cultivated *V. corymbosum* intercrosses for increasing the genetic diversity in the cultivated northern hghbush genepool.

The majority of the effort in the North Carolina program is centered on southern highbush blueberry improvement due to the superior adaptation and fruit quality they have proven to produce over the years. A total of 631 elite southern highbush genotypes were identified which can be broken down into subcatagories by species composition. 185 selections only involved *V. darrowii* and *V. corymbosum*: These included 17 F_1 hybrid selections; 61 $BC_{1's}$ to *V. corymbosum*; 77 $BC_{2's}$ to *V. corymbosum*; and 30 wild *V. corymbosum* x *(V. darrowii-V. corymbosum)* selections. Elite $F_{1's}$ from the Draper era of the USDA/Beltsville program were mainly used to produce the backcross generations.

232 selections involved *V. corymbosum, V. darrowii, V. virgatum,* and *V. tenellum*: These included 17 $BC_{1's}$ to *V. corymbosum*; 21 $BC_{2's}$ to *V. corymbosum*; 85 $BC_{3's}$ to *V. corymbosum*; 29 $BC_{4's}$ to *V. corymbosum*; 41 $BC_{4's}$ to root rot (*Phytophthora cinnamoni* Rands) resistant *V. corymbosum*; 32 intercrosses; and 7 outcrosses to wild *V. corymbosum*. The majority of the cultivated parents for this group came from Draper's work at Beltsville combining the elite germplasm developed by Sharpe and Darrow along with his own contributions.

105 selections only involved *V. elliottii* Chapman (2n=2x=24) and *V. corymbosum* and represent a new type of southern highbush: These included 22 F_1 hybrid selections; 73 $BC_{1's}$ to *V. corymbosum*; and 10 $BC_{2's}$ to *V. corymbosum*. *Vaccinium elliottii* also produces viable unreduced gametes and the plant is at least as tolerant to droughty upland soils as *V. virgatum ,* however the fruit in early generation hybrids and backcrosses is often soft and dark. All the *V. elliottii* germplasm utilized in these crosses originated in the North Carolina program.

19 selections involved intercrosses of *V. darrowii-V. corymbosum* and *V. elliottii-V. corymbosum* backcrosses, and 32 involved intercrosses of *V. darrowii-V. virgatum-V. tenellum-V. corymbosum* and *V. elliottii-V. corymbosum* backcrosses. Combining both *V. darrowii* and *V. elliottii* in southern highbush genotypes appears very promising at the present time from the standpoint of fruit quality and plant adaptability.

46 selections involved *V. myrsinites* Lam. (2n=4x=48) and *V. corymbosum*: These included 19 F_1 hybrid selections; 15 $BC_{1's}$ to *V. corymbosum*; and 12 $BC_{2's}$ to *V. corymbosum*. *Vaccinium myrsinites* hybrids have shown limited promise for the most part. However several $F_{1's}$ with *V. corymbosum* produce very small, light blue, extremely firm, high acid fruit on a 1.8 m, essentially highbush type plant that should be valuable as a parent for adaptation to mechanical harvest.

7 selections involved crosses of *V. pallidum* Ait. (2n=2x=24) x *V. darrowii* $F_{1's}$ to *V. corymbosum*. 2 selections involved intercrosses of *V. darrowii-V. corymbosum* backcross selections with *V. simulatum* Small (2n=4x=48) x *V. corymbosum* $F_{1's}$. 3

selections involved intercrosses of *V. darrowii-V. virgatum-V. corymbosum* backcross selections with *V. simulatum-V. corymbosum* $F_{1's}$. These are the first hybrids in the North Carolina program involving *V. simulatum* that appear to have direct cultivar potential.

61 elite selections were identified among interspecific hybrids involving tetraploid *V. pallidum* (2n=4x=48) and *V. corymbosum*: These included 44 F_1 hybrid selections; 2 F_2 hybrid selections; 9 $BC_{1's}$ to *V. corymbosum*; and 6 $BC_{2's}$ to *V. corymbosum*. *Vaccinium pallidum* also appears promising as a parent for broad soil adaptation.

21 elite stem blight resistant selections were identified in F_1 hybrid progenies between *V. angustifolium* and *V. corymbosum*. These F_1 hybrids are now being utilized in backcrosses to both northern and southern highbush to incorporate higher levels of stem blight resistance into both types.

15 elite selections were identified that involved interspecific hybridization between *V. simulatum* and *V. corymbosum*: These included 11 F_1 hybrid selections and 4 $BC_{1's}$ to *V. corymbosum*. 7 elite selections were identified that involved 1/8 *V. elliottii*, 2/8 *V. simulatum*, and 5/8 *V. corymbosum*. These appear most promising as parents.

7 elite F_1 hybrid selections were identified between *V. hirsutum* Buckley (2n=4x=48) and *V. angustifolium*. The purpose of this cross was to develop later blooming lowbush hybrids with somewhat improved heat tolerance.

8 elite selections were identified that involved *V. angustifolium* and *V. myrsinites*, including 7 $F_{1's}$ and 1 F_2. The purpose for making this interspecific combination was for developing evergreen low statured ornamental blueberries. While the hybrids were attractive ornamental plants none were fully evergreen when grown in North Carolina.

Pentaploids and pentaploid backcrosses. To continue to transfer useful genes from species at the tetraploid level to hexaploids and vice versa, a total of 346 partially fertile to fertile elite selections were identified involving the following interspecific hybrid combinations.

65 elite selections involved *V. corymbosum* and *V. virgatum*: These included 45 F_1 hybrids; 16 $BC_{1's}$ to *V. corymbosum*; 7 $BC_{2's}$ to *V. corymbosum*; and 2 $BC_{1's}$ to *V. virgatum*.

135 elite selections involved *V. tenellum, V. corymbosum,* and *V. virgatum* to transfer non-feeding preference reistance to the sharpnosed leafhopper (*Staphytopius magdalensis* Peoc.) from rabbiteye to highbush blueberries. The sharpnosed leafhopper is the vector for the Blueberry Stunt phytoplasma. These included 14 *V. virgatum* x (*V. tenellum x V. corymbosum*) pentaploid $F_{1's}$ and 7 $F_{2's}$; 52 $BC_{1's}$ to *V. corymbosum*; 38 intercrosses of $BC_{1's}$ to *V. corymbosum*; and 24 $BC_{2's}$ to *V. corymbosum*.

66 elite selections involved (4x)*V. pallidum* and *V. virgatum*: These included 44 pentaploid $F_{1's}$; 3 $BC_{1's}$ to (4x)*V. pallidum*; and 19 $BC_{1's}$ to *V. virgatum*.

10 elite selections resulted from backcrossing pentaploid (4x)*V. pallidum x V. virgatum* hybrids to *V. corymbosum*.

8 elite selections involved *V. angustifolium* and *V. virgatum*: These included 7 pentaploid $F_{1's}$ and 1 BC_1 to *V. virgatum*.

15 elite selections involved *V. corymbosum, V. constablaeii,* and *V. virgatum*: These included 8 pentaploid $F_{1's}$; 6 $BC_{1's}$ to *V. virgatum*; and 1 BC_2 to *V. virgatum*.

8 elite selections involved *V. corymbosum, V. myrtilloides* Michx. (2n=2x=24), and *V. virgatum*: These included 2 pentaploid [(4x)(*V. corymbosum x V. myrtilloides*) x *V. virgatum* $F_{1's}$ and 6 $BC_{1's}$ to *V. virgatum*.

2 elite $BC_{1's}$ of a pentaploid [(*V. corymbosum x V. myrtilloides*) x *V. virgatum*] hybrid crossed to a *V. virgatum x V. constablaeii* selection.

8 elite $BC_{1's}$ of a pentaploid *V. simulatum x V. virgatum* selection crossed to a hexaploid *V. constablaeii x V. virgatum* selection.

10 elite $BC_{1's}$ of pentaploid *V. angustifolium x V. virgatum* selections crossed to tetraploid *V. darrowii x V. corymbosum* backcross selections.

7 elite $BC_{1's}$ of a pentaploid selection involving (*V. tenellum x V. corymbosum*) x *V. virgatum* crossed to *V. angustifolium*.

4 elite $BC_{1's}$ of a pentaploid selection involving (*V. elliottii x V. corymbosum*) x *V. virgatum* crossed to *V. virgatum*.

2 elite $BC_{1's}$ of a pentaploid selection involving (*V. elliottii x V. corymbosum*) x *V. virgatum* crossed to a hexaploid *V. constablaei x V. virgatum* selection.

2 elite $BC_{1's}$ of pentaploid selections involving *V. virgatum* x (*V. tenellum x V. corymbosum*) crossed to *V. simulatum*, and 1 BC_2 of the same genetic constitution.

1 BC_2 of a *V. virgatum* x (*V. tenellum* x *V. corymbosum*) pentaploid BC_1 hybrid with (4x)*V. pallidum* crossed to *V. corymbosum*.

1 BC_1 of a *V. virgatum* x (*V. tenellum x V. corymbosum*) pentaploid to *V. corymbosum*, outcrossed to a *V. darrowii* x (*V. virgatum x V. constablaeii*) pentaploid.

1 BC_1 of a *V. virgatum* x (*V. tenellum x V. corymbosum*) pentaploid to *V. angustifolium* outcrossed to a *V. hirsutum x V. angustifolium* hybrid.

Hexaploids. Using cultivated rabbiteye blueberry (*V. virgatum*) as a basis for comparison, a total of 217 elite selections were identified: These included 113 varietal potential selections derived from intercrosses of cultivated cultivars and/or selections, and 94 selections derived from intercrosses of wild x cultivated *V. virgatum* parents.

A total of 315 elite interspecific hybrid selections derived from *V. constablaeii* and *V. virgatum* were identified: These included 133 elite F_1 and 16 F_2 hybrid selections; 48 elite selections derived from intercrosses of unrelated F_1 hybrid selections; 101 elite $BC_{1's}$ to *V. virgatum*; 2 elite $BC_{2's}$ to *V. virgatum*; 10 elite $BC_{1's}$ to *V. constablaeii*; 3 selections that are 5/8 *V. constablaei* and 3/8 *V. virgatum*, and 2 that are 3/8 *V. constablaeii* and 5/8 *V. virgatum*. In spite of the large numbers of selections identified, no cultivars have been named to date involving this interspecific combination, largely due to poor plant habit and dark and soft fruit. A number of selections do still show promise.

22 elite selections were identified that were derived from (6x)southern highbush crosses with cultivated *V. virgatum*. All these $F_{1's}$ showed epistasis for inhibition of surface wax development on fruit, but segregation for blue fruit color will occur in backcrosses to *V. virgatum*.

Summary

The current North Carolina blueberry breeding program has built upon and expanded the efforts of previous programs in interspecific hybridization and introgression of useful traits from related species into the cultivated blueberry genepool. A total of 1771 elite selections have been identified in the program since 1977. A significant percentage of these have also already been eliminated for various reasons. Of these 1771 selections, 871 (43%) are tetraploid, 554 (31%) are hexaploid, and 346 (26%) are pentaploids or pentaploid backcrosses to tetraploids or hexaploids. 80.5% of these 1771 selections involve interspecific hybridization in their backgrounds to some degree. Of the 871 tetraploid selections, 631 (63%) are southern highbush. Of the southern highbush, 480 (76%) involve *V. darrowii* in their background, 264 (42%) involve *V. tenellum* and *V. virgatum*, and 156 (25%) involve *V. elliottii*. Of the 554 hexaploid selections, 337 (60%) are interspecific hybrids. Only one selection in the pentaploid and pentaploid backcross group has been fertile enough to release as a cultivar to date. However several additional selections are promising, and a significant number are quite valuable parents for traits such as broad soil adaptation, sharpnosed leafhopper resistance, late bloom, excellent fruit firmness, and extended shelf life of fruit.

Of the 24 blueberry cultivars released by the North Carolina breeding program since 1986, 16 cultivars involve interspecific hybridization in their genetic background, and 8 of these were originated by the program since 1977. Five of these 8 cultivars (Beaufort, Craven, Lenoir, Pamlico, Sampson) are $BC_{2's}$ from *V. darrowii x V. corymbosum* to *V. corymbosum*, 1 (New Hanover) resulted from an intercross of a BC_3 with a BC_1 and involves *V. darrowii, V. corymbosum, V. tenellum,* and *V. virgatum*, 1 (Carteret) is a

BC_1 from *V. elliottii x V. corymbosum* to *V. corymbosum*, and 1 (Robeson) is a pentaploid cultivar derived from (*V. corymbosum x V. myrtilloides*) x *V. virgatum*.

Literature Cited

Ballington, J. R. 1980. Blueberry improvement through interspecific hybridization: recent progress in North Carolina. pp 35-39. In J. N. Moore (ed.) Proc. 4th N. Amer. Blueberry Res. Workers Conference, 1979, Univ. Arkansas, Fayetteville, AR.

Ballington, J. R. 1990. Germplasm resources available to meet future needs for blueberry cultivar improvement. Fruit Var. J. 44:54-62.

Ballington, J. R., W. B. Kirkman, D. V. Barkley and A. F. Huyler. 1980. *Vaccinium* germplasm collections, North Carolina and South Carolina, 1978 and 1979. Hort. Crops Res. Series No. 51. N. C. State University, Raleigh, NC.

Ballington, J. R., W. B. Kirkman, W. H. Gensel, Y. M. Isenberg and C. A. Walker. 1982. *Vaccinium* germplasm collections, 1980-1982. Hort. Crops Res. Series No. 60. N. C. State University, Raleigh, NC.

Ballington, J. R., Y. M. Isenberg and A. D. Draper. 1986a. Flowering and fruiting characteristics of *Vaccinium ashei-V. constablaei* derivative blueberry progenies. J. Amer. Soc. Hort. Sci. 111: 950-955.

Ballington, J. R., W. B. Kirkman, C. A. Walker, B. L. Shoemaker and D. Finch. 1986b. Small fruits crops germplasm collections, 1983-1985. Hort, Crops Res. Series No. 71. N. C. State University, Raleigh, NC.

Brightwell, W. T., G. M. Darrow and O. J. Woodard. 1949. Inheritance in seedlings of *Vaccinium constablaei* and *V. ashei* variety Pecan. Proc. Amer. Soc. Hort. sci. 53:239-240.

Coville, F. V. 1937. Improving the wild blueberry. In: USDA Yearbook of Agriculture 1937:559-574.

Darrow, G. M. and W. H. Camp. 1945. *Vaccinium* hybrids and the development of new horticultural material. Bull. Torrey Bot. Club 72:1-21.

Darrow, G. M., E. B. Morrow and D. H. Scott. 1952. An evaluation of interspecific blueberry crosses. Proc. Amer. Soc. Hort. Sci. 59:277-282.

Darrow, G. M., D. H. Scott and H. Dermen. 1954. Tetraploid hybrids from hexaploid x diploid species crosses. Proc. Amer. Soc. Hort. Sci. 62:266-270.

Draper, A. D. 1977. Tetraploid hybrids from crosses of diploid, tetraploid and hexaploid *Vaccinium* species. Acta Hort. 61:33-37.

Ehlenfeldt, M. K. and N. Vorsa. 1993. The generation, evaluation and utilization of hexaploid progeny from 3x X 3x crosses of highbush blueberry. Acta Hort. 346:95-102.

Galletta, G. J. 1975. Blueberries and cranberries. pp 154-196. In: J. Janick and J. N. Moore (eds.), Advances in Fruit Breeding. Purdue Univ. Press, West Lafayette, IN.

Jelenkovic, G. and A. D. draper. 1973. Breeding value of pentaploid interspecific hybrids in *Vaccinium*. J. Yugoslav Pomology 25-26:237-244.

Johnston, S. 1946. Observations on hyhridizing lowbush and highbush blueberries. Proc. Amer. Soc. Hort. Sci. 47:199-200.

Luby, J. J. 1991. Breeding cold-hardy fruit crops in Minnesota. HortScience 26:507-512.

Lyrene, P. M. 1988. Fecundity of crosses between tetraploid and hexaploid *Vaccinium*. J. Amer. Soc. Hort. Sci. 113:592-595.

Lyrene, P. M. 1990. Low-chill highbush blueberries. Fruit Var. J. 44:82-86.

Sharpe, R. H. 1966. Blueberry varieties and breeding: Florida. pp 72-77. In W.J. Kender and D. A. Abdalla (eds.) Proc. N. Amer. Blueberry Workers Conf., Maine Agri. Expt. Sta. Misc. Rpt. 118.

Vorsa, N. 1983. A phenotypic, fertility and cytological study of backcross derivatives of the pentaploid hybrids of *Vaccinium australe* Small x *Vaccinium ashei* Reade. Thesis, Rutgers Univ., New Brunswick, NJ.

Seasonal & Varietal Variation in Hardiness of Blueberry Flower Buds

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Summary

Low temperatures often injure highbush blueberry (*Vaccinium corymbosum*) in Michigan. Injury can occur in the autumn as tissues are acclimating, in mid-winter when tissues are fully acclimated, or in the spring during deacclimation. Flower buds are often injured, but extreme cold events occasionally kill cane tissues as well

Many species have been utilized to develop blueberry varieties adapted to diverse climates. Predicting hardiness from the diversity of genetic makeup is difficult. For example, lowbush blueberry (V. angustifolium) and lowbush/highbush hybrids may acclimate earlier than highbush varieties and tolerate early winter cold, but some may also deacclimate quickly and lose hardiness in the late winter. 'Patriot' (*V. angustifolium* x *V. corymbosum*), for example, is prone to cold injury in the late winter and early spring in Michigan. Other varieties contain genes from southern species. Although most of these complex hybrids are not hardy in cold locations, some like 'Sierra' are as hardy as standard northern highbush varieties (Hancock et al., 1997). Work in New Jersey indicated that two varieties containing southern species ('Legacy', 'Ozarkblue') were less hardy than northern highbush cultivars in mid-winter, but varieties tested deacclimated at comparable rates. 'Legacy' plants in Michigan retain their leaves late into the fall, raising questions about how quickly it acclimates to cold.

We compared diverse blueberry varieties in Michigan to determine how they differ in hardiness during acclimation, deep winter rest, or de-acclimation. Assessments were made during two years using field grown bushes at two southern Michigan locations. Twigs at least 10 cm long and with three or more flower buds were removed in late Nov, Jan, and early March. Twigs were held on ice, then wrapped in moist cotton and aluminum foil, and subjected to controlled freezing within 36 hrs of sampling. Temperature was programmed to decline at 2 ^{o}C per hour, and subsamples were removed at intervals bracketing expected lethal temperatures. Buds were later dissected to assess injury. The temperature resulting in 50% flower primordia mortality (LT_{50}) was calculated using the modified Spearmann-Karber method.

The hardiness of varieties was relatively consistent across sampling dates. 'Sierra', 'Patriot', and 'Elliott' were among the most hardy at all sampling times. The *V. angustifolium* x *V. corymbosum* hybrid 'Patriot' was extremely hardy even in early Mar., indicating that it does not lose hardiness more quickly in the spring than highbush varieties. 'Legacy', which has been observed to retain leaves in the fall and suffer

regular winter injury in Michigan, was the least hardy variety at all times, suggesting that field injury is not due simply to a slow rate of acclimation in the fall. Two new varieties from MSU, ‘Aurora’ and ‘Liberty’, were as hardy as standard northern highbush varieties at all sampling times.

Soil Characteristics Associated with Wild Huckleberry and Bilberry Colonies in the Northwestern United States: Implications for Managed Production and Cultivation

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Summary

With few exceptions, huckleberries and bilberries (*Vaccinium spp*.) native to western North America have not been managed in native stands or cultivated in fields. With efforts underway to produce these crops commercially under cultivated or managed conditions, more information is needed on soil requirements. Soil samples collected from naturally occurring huckleberry and bilberry colonies in Idaho, Washington, Oregon, Montana, and Wyoming were analyzed to determine physical and chemical characteristics of the soils. Soil texture and pH were the most consistent soil factors associated with the colonies. Acidic loams and sandy loams, followed by silt loams were the most common soil textures across species. *Vaccinium uliginosum* Linnaeus (alpine bilberry) and *V. membranaceum* Douglas ex Hooker (black, thin-leaf, or mountain huckleberry) were associated with wider ranges of soil textures than the other species. *Vaccinium deliciosum* Piper (Cascade huckleberry) and *V. uliginosum* were often found on seasonally wet soils adjacent to ponds, streams, and dry lakebeds. Soil pH values for individual collection sites ranged from 3.6 (*V. ovalifolium* Smith, oval-leaved bilberry or Alaska blueberry) to 6.2 (*V. membranaceum*), averaging 5.0 for all combined samples. Highly variable nutrient concentrations, even between samples from vigorous, fruitful colonies of the same species, suggest that these species tolerate relatively wide ranges of soil macro- and micronutrient concentrations. Although some of the soils were highly influenced by volcanic ash, many were not and volcanic ash does not appear to be required for survival and growth of these species. These results suggest that, with the exceptions noted above, a suitable site for cultivation or management of these crops will have a well-drained loam, sandy loam, or for *V. membranaceum* and *V. uliginosum*, silt loam soil with pH between 4.0 and 5.3.

Introduction

Despite a long history of commercial use, huckleberries and bilberries native to western North America have been harvested almost exclusively from the wild, rather than being grown in cultivation like highbush blueberries (*V. corymbosum*) and rabbiteye blueberries (*V. ashei*) or harvested from managed native stands, as for eastern lowbush blueberries (*V. angustifolium* and *V. myrtilloides*). The exception is *Vaccinium ovatum* Pursh (evergreen huckleberry), which has been cultivated on a small scale along the Pacific Coast in North America and harvested both for its fruits and ornamental foliage. At least five of the species described in this paper have long histories of domestic and/or commercial utilization and commercial demands are increasing. Recent research has also shown that some of these crops are rich sources of anthocyanins, antioxidants, and polyphenolic compounds with potential to benefit human health (Taruscio et al., 2004; Lee et al., 2004). Prospects for expanding the huckleberry and bilberry industries appear promising (Barney, 2003a).

While demands for culinary and medicinal/nutritional huckleberry and bilberry products have increased, supplies of these fruits from wild stands have dwindled (Minore, 1972). In 1994 the University of Idaho began efforts to produce these crops in cultivated fields and managed, forest colonies. Seed and in vitro propagation methodologies have been published for *V. membranaceum* (Barney, 2003b; Barney and Shafii, 2001; and Shafii and Barney, 2001) and similar trials on other species are underway. A germplasm evaluation and cultivar development program is also underway (Barney, 2004).

A critical factor in crop production is selecting a suitable site. Aside from research on *V. membranaceum* (Minore and Dubrasich, 1978; Stark and Baker, 1992), no comprehensive characterization of soil properties for these crops in western North America has been conducted. Much has been published on soil influences for highbush and lowbush blueberries in eastern North America (Kender and Eggert, 1966; Korcak, 1989; Finn et al., 1993a and 1993b), *V. myrtillus* Linnaeus (bilberry) in Europe (Ingestad, 1973), and *V. uliginosum* in Europe and Canada (Jacquemart, 1975).

Vaccinium species, like other members of the Ericaceae family, require acidic soils and are classified as calcifuges (Ingestad, 1973; Jacquemart, 1975; Korcak, 1988). According to Brown and Draper (1980) the optimum soil pH for good blueberry growth is between 4.0 and 5.2, with iron chlorosis symptoms often appearing at pH levels above 5.2. Korcak (1988) suggested a pH range of 4.5 to 5.5, with a lower limit of about 3.2. In testing 60 *V. angustifolium* soils, however, Vander Kloet (1978) observed a pH range from 2.8 to 6.6. Rorison (1986) observed that plants most capable of surviving acid soils are those with inherently slow growth rates and low nutrient requirements.

With the exception of bog-dwelling species, *Vacciniums* are usually found on moist, well-drained loamy sand or sandy loam soils that are high in organic matter and low in calcium and available nutrients (Finn et al., 1993a; Ingestad, 1973; Kender and Eggert, 1966; Korcak, 1986). Commercial highbush blueberry production, for example, is largely limited to imperfectly drained acid sand and peat soils, although rabbiteye

blueberry (*V. ashei*) grows on both upland and lowland soils that range in texture from clay to sandy loams. Even with its greater soil adaptability, rabbiteye blueberry performs best on light, well-drained acidic soils with pH between 4.5 and 5.5 (Luby et al., 1990). *Vaccinium uliginosum* also requires acidic soils low in nutrients, but is typically found on moist to wet, shallow, poorly drained soils (Jacquemart, 1975).

Vaccinium adaptation to low-nutrient soils has been observed in multiple species (Ingestad, 1973; Jacquemart, 1975; Rorison, 1986). *Vaccinium* roots and rhizomes tend to be shallow and, in some cases, may lie entirely within the litter horizon. Ingestad (1973) regarded the litter horizon as the dominant nutrient source, although observing that deeper roots may be found on old rhizomes. *Vaccinium* species commonly form associations with ericoid mycorrhizae, and these associations influence uptake of plant nutrients (Haynes and Swift, 1985; Korcak, 1989; Raisa, 1999). Korcak (1989) and Raisa (1999) also concluded that soil organic matter, the presence of surface litter, and soil horizons affect mycorrhizal development and, therefore, nutrient uptake by *Vaccinium* plants. Soil pH may have implications other than direct effects on the *Vaccinium* roots and plant nutrient availability. In a greenhouse peat medium study, Haynes and Swift (1985) found the percentage of mycorrhizal infection was much greater at pH 4.5 than pH 6.5.

Vaccinium species are typically associated with organic-rich soils (Finn et al., 1993a; Jacquemart, 1975); Korcak, 1989; Luby et al., 1990). The term "rich," however, is relative. According to Korcak (1987) the organic matter requirement for *Vaccinium* can be satisfied by as little as 2-4% organic matter. *Vaccinium* colonies can be associated with an organic surface (litter or duff) layer (Jacquemart, 1975; Korcak, 1987; Stark and Baker, 1992) that has implications for *Vaccinium* management and cultivation. Under certain conditions a thick mulch of peat, sawdust, or other organic matter is required for optimum *Vaccinium* growth and production (Korcak, 1987). Raisa (1999) concluded that *V. myrtillus* and *V. vitis-idaea* Linnaeus (lingonberry) distributions reflect the nitrogen concentrations of the humus layer.

Subsurface soil layers may also be important in *Vaccinium* distribution and productivity. Korcak (1989) noted that blueberry roots in a layered soil are concentrated in the more decomposed organic material and develop endomycorrhizal associations of the ericoid type. The more decomposed a material is, the lower it typically lies in the soil profile. Kender and Eggert (1966) observed that *V. angustifolium* plants grew more vigorously on an undisturbed, rather than a homogenized or tilled soil.

Studies with *V. globulare* (syn. *V. membranaceum*; Vander Kloet, 1988) support the general rules for *Vaccinium* soil optima. Stark and Baker (1992) concluded that suitable soils have low bulk density (< 0.8 g/cc) but high water-holding capacity (>24% w:w). Volcanic ash soils may favor huckleberry production because such soils have low bulk densities and high water-holding capacity. *Vaccinium globulare* produces shallow roots and rhizomes, and the top 10-20 cm of soil are the most important for huckleberry health. Survival and production on compacted and heavy-textured soils was observed to be poor and the best soils to have a fine, loamy texture with combined clay and silt

content less than 40%. A key to productivity appeared to be high concentrations of rotten wood in and on the soil. This was determined to be especially important on heavier-textured soils, where the huckleberry roots and rhizomes may exist mostly in the surface organic layer. The best huckleberry growth occurred on soils with more than 30% organic matter. Stark and Baker concluded that, under northwestern Montana conditions, the best *V. globulare* growth and production occurs on soils with pH 4.0 to 5.5, but production is possible at pH 6.8 if the correct balance of nutrients is available. Minore and Dubrasich (1978) evaluated soil pH and other physical and biological factors related to the distribution and fruit production of *V. membranaceum* near Mt. Adams in south-central Washington. They found that soil pH correlated with abundance of *V. membranaceum* across the site. Regression analyses indicated an optimal pH of 5.5.

The purpose of our soil survey was to identify the soil physical and chemical characteristics associated with *Vaccinium* species over large areas of their ranges in the northwestern United States.

Materials and Methods

We collected soils from colonies of *V. caespitosum* Michaux (dwarf huckleberry), *V. deliciosum*, *V. membranaceum*, *V. myrtillus*, *V. ovalifolium* (synonymous with *V. alaskaense* Howell and *V. chamissonis* Bong.; Vander Kloet, 1988), *V. ovatum*, *V. parvifolium* Smith (red huckleberry), and *V. uliginosum* in Idaho, Oregon, Washington, Montana, and Wyoming (Table 1). Because these species have shallow root systems, soil samples were collected to depths of 15 cm using a trowel after removing the surface duff layer. One sample for each site and species combination was collected from the base of a representative plant.

Soil samples were air-dried and crushed in a mortar to pass a 2-mm sieve. Particle-size distribution of bulk samples was determined by a combination of sieving and sedimentation procedures following digestion of organic matter with NaOCl (pH 9.5) and dispersion of soil particles using Na hexametaphosphate (Gee and Bauder, 1986). Chemical properties were determined using the following methods: pH (H_2O) of saturated paste (Richards, 1954); organic matter by wet digestion with $K_2Cr_2O_7$ (Sims and Haby, 1971); exchangeable cations by ammonium acetate (pH 7) extraction (Thomas, 1982); available phosphorus and potassium extracted with 0.75 N sodium acetate (Gavlak et al., 1994); ammonia and nitrate extracted with 2M KCl and analyzed by flow injection analysis (Westfall et al.,1982; 1993); sulfate-S extracted with 0.01 M calcium phosphate solution (Kalra and Maynard, 1991; Gavlak et al., 1997); micronutrients (Cu, Mn, Fe, Zn) by DTPA extraction (Lindsay and Norvell, 1978); and water soluble boron by the pouch method (McGeehan et al., 1989). The relative influence of volcanic ash was determined by NaF pH (Fieldes and Perrott, 1966). Samples with a NaF pH of 9.4 or greater were categorized as having high volcanic ash influence. General environmental observations of the plants in their respective colonies are included in this report.

Results and Discussion

Particle size distribution analyses showed that loams, sandy loams, and silt loams were the most common soil textures associated with the *Vaccinium* species sampled, although *V. membranaceum* and *V. uliginosum* were collected from broader ranges of soils than the other six species (Table 2). These results are consistent with reported findings for other *Vaccinium* species, as described in the preceding section. How soil type impacts plant survival and growth is not necessarily clear, however. In his studies with *V. corymbosum* and hybrids of *V. corymbosum* with *V. angustifolium*, *V. darrowii*, *V. atrococcum*, and *V. ashei*, Korcak (1986) found that while soil type can have pronounced effects on plant growth and rooting, the growth differences were due to soil characteristics other than particle size distribution.

Vaccinium membranaceum soils ranged from loamy sands to clay loams. In the case of *V. membranaceum,* more soil samples were available than for the other species. The ability to sample from many sites may have contributed to the finding of greater soil adaptability of V. membranaceum. Luby et al. (1990), however, noted that *V. membranaceum* is, apparently, a very plastic and polymorphic derivative of several species, including *V. chamissonis*, *V. caespitosum*, *V. scoparium*, and *V. myrtillus*. Genetic differences within and between species affect plant adaptability to varying soil conditions (Brown and Draper, 1980; Finn et al., 1993b). Survival does not necessarily correlate well with productivity. Stark and Baker (1992) observed that, while *V. globulare* tolerated a range of soil textures, the best huckleberry soils were characterized by low bulk densities. *Vaccinium membranaceum* grows from Alaska through British Columbia, Alberta, south to northern California, eastern Idaho and Montana with disjunct populations in Arizona and northern Michigan (Vander Kloet, 1988). It is found on mountain slopes; on dry, open sites in coniferous forests; and is abundant in many clear cut tracts (Luby et al., 1990). Observations of field-cultivated plants and native stands (Barney, unpublished data) suggest that *V. membranaceum* is intolerant of poorly drained soils.

We collected *V. uliginosum* from sites with soil textures ranging from loamy sands to clay loams. *Vaccinium uliginosum* also has a complex genetic makeup that allows it to colonize sites across a great range of latitudes, elevations, and habitat types (Jacquemart, 1975; Luby et al., 1990; Young, 1970). *Vaccinium uliginosum* is a characteristic tundra shrub native to boreal, alpine, and arctic regions, extending southward into the temperate zone in coastal and mountain areas in North America, Asia, and Europe from 38^{o} to 80^{o} north latitude (Young, 1970; Vander Kloet, 1988). With the exception of one sample from an upland site in a whitebark pine forest lying above the Little Popo Agie River in Wyoming, we found *V. uliginosum* along the shores of small subalpine lakes, in boggy subalpine meadows, seasonally wet meadows, or on mountain stream banks. Our observations are consistent with other populations of *V. uliginosum* that colonize shallow, poorly-developed montane-heath soils; waterlogged podosols of upland heaths; poorly-drained podosols of birch woods; organic soils in

humus and peaty bog communities; sometimes on calcareous soils of calciolus grasslands in Scandinavia and Scotland; peaty woodlands, tundra (Jacquemart, 1975); dry peaty barrens, exposed outcroppings, talus slopes, and headlands (Luby et al., 1990).

Vaccinium caespitosum and *V. deliciosum* occurred on many of our collection sites growing alongside or close to *V. uliginosum* and were abundant on some seasonally wet meadows and organic soils alongside ponds. *Vaccinium caespitosum* exhibited the greatest variety of habitats, ranging from a boggy pond bank to steep droughty hillsides. *Vaccinium deliciosum* also grew on seasonally wet soils, extending its colonization upland onto dryer soils forest. Other than one *V. caespitosum* colony on a silt-loam soil, however, both species were found on sites with underlying mineral, loam or sandy loam soils. These observations are consistent with other reports. *Vaccinium caespitosum* is widely distributed, very plastic, and polymorphic (Luby et al., 1990). It occurs from south-central Alaska through British Columbia, south in the Rocky Mountains to Arizona and south through the Cascades and Sierra Nevada, east at scattered locations from Minnesota through New York, New Hampshire, Vermont, Maine, and Labrador (Vander Kloet, 1988). In the Pacific Northwest, *V. caespitosum* ranges from sea level to 2000 m elevation and is found in wet meadows, mountain slopes, moist rocky ledges, subalpine forests, and alpine tundra (Luby et al., 1990). *Vaccinium deliciosum* is distributed from southwestern British Columbia south through the Cascade Mountains in central Oregon and also in the Olympic Mountains where it grows in open areas in subalpine forests and meadows and alpine tundra (Luby et al., 1990).

Four of the five *V. ovalifolium* collection sites were on loam soils, with one site having a sandy loam. Sites ranged from moist but reasonably well drained sites slightly upslope in riparian areas to coniferous woodlands. This finding is consistent with Luby et al. (1990) who describe *V. ovalifolium* in the northwestern United States and western Canada as typically growing on raw humus in moist coniferous forests. Vander Kloet observed that *V. ovalifolium* in western North America is native to moist or mesic coniferous woods and transitional habitats adjacent to these woods, including peaty slopes, subalpine shrubberies and ravines, and on drier and more open habitats on inland sites. *Vaccinium ovalifolium* is concentrated in the Northwestern United States northward to southern Alaska with disjunct populations in South Dakota, the Upper Great Lakes Region, and Cape Breton Island and Newfoundland in Canada (Vander Kloet, 1988). Seed collections have also been made from Japan and Sakhalin Island in the Russian Federation (U.S.D.A. 2006).

We collected *V. myrtillus*, *V. parvifolium* and *V. ovatum* from forest sites on well drained loam and/or sandy loam soils. *Vaccinium parvifolium* was approximately equally distributed between the loam and sandy loam soils. *Vaccinium parvifolium* is fairly widespread at low to intermediate elevations on the west slopes of the coastal ranges from Alaska to northern California and occurs inland to southeastern British Columbia Luby et al., 1990).

Unfortunately, as we were limited to single samples of *V. myrtillus* and *V. ovatum*, we can draw no conclusions as to optimal soil textures for these species. *Vaccinium myrtillus* is widely distributed in northern Europe and Asia where it occurs in lowland to alpine open pine or spruce forests, mostly on moist, humus, or peaty soils. In the northwestern United States and Rocky mountains, *V. myrtillus* grows in moist, open sites in montane or subalpine communities, often in clear cut areas or regenerating pine or spruce/fir forests. The species is native from Alaska and Alberta to New Mexico, west to British Columbia, south through the Cascade Mountains to central Oregon. *Vaccinium myrtillus* appears much less frequently through this range than other *Vaccinium* species (Luby et al., 1990). *Vaccinium ovatum* is native only along the Pacific coast from southern California to central British Columbia (Vander Kloet, 1988).

All soils we sampled were acidic, ranging from pH 3.6 to 6.2 and averaging pH 5.0 across species and sites (Table 3). This finding is consistent with published reports for *Vaccinium* species generally (Korcak, 1988; Luby et al., 1990), European and Canadian populations of *V. uliginosum* (Jacquemart, 1975), European populations of *V. myrtillus* (Ingestad, 1973), and *V. membranaceum* (*globulare*) growing in Montana and Washington State (Minore and Dubrasich, 1978; Stark and Baker, 1992).

Soil organic matter concentrations were highly variable, ranging from 1% to 60% (Table 3). Soil samples exhibiting organic-rich, poorly drained, wetland (histic) properties were associated with 80% of the *V. deliciosum,* 50% of the *V. uliginosum*, and 40% of the *V. ovalifolium* sites. Although we did not sample the litter or duff layers, virtually all sample sites in this survey had surface layers of intact to partially decomposed forest or wetland organic matter. Decomposing wood on the soil surface and within the soil profile was abundant on many of the collection sites, and we frequently observed roots and rhizomes from *Vaccinium* species colonizing the duff layer or penetrating into decomposed stumps and fallen trunks. Our observations are consistent with those made by other investigators (Jacquemart, 1975; Korcak, 1987; Stark and Baker, 1992). These observations suggest that maintenance of forest litter in managed forest stands or organic mulches in field cultivation of western *Vaccinium* species may be beneficial.

Macro- and micronutrient concentrations (Tables 3 and 4) varied widely, even within species. Ammonium-nitrogen concentrations averaged higher than nitrate-nitrogen concentrations for all species. Relatively high concentrations of both ammonium- and nitrate-nitrogen are likely due to two factors. First of all, average organic matter contents of the soils are relatively high, reflecting the poorly drained or higher-elevation environments. Secondly, because we were unable to air-dry samples immediately, there was considerable mineralization of organic nitrogen following sample collection. It is clear, however, that many of the *Vaccinium* soils are characterized by relatively large quantities of organic matter and mineralizable nitrogen.

The wide variations seen in soil nutrient concentrations are consistent with observations reported by Raisa (1999) who found no differences in optima for *V. myrtillus* and *V.*

vitis-idaea along nutrient gradients. Raisa suggested that light and moisture may be more important factors determining site dominance of these species, although it seems clear from the present and other studies that soil pH is also a critical factor affecting *Vaccinium* distribution. Western *Vaccinium* species' tolerance of wide ranges of soil nutrient profiles is also consistent with observations that *Vaccinium* species, in general, are adapted to nutrient-poor soils (Ingestad, 1973; Jacquemart, 1975; Rorison, 1986).

Of the 56 soil samples analyzed, 48% were categorized as high volcanic ash influenced soils. It is clear that volcanic ash-influenced soils are not required for *Vaccinium* growth. However, there does appear to be considerable overlap between the environments in which volcanic ash is found and those that support many of western North America's *Vaccinium* species.

Conclusions

From the perspective of selecting a growing site or expanding a native stand, soil texture and pH were the most consistent soil factors associated with naturally occurring western huckleberry and bilberry colonies during our survey. Well-drained, acidic loams and sandy loams appear suitable for cultivating all of the species surveyed. Well-drained silt loams also appear suitable for *V. membranaceum*, as do loamy sands, provided adequate irrigation is available. *Vaccinium uliginosum* is also adapted to silt loams, loamy sands, and organic, peat soils. *Vaccinium uliginosum* and *V. deliciosum* tolerate seasonally wet soils, as well as drier, upland soils, although the effects of poor soil drainage on fruit production remain to be determined. As all of these species have been successfully grown in container culture in peat-moss or bark-based potting soils, production on organic, peat soils may be feasible if appropriate pH and water drainage are provided.

Soil pH values between 4.0 and 5.3 appear suitable for all surveyed species. Production on soils up to pH 6.2 seems possible for *V. membranaceum*, given that other soil and environmental conditions are favorable. Highly variable nutrient concentrations, even between vigorous, fruitful colonies of the same species, suggest that naturally-occurring colonies of western huckleberries and bilberries tolerate relatively wide ranges of soil macro- and micronutrient concentrations. Likewise, high concentrations of soil organic material or high volcanic ash influence do not appear to be necessary for plant vigor and berry production. For managed production and cultivation, a target of 4% or greater organic matter would seem appropriate. Application of an organic mulch or maintenance of natural forest litter may be beneficial to plant survival and productivity.

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Literature cited

Barney, D.L. 2003a. Prospects for domesticating western huckleberries. Small Fruits Rev. 2 (1):15-29.

Barney, D.L. 2003b. Effects of light, surface sterilization, and fungicides on the germination of black huckleberry seeds. Small Fruits Rev. 2(2):73-80.

Barney, D.L. 2004. Domestication of western huckleberries. Proc. Northwest Ctr. Small Fruit Res. 13:10-11.

Barney, D.L., B. Shafii, and W.J. Price. 2001. Cold stratification delays germination of black huckleberry seed. HortSci. 36:813.

Brown, J.C. and A.D. Draper. 1980. Differential response of blueberry (*Vaccinium*) progenies to pH and subsequent use of iron. J. Amer. Soc. Hort. Sci. 105:20-24.

Fieldes, M., and K.W. Perrott. 1966. The nature of allophane in soils. III. Rapid field and laboratory test for allophane. New Zealand J. Sci. 9: 623-629.

Finn, C.E., C.J. Rosen, J.J. Luby, and P.S. Ascher. 1993b. Blueberry germplasm screening at several soil pH regimes. II. Plant nutrient composition. J. Amer. Soc. Hort. Sci. 118:383-387.

Finn, C.E., J.J. Luby, C.J. Rosen, and P.D. Ascher. 1993a. Blueberry germplasm screening at several soil pH regimes. I. Plant survival and growth. J. Amer. Soc. Hort. Sci. 118:377-382.

Gavlak, R. G., D.A. Horneck, and R.O. Miller. 1997. Western States Laboratory Proficiency Testing Program Soil and Plant Analytical Methods, version 4.00 from 1994. Plant, Soil, and Water Reference Methods for the Western Region. WREP 125. pp. 87-89.

Gavlak, R.G., D.A. Horneck, and R.O. Miller. 1994. Extractable soil phosphorus modified Morgan. In: Western States Laboratory Proficiency Testing Program Soil and Plant Analytical Methods, ver. 4.00. Plant, Soil and Water Reference Methods for the Western Region. WREP 125, pp. 63-65.

Gee, G.W., and J.W. Bauder. 1998. Particle-size analysis. p. 383-411. *In* A. Klute (ed.) Methods of soil analysis: Part 1. - Physical and mineralogical methods. Soil Sci. Soc. Am. Book Series no. 5. Madison, WI.

Haynes, R.J. and R.S. Swift. 1985. Growth and nutrient uptake by highbush blueberry plants in a peat medium as influenced by pH, applied micronutrients, and mycorrhizal inoculation. Scientia Hort. 27:285-294.

Ingestad, T. 1973. Mineral nutrient requirements of *Vaccinium vitis idaea* and *V. myrtillus*. Physiol. Plant. 29:239-246.

Jacquemart, A.-L. 1975. *Vaccinium uliginosum* L. J. Ecol. 84:771-785.

Kalra, Y. P and D.G. Maynard. 1991. Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X-319. For. Canada. pp. 79-83.

Karlsson, P.S. 1985. Effects of water and nutrient supply on a deciduous and an evergreen dwarf shrub: *Vaccinium uliginosum* L. and *V. vitis-idaea* L. Holoarctic Ecol. 8: 1-8.

Kender, W.J. and F.P. Eggert. 1966. Several soil management practices influencing the growth and rhizome development of the lowbush blueberry. Can. J. Plant Sci. 46:141-149.

Korcak, R.F. 1986. Adaptability of blueberry species to various soil types: I. Growth and initial fruiting. J. Amer. Soc. Hort. Sci. 111:816-821.

Korcak, R.F. 1987. Satisfying and altering edaphic requirements for acidophilic plants. J. Plant Nutr. 10 (9-16)1071-1078.

Korcak, R.F. 1988. Nutrition of blueberries and other calcifuges. Hort. Rev. 10:183-227.

Korcak, R.F. 1989. Variation in nutrient requirements of blueberries and other calcifuges. HortSci. 24:573-578.

Lee, J., C.E. Finn, and R.E. Wrolstad. 2004. Anthocyanin pigment and total phenolic content of three *Vaccinium* species native to the Pacific Northwest of North America. HortSci. 39:959-964.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42:421-428.

Luby, J.J., J.R. Ballington, A.D. Draper, K. Pliszka, and M.E. Austin. 1990. Blueberries and Cranberries (*Vaccinium*). p. 391-456, In: J. N. Moore and J.R. Ballington, eds. Genetic resources of temperate fruit and nut crops. Int. Soc. Hort. Sci., Wageningen, The Netherlands.

McGeehan, S.L., and D.V. Naylor. 1989. Sources of variation in hot water extraction and colorimetric determination of soil boron. Commun. in Soil Sci. Plant Anal. Vol. 20, No. 17-18, 1777-1786.

Minore, D. 1972. The wild huckleberries of Oregon and Washington--a dwindling resource. USDA - Forest Serv. Res. Paper-143. Pacific Northwest Forest and Range Expt. Sta., Portland, OR.

Minore, D. and M.E. Dubrasich. 1978. Big huckleberry abundance as related to environment and associated vegetation near Mount Adams, Washington. Research Note PNW-322. U.S. Dept. Agr. For. Serv. Pacific Northwest For. and Range Expt. Sta., Portland, Ore.

Raisa, M. 1999. Response patterns of *Vaccinium myrtillus* and *V. vitis-idaea* along nutrient gradients in boreal forest. J. Vegetation Sci. 10:17-26.

Richards, L.A. ed. 1954. Diagnoses and Improvement of Saline and Alkali Soils, U.S. Dept. Agr. Handbook 60, p. 102.

Rorison, I.H. 1986. The response of plants to acid soils. Experientia 42:357-362.

Shafii, B. and D.L. Barney. 2001. Drying and cold storage affect germination of black huckleberry seeds. HortSci. 36:145-147.

Shaver, G. and F.S. Chapin. 1980. Response to fertilization by various plant growth forms in an Alaskan tundra: Nutrient accumulation and growth. Ecol. 61:662-675.

Sims, J.R. and V.A. Haby. 1971. The colorimetric determination of soil organic matter. Soil Sci. 112:137-141.

Stark, N., S. Baker, and D. Essig. 1989. Allocation of nutrients in huckleberries. J. Amer. Soc. Hort. Sci. 114:259-264.

Stark, N. and S. Baker. 1992. The ecology & culture of Montana huckleberries: A guide for growers & researchers. Misc. Pub. 52. Montana For. and Conservation Expt. Sta., School of For., Univ. of Montana, Missoula.

Taruscio, T., D. Barney, and J. Exon. 2004. Content and profile of flavanoid and phenolic acid compounds in conjunction with the antioxidant capacity for a variety of northwest *Vaccinium* berries. J. Agric. Food Chem. 52 (10):3169-3176.

Teär, J. 1972. Vegetative och fruktfikativ utveckling hos vildväxande och odlade lingon. Alfa-Laval. Tumba. Sweden, 1-107.

Thomas, G. W. 1982. Exchangeable cations. p. 159-165. In A. L. Page et al. (ed.) Methods of Soil Analysis. Part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

U.S.D.A. National Clonal Germplasm Repository, Corvallis, Oregon. 2006. http://www.ars.usda.gov/Main/docs.htm?docid=11371

Vander Kloet, S.P. 1978. Systematics, distribution, and nomenclature of the polymorphic *Vaccinium angustifolium*. Rhodora 80:358-376.

Vander Kloet, S.P. 1988. The genus *Vaccinium* in North America. Publication 1828. Research Branch Agriculture Canada. Ottawa.

Westfall, D. R. Keeney, D. W. Nelson. 1982. Nitrogen-Inorganic Forms. Methods of Soil Analysis, Part 2, Agron. No. 9, 2nd Edition: pp 643-693.

Westfall, D.G. Maynard and Y.P. Kalra 1993. Nitrate and Exchangeable Ammonium Nitrogen. Soil Sampling and Methods of Anal. pp 25-38.

Young, S.B. 1970. On the taxonomy and distribution of *Vaccinium uliginosum*. Rhodora 72:43-459.

Table 1. Collection sites for huckleberry and bilberry soils.

National Forest	Species [z] CP	DE	ME	MS	OF	OV	PA	UG
Idaho								
Boise N.F.	1	0	1	0	0	0	0	1
Clearwater N.F.	0	0	0	0	0	0	0	0
Kaniksu N.F.	1	0	2	0	1	0	0	0
Nez Perce N.F.	0	0	1	0	0	0	0	0
St Joe N.F.	0	0	1	0	0	0	0	0
Targhee N.F.	0	0	2	0	0	0	0	0
Montana								
Beaverhead-Deer Lodge N.F.	0	0	0	0	0	0	0	1
Bitterroot N.F.	0	0	1	0	0	0	0	0
Flathead N.F.	1	0	2	0	0	0	0	0
Gallatin N.F.	0	0	1	0	0	0	0	0
Lolo N.F.	1	0	2	0	0	0	0	0
Oregon								
Deschutes N.F.	1	0	0	0	0	0	0	1
Mount Hood N.F.	0	1	1	0	2	0	2	2
Willamette N.F.	0	1	2	1	0	0	0	1
Washington								
Colville N.F.	1	0	0	0	0	0	0	0
Gifford Pinchot N.F.	1	1	3	0	0	0	1	0
Mt. Baker-Snoqualmie N.F.	0	0	1	0	0	0	0	0
Okanogan N.F.	0	0	1	0	0	0	0	0
Olympic N.F.	0	0	0	0	3	1	5	0
Wenatchee N.F.	0	2	1	0	1	0	0	0
Wyoming								
Shoshone N.F.	0	0	1	0	0	0	0	1

[z] CP = *V. caespitosum*, DE = *V. deliciosum*, ME = *V. membranaceum*, MS = *V. myrtillus*, OF = *V. ovalifolium*, OV = *V. ovatum*, PA = *V. parvifolium*, UG = *V. uliginosum*

Table 2. Physical characteristics of native huckleberry and bilberry soils. Columns show the number and percentage of samples falling within each textural class and high volcanic ash concentration designations.

Species	Clay Loam	Silty Clay Loam	Silt Loam	Loam	Sandy Loam	Loamy Sand	High Volcanic Ash Soils
V. caespitosum	0	0	1 (14%)	3 (43%)	3 (43%)	0	3 (43%)
V. deliciosum	0	0	0	2 (50%)	2 (50%)	0	2 (40%)
V. membranaceum	1 (4%)	1 (4%)	6 (25%)	7 (29%)	5 (21%)	4 (17%)	12 (52%)
V. myrtillus	0	0	0	1 (100%)	0	0	1 (100%)
V. ovalifolium	0	0	0	4 (80%)	1 (20%)	0	2 (29%)
V. ovatum	0	0	0	0	1 (100%)	0	1 (100%)
V. parvifolium	0	0	0	4 (57%)	3 (43%)	0	5 (63%)
V. uliginosum	2 (29%)	0	1 (14%)	1 (14%)	2 (29%)	1 (14%)	3 (38%)
Totals	3 (5%)	1 (2%)	8 (14%)	22 (39%)	17 (30%)	5 (9%)	29 (48%)

Table 3. Mean pH, organic mater, and micronutrient concentrations in native huckleberry and bilberry soils with ranges in parentheses.

Species	pH	Organic Matter (%)	Boron (ppm)	Copper (ppm)	Iron (ppm)	Manganese (ppm)	Zinc (ppm)
V. caespitosum	5.1 (4.3-5.4)	6.5 (3.4-9.5)	0.25 (<0.1-0.6)	0.51 (0.3-0.8)	136.1 (81-200)	70 (5.0-240)	4.1 (0.3-16)
V. deliciosum	4.9 (3.9-5.6)	25.8 (13.0-55)	0.7 (0.5-1.2)	1.0 (0.2-1.7)	582.5 (180-1100)	13.4 (1.3-23)	4.8 (0.3-14)
V. membranaceum	5.2 (3.7-6.2)	10.1 (1.1-52)	0.4 (<0.1-1.5)	0.9 (0.2-2.3)	165.0 (40-510)	71.0 (2.3-330)	4.0 (0.2-20)
V. myrtillus	5.2	16.0	0.1	0.5	140.0	110.0	0.9
V. ovalifolium	4.5 (3.6-5.3)	22.8 (6.5-59)	0.7 (<0.1-1.6)	1.4 (0.2-3.5)	438.6 (110-1100)	89.9 (7.1-500)	6.5 (0.4-20)
V. ovatum	5.2	13.0	0.2	1.7	180.0	71.0	1.4
V. parvifolium	4.9 (3.9-5.6)	16.9 (4.0-60)	0.5 (<0.1-1.6)	1.5 (0.4-4.4)	431.3 (130-2000)	46.8 (14.0-150)	5.6 (0.3-32)
V. uliginosum	5.1 (4.3-5.7)	21.9 (5.3-56)	0.4 (0.1-0.9)	2.5 (0.2-14)	310.5 (72-770)	19.6 (0.6-75)	2.0 (0.2-5.8)

Table 4. Macronutrient characteristics of native huckleberry and bilberry soils. Columns show averages with value ranges in parentheses.

Species	NO_3-N (ppm)	NH_4-N (ppm)	Phosphorus (ppm)	Potassium (ppm)	SO_4-S (ppm)	Calcium (cmolc/kg)	Magnesium (cmolc/kg)
V. caespitosum	14.9 (<0.8-80)	25.2 (4.1-96)	5.2 (2.2-16)	110.6 (60-180)	6.0 (3.6-12)	3.9 (1.4-5.9)	0.8 (0.3-1.2)
V. deliciosum	62.9 (<0.8-170)	510.2 (31-1200)	4.0 (1.5-8.4)	236 (110-360)	42.4 (8.7-110)	4.9 (2.5-8.1)	1.4 (0.7-2.0)
V. membranaceum	13.0 (<0.8-120)	64.4 (2.0-640)	9.9 (1.0-79)	198.3 (33-810)	11.4 (2.3-27)	6.1 (0.7-21)	1.5 (0.1-7.4)
V. myrtillus	1.2	60.0	2.9	100.0	4.5	3.6	0.7
V. ovalifolium	40.4 (<0.8-130)	157.5 (6.7-740)	9.9 (<1.0-45)	160.1 (60-470)	17.0 (5.8-39)	4.1 (0.6-11)	1.6 (0.1-4.3)
V. ovatum	1.5	24.0	3.4	77.0	7.7	4.3	1.3
V. parvifolium	130.9 (<0.8-820)	180.4 (8.8-1200)	5.5 (2.0-11)	136.8 (50-410)	22.4 (5.8-110)	5.3 (0.7-17)	1.8 (<0.02-7.6)
V. uliginosum	61.9 (1.0-190)	320.4 (2.7-800)	16.7 (<1.0-120)	223.4 (54-660)	35.0 (5.8-100)	7.7 (2.3-24)	2.3 (0.6-7.3)

Evaluation of Two Organic Fertilizer Blends for Highbush Blueberry Production in Oregon

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Summary

The effects of two organic fertilizer blends on the growth and production of three highbush blueberry (*Vaccinium corymbosum L.*) cultivars ('Bluecrop', 'Duke', and 'Elliott') were evaluated for one growing season. The two organic fertilizer blends were fish waste and/or protein based with complete macro nutrients applied in a conventionally managed research plot beginning late Spring 2005. No interactions between organic fertilizer treatment and cultivar were observed on any of the plant-related parameters measured during the growing season. Differences in plant growth and yield are essentially all cultivar effects. 'Elliott' and 'Bluecrop' visually responded similarly to the fertilizer treatments, while 'Duke' showed some symptoms of leaf chlorosis during the growing season. Foliar analysis in all three cultivars indicated nitrogen was deficient. Berry firmness was not affected by fertilizer treatment. Soil pH was decreased by fish waste-based fertilizer than by protein-based fertilizer at one sampling date.

Introduction

Blueberries are a rapidly growing agricultural commodity in Oregon. In 2005, there were 4,400 acres of blueberries with a record crop of 34 million pounds, making Oregon the third ranked state in the USA for blueberry production. As a popular fruit branded for health, organic blueberries are becoming a novelty sought after by health-consciousness consumers. Organic blueberries typically command a 20% or more premium than conventionally-grown blueberries (Kuepper and Diver, 2004). In the last two years, the supply of fresh and processed organic blueberries is far short of the market demand; the supply shortage is expected to continue to grow worldwide. Because of the large market demand for organic blueberries, both new and established blueberry growers are starting to explore organic blueberry production. This has resulted in a thirst for research-based information on organic blueberry production systems.

There has been little research specifically conducted on organic blueberry production systems to date in the Northwest. Although a few fungicides and insecticides are labeled for organic use, their effectiveness for controlling diseases and pests has not been investigated in organic blueberry production systems. Field visits to a few organic

blueberry farms and grower calls indicate nutrition (especially nitrogen) and weed control are the top two problems facing organic blueberry growers today in Oregon. There are many different kinds of organic nitrogen fertilizers which all have a slower release rate than most inorganic forms. A single application of organic nitrogen fertilizer is recommended if nitrogen will be released slowly over a growing season (Strik et al., 1993). In our study, we are interested in evaluating a fish waste-based and a protein-based organic nitrogen fertilizer and determining their effects on growth, yield, and fruit quality of three popular blueberry cultivars grown in the Northwest.

Materials and Methods

The field experiment was conducted at the North Willamette Research and Extension Center in Aurora, OR. The three highbush blueberry cultivars were 'Duke', 'Bluecrop', and 'Elliott', which were established in October 1999 at either 1.5' or 4' in-row spacing and 10' between the rows. These mature plants were used for an early cropping and spacing experiment (Strik and Buller, 2005), and were conventionally managed prior to the initiation of this study in April 2005. On 25 Apr., the whole plot had already received 40 lb N/acre as ammonium sulfate. Only the plants spaced at 1.5' in the row were used for the organic fertilizer treatments arranged in a randomized complete block design with five replications. Each experimental unit consisted of 11 plants. The fish waste based organic fertilizer blend consisted of fish meal, fish powder, fish bone meal, and potassium sulfate (N-P-K: 9-4-4). The protein-based organic fertilizer blend contained blood meal, feather meal, corn gluten, fish bone meal, and potassium sulfate with a final N-P-K ratio of 9-4-4.

The two organic fertilizers were applied on 9 May 2005 at a rate of 60 lb N/acre; therefore also providing 24 lb P and 24 lb K per acre. Organic fertilizers were applied uniformly by hand in a band 6" away from the crown. Irrigation was applied 1-2 times per week using overhead sprinklers and was scheduled by four tensiometers (Irrometer Co., Riverside, CA) placed at a depth of 12 and 24 inches. Approximately 24" water was used for irrigation during the growing season (Mar – Sept).

Plant growth was measured weekly by recording whip and shoot length of tagged plants which were also used to determine canopy size at the start and the end of the 20-week growing season.
One week after the organic fertilizer application, soil samples were taken every eight weeks (19^{th}, 27^{th}, 35^{th} weeks) to measure soil pH from two pooled samples of 6"-8" long soil cores per experimental unit. After drying the samples for 48 hours at 60 ºC, the soil pH was determined by using a pH meter (WTW pH330i, Weilheim, Germany) in the supernatant of the 1:1 mix of dried soil and distilled water (Gavlak et al., 1994).

Foliar nitrogen levels were measured in four-week intervals (week 22, 26, 30, and 34) by pooling the fifty youngest, fully developed leaves from nodes 4, 5, and 6 of current year shoots (Gough, 1994). Leaf samples were washed in a mild phosphate-free detergent (1% by volume), followed by one rinse in deionized water, and dried at 60 ºC

for 72 hrs before sending to the Central Analytic Laboratory at Oregon State University for tissue N analysis. At leaf sampling, a ranking table (based on a 1-5 scale, 1 = 100 – 85% green, 5 = 39 – 25% pale) was used to subjectively assess leaf yellowing, a visual symptom of possible N deficiency.

Fruit were harvested by hand with berry size determined from the average weight of 100 sub-sampled berries. Percent soluble solid (^{o}Brix) of berries was measured using a digital refractometer (PAL-1/Atago, Tokyo, Japan). Berry firmness was measured with a FirmTech 2 firmness tester (BioWorks, Inc., Wamego, Kansas) using 25 sub-sampled berries.
All data were analyzed using the General Linear Model (GLM) procedures of the SAS software package version 6 (SAS Institute, Cary, NC). Treatment means were compared with Duncan's multiple range test.

Results and Discussion

Plant growth. There was no effect of fertilizer treatment on growth. However, cultivar affected growth. 'Bluecrop' had greater shoot length than 'Duke' and 'Elliott' throughout the growing season (Fig. 1). Except for the first two weeks when 'Duke' outgrew 'Elliott', both 'Duke' and 'Elliott' had similar shoot growth during the rest of the growing season (week 21 to 38). Our observation was consistent with an earlier experiment indicating 'Bluecrop' had more vigor than 'Duke' and 'Elliott' (Strik and Buller, 2005).

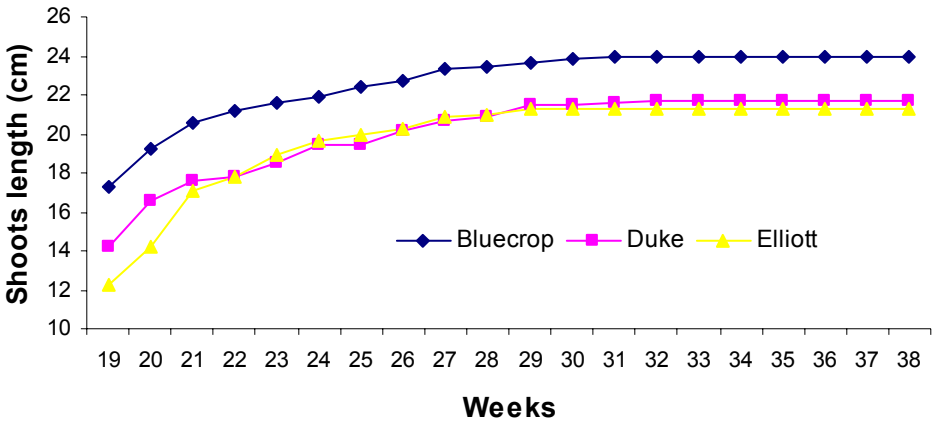

Figure 1. Shoot growth of three cultivars, averaged over fertilization treatment

Soil pH. There was a significant effect of fertilizer type on soil pH only at week 27 with a soil pH of 4.57 for the fish-based fertilizer and 4.83 for the protein-based fertilizer, suggesting that fish-based fertilizer decreased soil pH more rapidly than did protein-based fertilizer (Fig. 2). Because soil pH at the last sampling date (week 35) was not affected by fertilizer type, the difference in soil acidification between two fertilizer

types will need to be further studied. During a 17 week period, there was a trend for soil pH to decrease in both fertilizer treatments. Soil acidification by fertilizer nitrogen in blueberries is common due to root exudation of H^+ during uptake of NH_4^+. The faster drop in soil pH in fish fertilizer treated plots from week 19 to 27 may be due to more available soil nitrogen for plant uptake. Fish-based fertilizer usually provides faster nitrogen release than protein-based fertilizer, which can take up to four months to get mineralized (Whiting et al., 2005). The actual nitrogen release rate from these two fertilizer types will be investigated under field conditions in 2006.

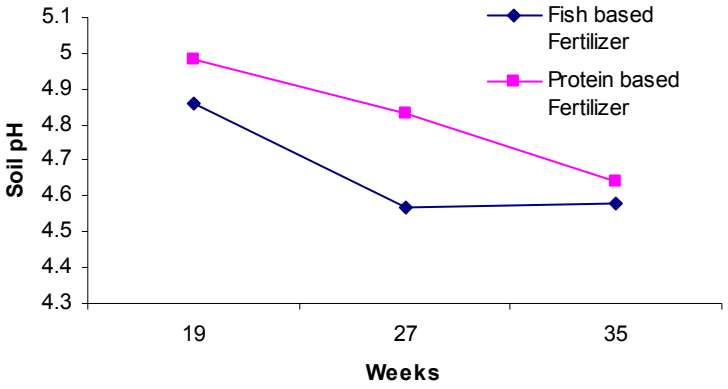

Figure2. Soil pH on three sampling dates

Leaf Nitrogen. There was no treatment effect on leaf N concentration. On week 22 (around fruit set), 'Duke' tended to have a higher %N than 'Bluecrop' and 'Elliott'. On week 26 (about three weeks before harvest), 'Bluecrop' tended to have the highest %N, while leaf %N in 'Duke' decreased to 1.83%. On the last two sampling dates (after harvest and before leaf senescence), leaf %N in all three cultivars was below the sufficient leaf N level of 1.75% (Fig. 3). Visual observation of leaf color indicated significant differences among cultivars with 'Bluecrop' being at scale of "1" (100 - 85% green), 'Elliott' at "2" (84 – 70% green), and 'Duke' at "3" (69 – 55% green) throughout the last three sampling dates.

Although foliar analysis at week 22 and 26 showed sufficient leaf %N in all three cultivars, 'Duke' had symptoms of leaf yellowing starting on week 26. There were no symptoms of chlorosis in 'Bluecrop' and 'Elliott' suggesting a higher nitrogen demand in 'Duke', perhaps due to its earlier fruiting season. The below normal leaf %N in all three cultivars after harvest indicates total N applied (100 lb N/acre) was not sufficient to meet plant demand when organic N was used for a portion of the fertilizer applied. The standard commercial N rate for a 6-year-old planting in Oregon is 100 lb N per acre. In our study, the availability of organic N for plant uptake may be delayed by the mineralization process.

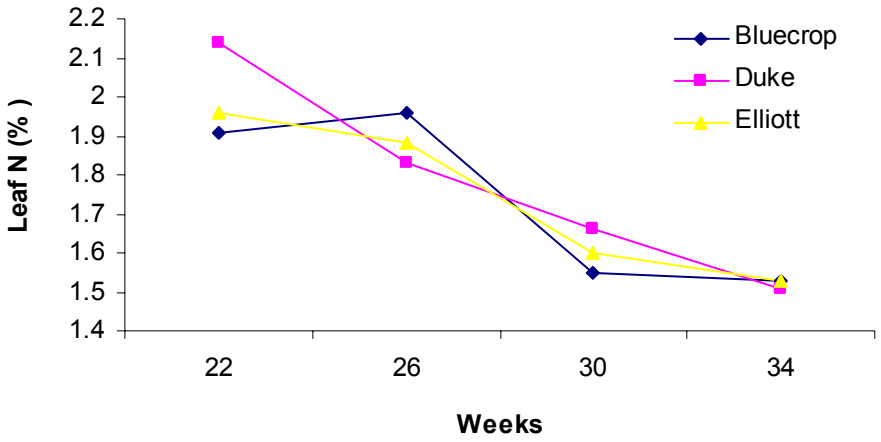

Figure 3. Leaf N %N during the growing season, averaged over fertilization treatment

Yield and fruit quality. There was no fertilizer treatment effect on yield or fruit quality. However, there were differences in total yield amongst cultivars with 'Elliott' having the highest yield, followed by 'Bluecrop' and 'Duke', agreeing with earlier findings from this experimental plot (Strik and Buller, 2005). The unusually low yield in 'Duke' was mainly due to bird damage and perhaps to heavy pruning the previous winter. 'Bluecrop' had larger berries than 'Duke' and 'Elliott' on the 1st and 2nd harvests, whereas 'Duke' was larger than 'Elliott' on the 2nd and 3rd picks. The decrease in berry weight toward the end of the harvest was expected and is common in blueberries (Table 1).

Table 1. Effect cultivar on berry weight and yield, averaged over fertilizer treatment.

	Berry weight (g/berry)				Yield (lbs/plot)				
Cultivar	Pick 1	Pick 2	Pick 3	Pick 4	Pick 1	Pick 2	Pick 3	Pick 4	Total (lbs/Acre)
Bluecrop	2.2 a[z]	1.92 a	1.71 a	1.11	17.69 a	11.32 a	7.75 a	2.38 b	9804 b
Duke	1.38 b	1.49 b	1.48 a	NA	1.81 b	1.17 b	0.32 b	NA	460 [x]
Elliott	1.35 b	1.23 c	0.96 b	1.03	14.55 b	11.61 a	7.86 a	8.71 a	10,701 a
P (F) [y]	*<.0001*	*<.0001*	*0.0005*	*0.1982*	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*

[z] Mean separation by Duncan's multiple range test, $P \leq 0.05$.
[y] *P (F)* values indicate significance level.
[x] Yield affected by bird damage.
NA = not applicable

There were significant differences in °Brix on the 1st and 2nd harvests amongst the three cultivars (Table 2). 'Elliott' and 'Duke' had higher °Brix than 'Bluecrop'. °Brix in 'Elliott' and 'Bluecrop' increased 12% and 26%, respectively, from the first pick to the 4th pick. Berry firmness varied between picks. 'Duke' had more berry firmness than 'Bluecrop' and 'Elliott' at the first pick, while 'Elliott' had better firmness than 'Bluecrop' on the 2nd

and 3rd picks, but not in the 4th pick (Table 2). The increase in berry firmness of 'Elliott' in the 2nd and 3rd picks is somewhat surprising since 'Elliott' is known as a 'soft' berry compared with other highbush cultivars. Perhaps N stress in our study contributed to the increased firmness in 'Elliott' at these harvests.

Table 2. Effect of cultivar on berry quality, averaged over fertilizer treatment.

	Brix (%)				Firmness (g.mm^{-1} of deflection)			
Cultivar	Pick 1	Pick 2	Pick 3	Pick 4	Pick 1	Pick 2	Pick 3	Pick 4
Bluecrop	11.46 b	12.26 b	13.09	14.4	167.98 b	152.84 b	154.87 b	193.12 a
Duke	13.37 a	13.83 a	11.92	NA	196.19 a	194.3 a	160.99 b	NA
Elliott	13.2 a	14.24 a	14.94	15.02	149.61 c	186.84 a	215.84 a	175.62 b
P (F) [z]	*0.0039*	*0.002*	*0.0691*	*0.3221*	*<.0001*	*<.0001*	*0.0009*	*0.0008*

[z] Mean separation by Duncan's multiple range test, $P \leq 0.05$. *P (F)* values indicate significance level.
NA = not applicable because of no picks.

Conclusion

The organic fertilizer blends we used did not affect plant growth, yield, and fruit quality of three highbush blueberry cultivars in the first year. There may be differences in the acidifying effects and rate of N mineralization between fish-based and protein-based organic fertilizer, which should be considered when they are used as a nitrogen source. Because organic N has to be mineralized before plant uptake, organic N fertilizer should be applied earlier than inorganic N to allow time for mineralization to occur. An adjustment in the rate of organic N application may also be necessary.

Literature Cited

Gavlak, R.G., D.A. Horneck and R.O. Miller 1994. Plant, soil, and water reference methods for the Western Region. Ref. 75.2 N4-1.

Gough R. 1994. The Highbush Blueberry and Its Management. Food Products Press, Binghamton, NY.

Kuepper, G. and S. Diver. June 2004. Blueberries: Organic Production. Operated by the National Center for Appropiate Technology (NCAT). http://www.attra.org/attra-pub/blueberry.html

Strik, B. and G. Buller. 2005. The impact of early cropping on subsequent growth and yield of highbush blueberry in the establishment years at two planting densities is cultivar dependant. HortScience. 40:1998-2001.

Strik, B. (ed.) and 15 co-authors in PNW. 1993. Highbush Blueberry Production, PNW 215. Strik, regional editor, OSU Extension Service, Jan. 1993, 80 pp.

Whiting, D., C.Wilson, and A. Card. 2005. Organic Fertilizers. Colorado State University, N. 7,733. Fort Collins, CO.
http://www.ext.colostate.edu/pubs/garden/07733.html#top

Nutrient Assessment Technologies for Wild Blueberry Production

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Introduction

The wild blueberry (*Vaccinium angustifolium* Ait.) is commercially managed on a two-year production cycle with the perennial shoot being pruned in alternate years to maximize floral bud initiation, fruit set, yield, and ease of mechanical harvest. Selective herbicides are applied to control competing weeds in the spring of the first year and fertilizers generally containing N, P, and K are typically applied in blanket applications on fields using rotary fertilizer applicators.

Past nutrient management research has provided valuable information on seasonal growth (Hainstock, 2002) and nutrient (Townsend and Hall, 1970; Trevett et al., 1968) dynamics, optimum nutrient levels for leaf tissue and subsequent vegetative growth (Korcak, 1988; Korcak, 1989; Trevett, 1972), influence of soil pH (Hall et al., 1964), denitrification (Eaton and Patriquin, 1989), nitrification potential (Eaton and Patriquin, 1988), inorganic nitrogen levels (Eaton and Patriquin, 1988; Percival and Privé, 2002), and the impact of inorganic nitrogen formulation (Percival and Privé, 2002; Smagula and Hepler, 1978). In addition, the effects of phosphorus fertilizer applications (Eaton et al. 1997), micronutrient applications including boron (Chen et al., 1998), N-P-K fertilizers (Percival and Sanderson, 2004), various timings of NPK fertilizer application (Smagula and Hepler, 1978), and methods to improve phosphorus deficiency (Smagula and Dunham, 1995) have been examined. This has been coupled with research indicating that inherent problems exist with the present range of soil extractions in accurately estimating available phosphorous (Ring, 2001).

With recent increases in wild blueberry yield components and harvestable yields being obtained with fertilizer applications, the use of nitrogen based fertilizers has drastically increased. However, with the wild blueberry plant generally having low nitrogen levels (i.e., 60 to 110 kg $N \cdot ha^{-1}$), applications typically consisting of 22 to 42 kg $N \cdot ha^{-1}$ applied in the vegetative phase of production, and the need to carefully manage stem heights to optimize harvest efficiency and yields, more attention has been placed on nutrient assessment technologies. These presently consist of collecting leaf tissue samples at the tip dieback stage of development, drying and grinding the samples, and assessing nitrogen content by combustion analysis (LECO CNS analyser) and other macro- and micronutrient content by ICAP analysis. Although these lab methodologies provide accurate and precise foliar nutrient levels, their use on a geospatial basis within fields becomes time consuming and cost prohibitive. Subsequently, more emphasis needs to

be directed to examining technologies that will quickly, efficiently and accurately estimate leaf tissue nutrient levels on a spatial and temporal basis in blueberry fields.

Methods and Materials

Two experiments examining alternative techniques to assess leaf tissue nitrogen levels were completed between 2002 and 2004. The first experiment consisted of an initial experiment examining various N assessment techniques (combustion of N via a LECO CNS Analyser, modified Jones Reductor, Kjeldahl, and chlorophyll extraction). The second experiment consisted of examining the use of a near infrared analyzer to estimate leaf macronutrient levels.

Field site. The field portion of this experiment was conducted at a commercial wild blueberry field situated at Kemptown, Nova Scotia (45°30' N, 63°8' W). This site consisted of indigenous and heterogenous wild blueberry phenotypes that were situated on Orthic Podzols belonging to the Cobequid soil classification (Webb et al., 1991).

A three-factor, rotatable, central composite design was used to identify the specific orthogonal treatment combinations required to attain a second order response surface (Cochran and Cox, 1957). Sixteen treatment combinations with five levels (0, 20, 50, 80 and 100% of full application rate) each of nitrogen, phosphorus, and potassium were used according to design criteria to investigate the main and interactive effects of nitrogen, phosphorus, and potassium. A plot size of 6 x 8 m was used and the N, P, and K application rates consisted of 0 to 80 kg $N \cdot ha^{-1}$ in the form of ammonium sulphate, 0 to 220 kg $P_2O_5 \cdot ha^{-1}$ in the form of triple-superphosphate, and 0 to 60 kg $K_2O \cdot ha^{-1}$ in the form of muriate of potash. Fertilizers were applied using a Scott SR2000 rotary fertilizer spreader (Marysville, OH). The fertilizer treatments were applied to plants in the vegetative (i.e., "sprout") stage of production and consisted of 5 May 2002.

Leaf Tissue Nitrogen Analysis. Leaf samples were collected in the vegetative year on 24 July 2002. Leaf tissue samples were collected by randomly collecting leaves from 100 stems per plot. The leaves were subsequently divided into four subsamples with three set of subsamples being placed in a 60 °C drying oven until constant dry weight had been achieved. The fourth set of subsamples was stored at 4 ºC for 2 days, and had chlorophyll extraction conducted using an 80% acetone extractant as outlined by Glass et al. (2005).

Once the leaf tissue samples had attained constant dry weight, the leaf tissue samples were ground in a Wiley mill equipped with a 20 mesh screen. The first set of the dried samples were sent to the Prince Edward Island Department of Agriculture and Forestry, Soil and Plant Tissue Analytical Laboratory for combustion analysis of N by LECO, and P, K, Ca, and Mg by ICAP analysis. The second set of dried samples was analyzed for nitrate N using the modified Jones reductor method (Lepper, 1990). The third set of samples was analyzed for total N via the Kjeldahl protocol according to Methods of Soil Analysis (Bremner and Mulvaney, 1982).

Upon the completion of the tissue sampling and harvest, the field was mowed in November of 2003 and re-initiated in 2004. The treatments that were used in 2002 were reapplied to the same plots on 20 May 2004 using the previously described procedure. Leaf tissue samples were collected on 27 July 2004, and leaf tissue samples from each plot were divided into three subsamples. The first subsample was kept at 4ºC and immediately sent to the University of Guelph Analytical Services lab for fresh tissue N, P, K, Ca and Mg analysis using a SpectraStar 2200 near infrared analyzer (Purceville, VA). The remaining two samples were dried and ground using the previously described protocol with one sample going to the Prince Edward Island Department of Agriculture and Forestry, Soil and Plant Tissue Analytical Laboratory for N, P, K, Ca, and Mg analysis, and the other sample being also being sent to the University of Guelph Analytical Services lab for estimation of N, P, K, Ca and Mg content using near a infrared analyzer.

Statistical Analysis. Statistical analysis of variance was completed using the general linear models (GLM) procedure of SAS (Version 9, SAS Institute, Cary, NC. Statistical assumptions of normality and constant variance were tested using the Proc UNIVARIATE procedure of SAS, and Proc CORR procedure was used to determine the correlation between each of the four analytical methods.

Results and Discussion

Upon examining the leaf tissue samples collected in 2002, the modified Jones reductor method indicated that measurable levels of nitrate N may have been present in the leaf tissue. This may have been attributed to the increasing N levels within the soil associated with the fertilizer applications which stimulated nitrifying activity even at the low soil pH levels observed at the experimental location (pH 4.6) (Eaton and Patriquin, 1989). Unfortunately, the colorimetric protocol used did not appear to be suitable for blueberry leaf tissue due to high coloration of the extract, and this may have been a major factor contributing to the high variability with the results obtained (Table 1) and lack of a correlation with total leaf N (Table 2). However, given the absence of nitrate N in blueberry leaf tissue observed by Darnell (2005), this warrants further examination.

Overall, the standardized Kjeldahl were on average 7% lower than the leaf tissue N levels obtained with the LECO analysis (Table 1). The reasons for this difference may have been due to the Kjeldahl procedure determining only organic N, and/or inefficiencies associated with the catalyst and digestion conditions (Matejovic, 1995). Conversely, the N application rates used in this study did not cause a significant difference in leaf tissue chlorophyll levels (Table 1). These leaf tissue levels were consistent with those found by Glass et al. (2005) and illustrate that estimating chlorophyll content or related measurements (leaf greenness) on a leaf area basis using the visible part of the light spectrum will not provide a viable means of estimating leaf tissue N. Subsequently, the second phase of this study initiated in 2004 focused on the

use of the 1200 to 2200 nm portion of the light spectrum to estimate leaf tissue N, P, K, Ca and Mg levels.

Upon comparing the NIR estimates of leaf tissue nutrient levels with those of existing laboratory techniques (i.e., LECO and ICAP analysis), NIR analysis was a relatively precise means of estimating leaf tissue N with dried and fresh N levels being only 3.2 and 9.8% lower that the LECO combustion analysis (Fig. 1). In addition, the NIR analysis provided a reasonable accuracy, with significant ($p<0.001$) Pearson correlation coefficients of 0.874 and 0.842 being obtained with the dry and fresh tissue respectively (Table 2). These results are consistent with those of Korcak et al. (1990) and indicate the potential of using NIR spectroscopic techniques with both dried and fresh leaf tissue.

Despite these promising NIR leaf tissue N results (Fig. 1), no significant correlations between NIR estimates of P, K, Ca and Mg and actual leaf tissue levels could be found either on a fresh or dried weight basis (data not reported). These results diverge from those of Clark et al. (1987) in which P, K, Ca and Mg could be accurately estimated. One possible explanation is that a broader portion of the NIR spectrum (i.e., >2200 nm) needed to be examined to acquire a good estimate of these nutrients (Hallett et al., 1997). Unfortunately, this spectrum was beyond the range of the instrument used in this study and needs to be taken into consideration with future studies.

Conclusions

Studies examining the feasibility of using various analytical techniques including the modified Hones reductor (nitrate N), standardized Kjeldahl (total organic N), chlorophyll a and b, and NIR spectroscopy to accurately and precisely estimate total N, P, K, Ca and Mg in the leaf tissue of wild blueberries were conducted from 2002 to 2004. Of the techniques examined, NIR analysis provided the most accurate and precise method of estimating N content of both fresh and dried leaf tissue. Unfortunately, no significant correlation between NIR analysis and actual leaf tissue P, K, Ca and Mg could be found. Therefore, results from this preliminary investigation indicate that NIR analysis has the potential to provide a viable, more efficient and potentially a field portable method of analyzing leaf tissue N of wild blueberries. However, further examination of other NIR analytical devises for leaf tissue P, K, Ca, and Mg quantification, and in particular, NIR analysis under field conditions has to occur before pertinent conclusions can be made.

Acknowledgements
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Literature Cited

Bremner, J.M., and C.S. Mulvaney. 1982. Methods of Soil Analysis, Part II. American Society of Agronomy: Soil Science of America.

Chen, Y., J. Smagula, W. Litten, and S. Dunham. 1998. Effect of boron and calcium foliar sprays on pollen germination and development, fruit set, seed development, and berry yield of lowbush blueberry. J. Amer. Soc. Hort. Sci. 123:524-531.

Clark, D.H., Mayland, H.F., Lamb, R.C., 1987. Mineral analysis of forages with near infrared reflectance spectroscopy. Agron. J. 79:485-490.

Cochran, W.C. and G.M. Cox. 1957. Experimental Designs. (2nd ed.). Wiley, New York. p335-369.

Darnell, R. 2005. Effect of external nitrate concentration on nitrate and iron uptake and assimilation in *Vaccinium* species. HortScience 40:1116.

Eaton, L.J. and D.G. Patriquin. 1989. Denitrification in lowbush blueberry soils. Can. J. Soil Sci., 69:303-312.

Eaton, L.J. and D.G. Patriquin. 1988. Inorganic nitrogen levels and nitrification potential in lowbush blueberry soils. Can. J. Soil Sci. 68:63-75.

Eaton, L.J., K.R. Sanderson and G.W. Stratton. 1997. Fertilizer phosphorus in lowbush blueberries: effects and fate. Acta Hort. 446:477-486.

Glass, V.M., D.C. Percival, and J.T.A. Proctor. 2005. Tolerance of lowbush blueberries to drought stress in both sprout and cropping phases of production. II. Leaf gas exchange, stem water potential and dry matter partitioning. Can. J. Plant Sci. 85:919-927.

Hainstock, L.J. 2002. Seasonal phytochemistry, growth dynamics and carbon allocation of the wild blueberry (*Vaccinium angustifolium* Ait.). MS Diss. Dalhousie University, Halifax, N.S.

Hall, I.V., L.E. Aalders and L.R. Townsend. 1964. The effects of soil pH on the mineral composition and growth of the lowbush blueberry. Can. J. Plant Sci., 44:433 - 438.

Hallett, R.A., Hornbeck, J.W., Martin, M.E. 1997. Predicting elements in white pine and red oak foliage with visible-near infrared reflectance spectroscopy. J. Near Infrared Spectrosc. 5:77-82.

Korcak, R.F. 1988. Nutrition of blueberries and other calcifuges. Hortic. Rev., 10:183-227.

Korcak, R.F. 1989. Variation in nutrient requirements of blueberries and other calcifuges. HortScience, 24:573-578.

Korcak, R.F., Walker, V., Norris, K.H. 1990. Measurement of fruit tree total leaf nitrogen by near infrared reflectance spectroscopy. Acta Hort. 274:241-247.

Lepper, H.A. 1990. Official methods of analysis of the association of anaytical chemists, Association of Official Analytical Chemists. 15th ed. Virginia.

Matejovic, I. 1995. Total nitrogen in plant material determined by means of dry combustion: A possible alternative to determination by Kjeldahl digestion. Commun. Soil Sci. Plant Anal. 26:2217-2229.

Percival, D. and J.P. Privé. 2002. Nitrogen formulation and application date influence plant nutrition, growth, development, and yield of wild blueberry. Acta Hort. 574:347-355.

Percival, D.C. and K. Sanderson. 2004. Main and interactive effects of nitrogen, phosphorous and potassium fertilizers. Small Fruits Review 3:105-122.

Ring, R., 2001. A comparison of five extraction methods for determining available phosphorus in Nova Scotia blueberry soils. MS Diss. Dalhousie University, Halifax, N.S.

Smagula, J.M. and S. Dunham. 1995. Diammonium phosphate corrects phosphorus deficiency in lowbush blueberry. J. Small Fruit Viticult. 3(4):183-191.

Smagula, J.M and P.R. Hepler. 1978. Comparison of urea and sulfur-coated urea as nitrogen source for lowbush blueberries growing on a colton gravelly sand loam. J. Amer. Soc. Hort. Sci. 103:818-820.

Townsend, L.R. and I.V. Hall. 1970. Trends in nutrient levels of lowbush blueberry leaves during four consecutive years of sampling. Nat. Can. 97:461-466.

Trevett, M.F., 1972. A second approximation of leaf analysis standards for lowbush blueberry. Research in the Life Sciences. Maine Agric. Sta. Bull. 19:15-16.

Trevett, M.F., P.N. Carpenter and R.E. Durgin. 1968. Seasonal trend and interrelation of mineral nutrients in lowbush blueberry leaves. Maine Agricultural Experiment Station Bulletin 665. University of Maine, Orono.

Webb, K.T., R.L. Thompson, G.J. Beke, and J.L. Nowland. 1991. Soils of Colchester County, Nova Scotia. Agriculture Canada Research Branch. Soil Survey Rpt. No. 19.

Table 1. Nitrogen concentrations in wild blueberry leaves as determined by LECO CNS analysis, Modified Jones reductor, standardized Kjeldahl and chlorophyll extraction.

	Mean leaf tissue nitrogen levels[z]			
Treatment (kg N·ha^{-1})	**LECO analysis (%N)**	**Modified Jones reductor (%N)**	**Standardized Kjeldahl (%N)**	**Chlorophyll a and b extraction (µg·cm^{-1} fresh weight)**
0	1.53	0.15	1.43	35.9
16.2	1.55	0.23	1.45	33.4
40.0	1.59	0.42	1.47	39.4
63.8	1.63	0.34	1.53	36.1
80.0	1.70	0.46	1.60	39.8
Standard error	0.0378	0.97	0.0269	1.91
ANOVA results[y]	Rep*** Trt*	NS	Rep*** Trt***	NS

[z]Leaf tissue N levels were based on a dry weight basis with the exception of chlorophyll content (fresh weight basis)

[y]Analysis of variance results indicate factors that were either non significant (NS: P>0.05) or significant at the P<0.05 (*),0.01 (**), and 0.001 (***) respectfully.

Table 2. Pearson correlation coefficients and associated p-values for the various nitrogen assessment technologies assessed in 2002.

	LECO analysis (%N)	**Modified Jones reductor (%N)**	**Standardized Kjeldahl (%N)**	**Chlorophyll a and b extraction (µg·cm^{-1} fresh weight)**
LECO analysis	1.000	-0.09060 0.7041	0.94509 0.0001	-0.06705 0.7788
Modified Jones redactor		1.000	0.01366 0.9333	-0.1604 0.4992
Standardized Kjeldahl			1.000	-0.17869 0.4510
Chlorophyll a and b extraction				1.000

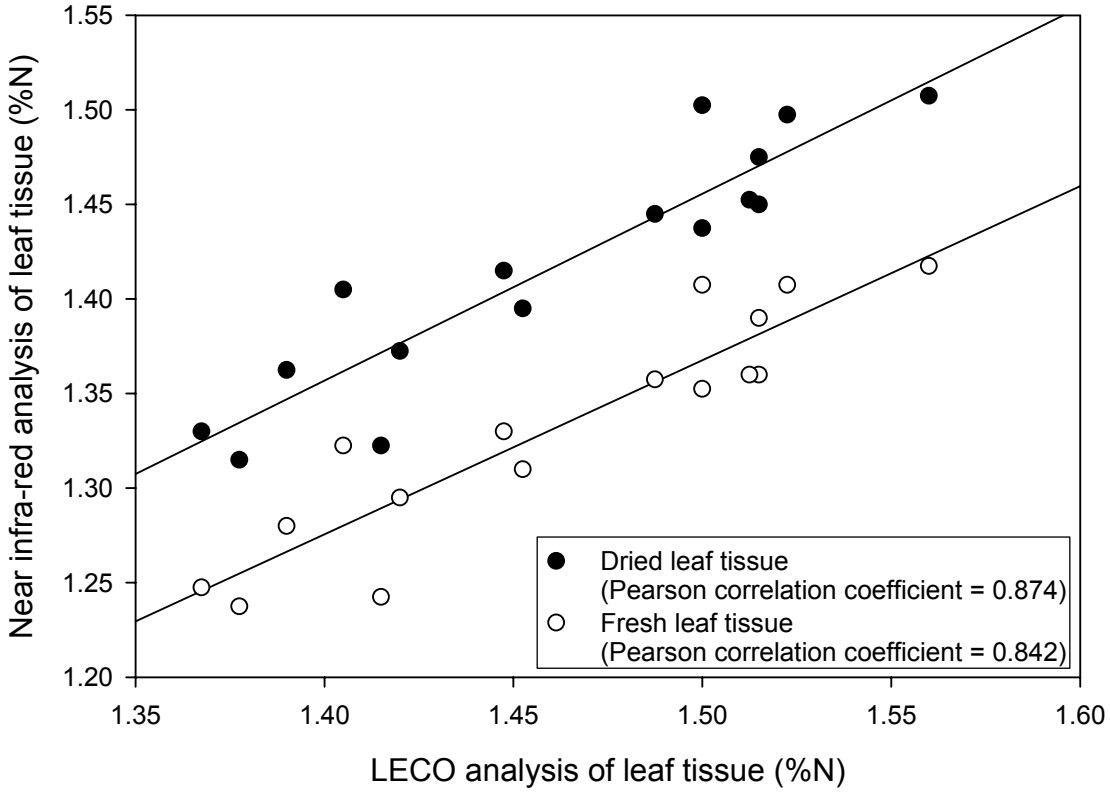

Figure 1. Relationship between analysis of leaf tissue by combustion analysis (LECO) and near infra-red spectroscopy of dried and associated fresh leaf tissue collected in 2004.

Comparison of Irrigation Methods for Establishing Highbush Blueberry

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Summary

A study was done to determine the effects of overhead sprinkler, drip, and microspray irrigation on water requirements and growth in a newly-planted field of northern highbush blueberry (*Vaccinium corymbosum* L.). Two cultivars, 'Duke' and 'Elliott', were irrigated by each system at 50, 100, and 150% of the estimated crop evapotranspiration requirement (ETc). During the first two years after planting, plants irrigated by microsprays required 12-36% more water as those irrigated by drip, while those irrigated by sprinklers required 117-138% more water. Interestingly, drip significantly increased growth in 'Elliott' compared to sprinklers and microsprays, but significantly decreased it in 'Duke'. The benefit of drip in 'Elliott' was likely due to higher soil water content in this treatment, which probably enhanced plant water status over sprinklers and microsprays. However, in 'Duke', higher soil water content with drip increased the incidence of *Phytophthora* and *Pythium* root rot, which then led to weakened and smaller plants. Growth was similar in plants irrigated by sprinklers and microsprays in both 'Duke' and 'Elliott'.

Introduction

Most commercial highbush blueberry fields in the U.S. are irrigated by overhead sprinklers or drip (Strik, 2005). Sprinkler systems are relatively simple to install and maintain, and when designed properly, obtain reasonable uniformity of water application. Some major advantages of sprinklers are that they can be used to maintain a cover crop, protect the crop from frost damage during subfreezing temperatures, cool the crop during hot conditions, and wash dust of the crop before harvest. Drip systems are somewhat more expensive to install and more difficult to maintain than sprinklers, but offer superior water control and distribution uniformity, improved application of fertilizer and other chemicals, improved cultural practices including the ability to irrigate during harvest, and fewer weed and disease problems (Kruse et al., 1990). Water is typically applied 1-2 times per week as needed with sprinklers, and every 1-3 days with drip.

A few growers are also using microsprays on blueberry. Although microsprays are not commonly used in blueberry, Holzapfel et al. (2004) found in Chile that production was higher with microsprays than with drip. Microspray irrigation offers advantages similar

to drip, but applies the water to the soil surface by a small spray. Because microsprays wet more soil volume than drip, plants tend to produce a larger root system, which may be a considerable advantage in shallow, densely-rooted crops like blueberry (Patten et al., 1988).

The objective of the present study was to compare the water requirements for growing blueberry with overhead sprinklers, drip, and microsprays, and determine which method produces the most growth after planting. We hypothesized that plants would not only require less water when irrigated with drip or microsprays than with sprinklers, but also would establish better as result of the more frequent and better controlled water applications with these low-volume systems.

Materials and Methods

The planting was established at the Oregon State University Lewis-Brown Horticultural Research Farm, Corvallis, Ore., in April 2004. Soil at the site is a Malabon silty clay loam adjusted to a pH of 5.5. The plants were grown on mulched raised beds and spaced 0.76 m apart within rows and 3.0 m apart between rows. Normal cultural practices for mulching, fertilizing, and pruning were followed (Strik et al., 1993).

Eighteen treatments were arranged at the site in a strip-plot design with two cultivars ('Duke' and 'Elliott'), three irrigation methods (overhead sprinkler, drip, microspray), and three irrigation levels (50,100, and 150% of the estimated crop evapotranspiration requirements, ET_c). Each treatment plot consisted of three rows of eight plants and was replicated five times. Overhead sprinkler treatments were irrigated by four sprinklers per plot; a sprinkler was located on each corner of the plots and set to rotate in a 90^o wetting pattern. Drip treatments were irrigated by drip tubing, with in-line emitters spaced 30 cm apart, placed along the row at a the base of the plants. Microspray treatments were irrigated with fan-jet emitters located between every other plant and suspended on a trellis wire 1.2 m above the plants. Although treatments will eventually be hand picked, each system was configured in such a way as not to interfere with mechanical harvesters. Irrigation treatments were initiated in July 2004 and controlled by an automatic timer set weekly. Overhead sprinkler treatments were irrigated twice per week, as needed, while drip and microspray treatments were irrigated three times per week. The total amount of water applied to each treatment each year is shown in Table 1.

All measurements were taken in 2004 and 2005 during the first two years after planting. Crop evapotranspiration (ET_c) estimates were obtained from the Pacific Northwest Cooperative Agricultural Weather Network (AgriMet), and were adjusted for plant size and irrigation system efficiency following procedures outlined in Holzapfel et al. (2004). Water applications were measured using flow meters installed in the irrigation manifold. Soil water content was measured in the top 30 cm of the plant bed using a Trase time domain reflectometry (TDR) system with a 30-cm heavy-duty waveguide; the waveguide was installed at two locations in the middle of the plot, approximately 15

cm from two representative plants per treatment. Whips were counted and fresh pruning weights were measured in January each year. Three plants were randomly selected from each plot (outer rows only) and destructively harvested in October 2005. Twenty fresh root pieces from each plant were plated on media (PARP and PARPH) selective for *Phytophthora* and *Pythium* root rot fungi, incubated, and quantified for the percentage of root fragments infected by the fungi (Jeffers and Martin, 1986). Shoots and remaining root material were then washed, oven-dried, and weighed.

Data were analyzed by analysis of variance (ANOVA) using ProcGLM (SAS Institute, Cary, N.C.) procedures. Means were separated at the 0.05 level using Duncan's multiple range test.

Results and Discussion

During the first year after planting, soil water content was similar between cultivars, but significantly different among irrigation methods ($P<0.0001$) and irrigation levels ($P=0.0053$). Essentially, soil water content was higher, on average, at 100% and 150% ET_c than at 50% ET_c, and lower in sprinkler treatments than in drip and microspray treatments (Table 2). An interaction between cultivar and irrigation method was also significant ($P=0.0462$), mostly due to lower soil water content in sprinkler treatments planted with 'Elliott' than in those planted with 'Duke'. This difference between cultivars appeared to be largely related to the fact that 'Elliott' produced a denser canopy than 'Duke' and therefore tended to shed more water away from the plant during overhead irrigations. Soil water content differences among treatments were even more apparent the second year, likely due to increased plant size and to higher rates of plant water uptake (Table 2).

By the end of the first season, drip irrigation produced the largest plants (based on whip counts and pruning weights) in both cultivars while sprinklers produced the smallest; plant size with microsprays was intermediate (Table 3). Surprisingly, we found no effect of irrigation level in any treatment. This indicates that, regardless of irrigation method, irrigation in year 1 was adequate at 50% of the estimated ET_c requirements obtained from AgriMet. Note, however, that irrigation levels were adjusted for irrigation system efficiency (defined as the ratio of the volume of irrigation water beneficially used by a crop in a specified area to the volume of irrigation water delivered to this area) in each treatment. With the adjustment, at 100% ET_c, we applied 20-36% more water by microspray and 117-138% more water by sprinkler than by drip (Table 1).

Drip continued to produce larger 'Elliott' plants the second season, but it no longer produced the largest 'Duke' plants (Table 3). In fact, by the end of this season, 'Duke' plants irrigated by drip not only had fewer whips and less pruning weight than those irrigated by sprinklers and microsprays, they also had only half the shoot and root dry weight (Table 4). Assessment of plants harvested destructively revealed that 'Duke' was significantly infected by *Phytophthora* and *Pythium* root rot fungi, while 'Elliott'

was not (Table 4). In 'Duke', root infection increased with irrigation level and was highest when plants were irrigated by drip. Clearly, root rot had reduced growth in 'Duke', especially when plants were irrigated by drip. Based on analysis of plant-free soil samples, it appears that the fungi probably originated with the planting stock. We are now attempting to control the fungi with Aliette and Ridomil fungicides. In 'Elliott', any benefit of drip was likely due to higher soil water content in this treatment, which probably improved water status of the cultivar. Drip has been shown to maintain higher plant water potentials than microsprays in other crops such as peach and almond, thereby improving both growth and production (Bryla et al., 2005; Edstrom and Schwankl, 2004).

This study demonstrates potential benefits of using drip in blueberry, provided plants are healthy. It also illustrates, however, the potential risks of using drip when plants are susceptible to root rot. Our next step, as the field matures, is to start cropping the plants and begin examining the effects of different irrigation methods and scheduling amounts on fruit production in blueberry. Crop growth, water use, yield, and fruit quality will be measured in the study for at least three more years.

Literature Cited

Bryla, D.R., E. Dickson, R. Shenk, R.S. Johnson, C.H. Crisosto, and T.J. Trout. 2005. Influence of irrigation method and scheduling on patterns of soil and tree water status and its relation to yield and fruit quality in peach. HortScience 40:2118-2124.

Edstrom, J. and L. Schwankl. 2004. Nickels Soil Lab project, p. 337-346. IN: Years of discovery. A compendium of production and environmental research projects, 1972-2003. California Almond Board, Modesto, California.

Holzapfel, E.A., R.F. Hepp, and M.A. Marino. 2004. Effect of irrigation on fruit production in blueberry. Agric. Water Mgt. 67:173-184.

Jeffers, S.N. and S.B. Martin. 1986. Comparison of two media selective for *Phytophthora* and *Pythium* species. Plant Dis. 70:1038-1043.

Kruse, E.G., D.A. Bucks, and R.D. von Bernuth. 1990. Comparison of irrigation systems, p. 475-508. In: B.A. Steward and D.R. Nielson (eds.). Irrigation of agriculture crops. ASA-CSSA-SSSA Publ. Agron. Monogr. 30.

Patten, K.D., E.W. Neuendorff, and S.C. Peters. 1988. Root distribution of 'Climax' rabbiteye blueberry as affected by mulch and irrigation geometry. J. Amer. Soc. Hort. Sci. 113:657-661.

Strik, B., C. Brun, M. Ahmedullah, A. Antonelli, L. Askam, D. Barney, P. Bristow, G. Fisher, J. Hart, D. Havens, R. Ingham, D. Kaufman, R. Penhalgon, J. Pscheidt, B

Scheer, C. Shanks, and R. William. 1993. Highbush blueberry production. Ore. State Univ. Ext. Serv. Pub. PNW 215.

Strik, B.C. 2005. Blueberry—An expanding world berry crop. Chronica Hort. 45:7-12.

Table 1. Total amount of water applied to 'Duke' and 'Elliott' plants irrigated at three different levels by overhead sprinklers, microsprays, and drip in 2004 and 2005.

		Water applied (mm)			
		2004		2005	
Irrigation system	Irrigation level (%ET_c)	Duke	Elliott	Duke	Elliott
Sprinkler	50	183	229	470	472
Sprinkler	100	366	457	826	919
Sprinkler	150	546	683	1242	1384
Microspray	50	114	155	208	229
Microspray	100	229	315	429	475
Microspray	150	340	457	632	701
Drip	50	97	104	175	185
Drip	100	190	203	358	376
Drip	150	272	295	493	526

Table 2. Soil water content measured by time-domain reflectometry (TDR) in 'Duke' and 'Elliott' plots irrigated at three different levels by overhead sprinklers, microsprays, and drip. Data are average measurements collected during the first two growing seasons in 2004 and 2005.

Cultivar	Irrigation system	Irrigation level (%ET_c)	Soil water content (%) 2004	2005
Duke	Sprinkler	50	25.0 ef[z]	24.7 d-f
Duke	Sprinkler	100	26.6 d-f	28.1 cd
Duke	Sprinkler	150	28.3 a-d	30.5 a-c
Duke	Microspray	50	27.2 b-f	21.5 ef
Duke	Microspray	100	28.8 a-d	28.0 cd
Duke	Microspray	150	28.8 a-d	31.4 a-c
Duke	Drip	50	27.7 b-e	30.8 a-c
Duke	Drip	100	29.8 ab	33.2 ab
Duke	Drip	150	29.5 a-c	34.1 ab
Elliott	Sprinkler	50	25.4 ef	20.8 f
Elliott	Sprinkler	100	24.8 f	25.4 de
Elliott	Sprinkler	150	24.5 f	25.7 de
Elliott	Microspray	50	26.8 c-f	15.8 g
Elliott	Microspray	100	28.9 a-d	20.7 f
Elliott	Microspray	150	29.2 a-d	24.8 d-f
Elliott	Drip	50	29.1 a-d	29.4 b-d
Elliott	Drip	100	29.2 a-d	30.4 a-c
Elliott	Drip	150	30.8 a	34.9 a

[z]Within a column, means followed by the same letter are not significantly different at $P < 0.05$ using Duncan's multiple range test.

Table 3. Number of whips and fresh pruning weights from 'Duke' and 'Elliott' blueberry plants irrigated at three different levels by overhead sprinklers, microsprays, and drip. Measurements were taken in January after the first two growing seasons.

Cultivar	Irrigation system	Irrigation level (%ET_c)	Whips (#/plant)		Pruning wt. (g/plant)	
			2004	2005	2004	2005
Duke	Sprinkler	50	0.4 c[z]	1.7 e	29 de	78 ab
Duke	Sprinkler	100	0.3 c	1.6 e	24 e	78 ab
Duke	Sprinkler	150	0.3 c	1.0 e	23 e	70 ab
Duke	Microspray	50	0.4 c	1.8 e	31 c-e	75 ab
Duke	Microspray	100	0.6 c	1.3 e	35 b-d	82 ab
Duke	Microspray	150	0.5 c	1.3 e	29 de	83 ab
Duke	Drip	50	1.0 c	0.9 e	38 a-d	50 b
Duke	Drip	100	0.8 c	1.1 e	36 b-d	51 b
Duke	Drip	150	0.4 c	1.0 e	37 a-d	51 b
Elliott	Sprinkler	50	2.0 ab	3.3 cd	45 ab	98 ab
Elliott	Sprinkler	100	1.9 ab	4.0 bc	42 ab	94 ab
Elliott	Sprinkler	150	1.7 b	4.7 ab	45 ab	104 a
Elliott	Microspray	50	2.1 ab	3.0 d	40 a-c	76 ab
Elliott	Microspray	100	2.4 ab	4.2 a-c	41 a-c	107 a
Elliott	Microspray	150	2.5 ab	4.3 a-c	47 a	90 ab
Elliott	Drip	50	2.6 a	4.7 ab	43 ab	89 ab
Elliott	Drip	100	2.5 ab	5.1 a	41 a-c	110 a
Elliott	Drip	150	1.9 ab	4.0 bc	41 a-c	78 ab

[z]Within a column, means followed by the same letter are not significantly different at $P < 0.05$ using Duncan's multiple range test.

Table 4. Plant dry weight and percentage of root fragments infected by *Phytophthora* and *Pythium* root rot fungi in 'Duke' and 'Elliott' blueberry plants irrigated at three different levels by overhead sprinklers, microsprays, and drip. Plants were destructively harvested in Oct./Nov. 2005.

Cultivar	Irrigation system	Irrigation level (%ET_c)	Plant dry weight (g/plant)[z]	Infected roots (%)[y]	
				PARP	PARPH
Duke	Sprinkler	50	268 ed[x]	12 c-e	1 e
Duke	Sprinkler	100	273 ed	23 b-d	9 b-d
Duke	Sprinkler	150	257 e	24 bc	9 b-d
Duke	Microspray	50	224 ef	11 de	4 c-e
Duke	Microspray	100	295 ed	20 b-d	3 de
Duke	Microspray	150	212 ef	28 ab	15 ab
Duke	Drip	50	116 g	20 b-d	11 a-c
Duke	Drip	100	137 fg	36 a	13 ab
Duke	Drip	150	113 g	31 ab	19 a
Elliott	Sprinkler	50	361 b-d	0 e	0 e
Elliott	Sprinkler	100	436 bc	1 e	0 e
Elliott	Sprinkler	150	394 bc	2 e	0 e
Elliott	Microspray	50	355 cd	1 e	0 e
Elliott	Microspray	100	433 bc	3 e	0 e
Elliott	Microspray	150	460 ab	4 e	0 e
Elliott	Drip	50	436 bc	0 e	0 e
Elliott	Drip	100	533 a	0 e	0 e
Elliott	Drip	150	449 a-c	1 e	0 e

[z]Includes shoots and roots.
[y]Twenty roots per plant were plated on PARP and PARPH media.
[x]Within a column, means followed by the same letter are not significantly different at $P < 0.05$ using Duncan's multiple range test.

Environmental Losses of Soil Applied Nitrogen in Wild Blueberry Production

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Introduction

The wild blueberry (*Vaccinium angustifolium* Ait.) is a plant indigenous to northeastern North America, where it has developed into a very important horticultural commodity. Wild blueberries grow on acidic, relatively infertile agricultural soils, and are managed on a two-year production cycle, with fertilization occurring in the vegetative phase of production to ensure maximum yield. Past nutrient management has included valuable information on the influence of soil pH (Hall et al., 1964), denitrification (Eaton and Patriquin, 1989) and nitrification potential (Eaton and Patriquin, 1988).

Although yield increases can be obtained with the use of soil applied fertilizers (Percival and Privé, 2002), the type and magnitude of environmental losses that may occur are largely unknown. Nitrogen can be lost to the environment to volatilization processes either as ammonia (NH_3) or as nitrous oxide (N_2O). Ammonia volatilization is influenced by soil pH, organic matter content, and the enzyme urease (Fenn and Hossner, 1985), while N_2O loss is influenced by soil temperature and moisture (Meng et al., 2005), and appears to occur in waterlogged soil (Eaton and Patriquin, 1989).

Concerns associated with the environmental losses of agrochemicals have increased in recent years, with agricultural practices shown to be contributors of greenhouse gas (GHG) and ammonia emissions (Killpack and Buchholz, 1993; Bovis and Touchton, 1998). These harmful effects can be reduced by using fertilizers more efficiently, using alternative nitrogen fertilizers, and by improving the basic understanding of the nitrogen cycle in the wild blueberry system. Subsequently, the objective of these studies was to determine the impact conventional and reduced environmental risk N fertilizers have on the release of nitrogen form emissions (NH_4, N_2O) and leachate (NO_3 and NH_4).

Materials and Methods

Ammonia Volatilization Experiment. The volatilization trials, examining ammonia loss, were established in commercial wild blueberry fields in the vegetative phase of production. The commercial fields were suited in Kemptown, Nova Scotia (45º30' N 63º8' W) and Mt. Vernon, Prince Edward Island (46º1' N 62º45' W). The wild

blueberries at the Kemptown and Mount Vernon sites consisted of indigenous and heterogenous phenotypes that were situated on Orthic Podzols belonging to the Cobequid (Webb et al., 1991) and Culloden (MacDougall et al., 1988) soil classifications, respectively. A randomized complete block experimental design with five replications and a plot size of 6 X 8 m was used. Treatments consisted of a control (no fertilizer application) and nitrogen applications (35 kg $N \cdot ha^{-1}$) of ammonium sulphate (AS), urea (U), diammonium phosphate (DAP) and sulfur coated urea (SCU). Fertilizers were applied using a Scott SR2000 rotary fertilizer spreader (Marysville, Ohio), on 10 June 2004 and 9 June 2004, for the Kemptown and Mount Vernon sites, respectively.

Measurement of ammonia losses from fertilizer N was completed using the vented chamber method (Selles, 2005). The apparatus contained two sponges (2.54 cm foam) placed inside a 15 cm wide polyvinyl chloride (PVC) cylinder at different heights. Sponges were prepared by double washing with distilled water, 0.001 M H_2SO_4 and a glycerol-phosphoric acid solution (Grant et al., 1996). Excess water was removed after each wash. Sponges were than placed in airtight bags to prevent possible contamination while being transported to the site.

Sponges were collected and replaced on days 1, 2, 5, 8 and 12 after fertilization. They were than rinsed using 250 mL of a 2 M KCl solution to extract the ammonia. Ammonium levels present in the extracted sample were determined using an auto-flow analyzer (Technicon, Terrytown, New York).

Leaching Experiment. A leaching experiment was established and completed in winter 2005 in a controlled laboratory environment at the Nova Scotia Agricultural College using intact soil cores collected from the Wild Blueberry Research Centre (Debert, N.S.) in November 2004. The soil type of the collected cores was a sandy loam of the Hebert series (Webb et al., 1991). Cores were stored at 4 ºC until the experiment was initiated. The bottom of each core was covered with a piece of 2 mm screen and a piece of landscape fabric and was than wrapped tightly. Cores were positioned in 30 cm funnels, kept in place with monofoam applied around the outside edge of the cores.

A randomized complete block experimental design was used, with five replications using aluminum cores, 180 mm long and 82.5 mm in diameter. Cores were leached twice before fertilizer was applied, beginning on 11 January 2005. Treatments were applied on 14 January 2005 and consisted of a control (no fertilizer application) and nitrogen applications (35 kg $N \cdot ha^{-1}$) of ammonium sulphate (AS), urea (U), diammonium phosphate (DAP), sulfur coated urea (SCU), isobutylidene diurea (IBDU) and nutriform (NU). Cores were leached on days 1, 4 and 7 after fertilization, with leaching then conducted once a week for 6 weeks, and then once biweekly for 6 weeks. Cores were leached using 200 mL of 0.01 M $CaCl_2$, solution and 20 mL leachate samples were collected. A N-Minus solution [$CaSO_4$, $MgSO_4$, $Ca(H_2PO_4)_2$, and K_2SO_4] was used to maintain the balance of other nutrients, excluding N, within the soil (Carter 1993). Leachate samples were analyzed at the Nova Scotia Agricultural

College using a Technicon auto-flow analyzer (Technicon Instuments Corp., Tarrytown, New York).

Greenhouse Gas Emissions Experiment. A preliminary experiment, measuring the greenhouse gas nitrous oxide (N_2O), was established at the Wild Blueberry Research Centre, in Debert, N.S, in the cropping phase of production on 20 June 2005. A randomized complete block design, with six replications, a plot size of 6 x 2 m with a 2 m buffer zone, and two treatments (no fertilizer and 35 kg $N \cdot ha^{-1}$ from AS) was used. Fertilization occurred on 21 June 2005, and static non-steady state chambers were placed in each plot to measure N_2O emissions. Due to the biology of the crop (large mat of rhizomes) the collars could not be pressed into the soil to the required 5 cm depth. Therefore, soil was placed around the outside of each chamber to form a seal.

Chamber tops were placed on top of the collar and headspace samples were drawn at intervals of 0, 10 and 20 minutes, using a 20 mL syringe. Gas samples were injected into evacuated 12 mL exetainers immediately after they were taken (Rochette and Bertrand, 2003). An air sample was taken at the beginning and end of the sampling interval. Samples were placed in a plastic bag and transported back to the lab in a cooler to prevent temperature fluctuation and provide secure storage. At the time of sampling, measurements of volumetric soil moisture content, air temperature and humidity, and soil temperature were also obtained. N_2O concentrations were determined using a CP-3800 gas chromatograph (Varian Analytical Instruments, California).

Results and Discussion

Ammonia volatilization. Overall, significant treatment effects ($p < 0.001$) of the soil-applied nitrogen sources were present at the Kemptown site, with cumulative volatilization rates of the urea (U) and sulphur coated urea (SCU) being 321 and 207% greater than the control respectively, by 12 days after fertilizer application (Fig. 1). Despite nitrogen source having a significant impact on volatilization rates of ammonia (Oenema and Velthof, 1993), this only amounted to 5.6% of the soil applied N applied (Fig. 1) and is consistent with results obtained in cotton production by Beene et al. (2004). There were no significant differences ($p > 0.05$) between treatments at the Mt. Vernon site (Fig. 1).

The divergence in volatilization results obtained at the two sites could have been due to rainfall (Bouwmeester et al., 1985), wind speed (Bergstrom and Byer, 2005) temperature, organic matter (Vitosh, 1990), soil texture, soil moisture, and soil pH (Oenema and Velthof, 1993). The combination of higher temperatures, high wind speed and coarser soil texture predisposed the Kemptown site to greater volatilization rates. In addition, rainfall between these two regions differed, with Kemptown receiving rain on the day of application (5 mm) and also between days 8-12, while Mt. Vernon received smaller amounts of rainfall near the end of the experiment.

Furthermore, temperatures in the Mount Vernon area were much lower throughout the course of the experiment.

Leaching experiment (NH_4^+ and NO_3). Significant differences in ammonium leaching were present by the second day of the experiment, with the AS, DAP and SCU treatments having ammonium leaching rates that were 736, 609, and 237% greater than the control (Fig. 2). During this interval, the slow and controlled release fertilizers SCU, IBDU and NU leached similar amounts of ammonium as the control (Fig. 2). Conversely, significant differences in nitrate leaching were present by 25 days after fertilization, and these differences continued as the experiment progressed with the IBDU, AS, and SCU treatments having nitrate leaching rates 105, 37.2, and 18.6% greater than the control (Fig. 2) 78 days after fertilizer application. Therefore, results from this study indicate that nitrification and mineralization within the collected blueberry samples occurred, leaching of both ammonium and nitrate were present, and nitrogen formulation had a major impact on both the type (i.e., ammonium versus nitrate) and magnitude of leaching. Other factors that have been observed to increase leaching under field conditions include higher N application rates (Zhu et al., 2005; Nyamangara et al., 2003), the amount of water applied to a system (Shuman, 2006), and increasing macropore flow rates (Nissen and Wander, 2003).

Greenhouse Gas Emissions Experiment. Overall, there was no significant influence of the fertilizer application on N_2O flux, with N_2O flux rates ranging from 0 to 1.78 g $N \cdot ha^{-1} \cdot day^{-1}$ (Fig. 3), with volumetric soil moisture being relatively consistent and ranging from 16 to 18 % throughout the experiment (data not reported). These results are in sharp contrast to those of van Groenigen et al. (2003) in which N fertilizer applications (0 to 188 kg $N \cdot ha^{-1}$) resulted in N_2O flux rates as high as 10 g $N \cdot ha^{-1} \cdot day^{-1}$. Other factors that have been noted to influence N_2O emissions include soil texture and soil moisture (Meng et al., 2005), and soil pH (Eaton and Patriquin, 1998). N_2O emissions are generally known to be less in acidic soils compared to neutral/alkaline soils (Slmek and Cooper, 2002). Combined with the low amounts of nitrogen applied (35 kg $N \cdot ha^{-1}$ applied bi-annually), soil acidity may have contributed to the low N_2O flux observed.

Conclusions

Results from the volatilization and leaching trials indicated that significant ammonium volatilization, and ammonium and nitrate leaching losses were present, and the magnitude of these losses varied between the field sites examined. The site specific attributes that may have contributed to the results observed include climatic conditions, soil properties and type of fertilizer applied. Nitrogen losses by means of N_2O emissions in the wild blueberry production system were not significant and barely detectable. Greater than anticipated leaching losses occurred under laboratory conditions, and despite using urea and ammonium sources of N, significant nitrate leaching was present suggesting nitrification activities were occurring, especially with

slow release urea fertilizers. Therefore, results from this initial investigation indicate that environmental losses of nutrients can occur and may be a limiting factor on plant growth and development. However, further replication of leaching and volatilization trials under field conditions needs to occur in conjunction with an examination of the organic N and mineralization processes before pertinent recommendations can be made.

Literature Cited

Beene, M., C. Krauter, and D. Goorahoo. 2004. Ammonia emissions related to fertilizers on field crops using precision application practices in the central valley of California. Center for Irrigation Technology, University of California Cooperative Extension, Kings County.

Bergstrom, K. and J. Byer. 2005. Can I Broadcast Nitrogen Fertilizer in the Winter? Frequently asked questions. Ag-Info Centre, Alberta Agriculture Food & Rural Development.

Bouwmesster, R.J.B., P.L.G. Vlek, and J.M. Stumpe. 1985. Effect of environmental factors on ammonia volatilization from a urea-fertilized soil. Soil Sci. Soc. Am. J. 49:376-381.

Bovis, M. and J. Touchton. 1998. Nitrogen Efficiency of Urea Fertilizers. Highlights of Agricultural Research. Vol. 45 Issue 1.

Carter, M.R. 1993. Soil Sampling and Method of Analysis. Can. Soc. Soil Sci. 33:344-346.

Eaton, L.J. and D.G. Patriquin. 1989. Denitrification in lowbush blueberry soils. Can. J. Soil Sci. 69:303-312.

Eaton, L.J. and D.G. Patriquin. 1988. Inorganic nitrogen levels and nitrification potential in lowbush blueberry soils. Can. J. Soil Sci. 68:63-75.

Fenn, L.B. and L.R. Hossner. 1985. Ammonia volatilization from ammonium or ammonium-forming nitrogen fertilizers. Adv. Soil Sci. 1:123-169.

Grant, C.A., S. Jia, K.R. Brown, and L.D. Bailey. 1996. Volatile losses of NH_3 from surface applied urea and urea ammonium nitrate with and without the urease inhibitors NBPT or ammonium thiosulfate. Can. J. Soil Sci. 76:417-419.

Hall, I. V., L.E. Aalders, and L.R. Townsend. 1964. The effects of soil pH on the mineral composition and growth of the lowbush blueberry. Can. J. Plant Sci. 44:433-438.

Killpack, S.C. and D. Buchholz. 1993. Nitrogen in the environment: Ammonia volatilization. Water Quality Initiative publication WQ257. Unv. of Missouri-Columbia.

MacDougall, J.I., C. Veer and F. Wilson. 1988. Soils of Prince Edward Island: Prince Edward Island Soil Survey. Agr. Can. L.R.R.C. Contrib. No. 84-85.

Meng, L., Z. Cai, and W. Ding. 2005. Long-term application of organic manure and nitrogen fertilizer on N_2O emissions, soil quality and crop production in a sandy loam soil. Soil Biology & Biochemistry. 37:2037-2045.

Nissen, T.M. and M.M. Wander. 2003. Management and soil-quality effects on fertilizer-use efficiency and leaching. Soil Sci. Soc. of America Journal. 67:1524-1532.

Nyamangara, J., L.F. Bergstom, and M.I. Piha. 2003. Fertilizer use efficiency and nitrate leaching in a tropical sandy soil. Journal of Environmental Quality. 32:599-606.

Oenema, O. and G.L. Velthof. 1993. Ammonia volatilization from compound nitrogen-sulfur fertilizers. M.A.C. Fragoso and M.L. van Beusichem (des.), Opitimization of Plant Nutrition. 341-349.

Percival, D.C. and J.P. Privé. 2002. Nitrogen formulation influences plant nutrition and yield components of lowbush blueberry (*Vaccinium Angustifolium* Ait.). Acta Hort. 574:347-355.

Rochette, P. and N. Bertrand. 2003. Soil air sample storage and handling using polypropylene syringes and glass vials. Can. J. Soil Sci. 83:631-637.

Selles, F. 2005. Protocol for NH_3 loss measurement using vented chambers. Workshop on Life Cycle Analysis for ETAA (Environmental Technology Assessment for Agriculture). May 25-26, AAFC, Ottawa.

Shuman, L. 2006. Normal and flush irrigation effects on nitrogen leaching from simulated golf greens in the greenhouse. Communications in Soil Sci. & Plant Analysis. 37:605-619.

Slmek, M. and J. Cooper. 2002. The influence of soil pH on denitrification: progress towards the understanding of this interaction over the last 50 years. European J. of Soil Sci. 53:345-354.

Vitosh, M.L. 1990. Nitrogen Fertilizers. Michigan State University Extension. Extension Bullentin E-896.

van Groenigen, J.W., G.J. Kasper, G.L. Velthof, A. van den Pol-van Dasselaar, and P.J. Kuikman. 2004. Nitrous oxide emissions from silage maize fields under different mineral nitrogen fertilizer and slurry applications. Plant and Soil 263:101-111.

Webb, K.T., R.L. Thompson, G.J. Beke and J.L. Nowland. 1991. Soils of Colchester County, Nova Scotia. Agr. Can. L.R.R.C. Contrib. No. 19.

Zhu, J.H., J.L. Li, P. Christie, and X.L. Li. 2005. Environmental implications of low nitrogen use efficiency in excessively fertilized hot pepper (*Capsicum frutescens* L.) cropping systems. Agriculture, Ecosystems & Environment. Vol. 111 (1-4):70-80.

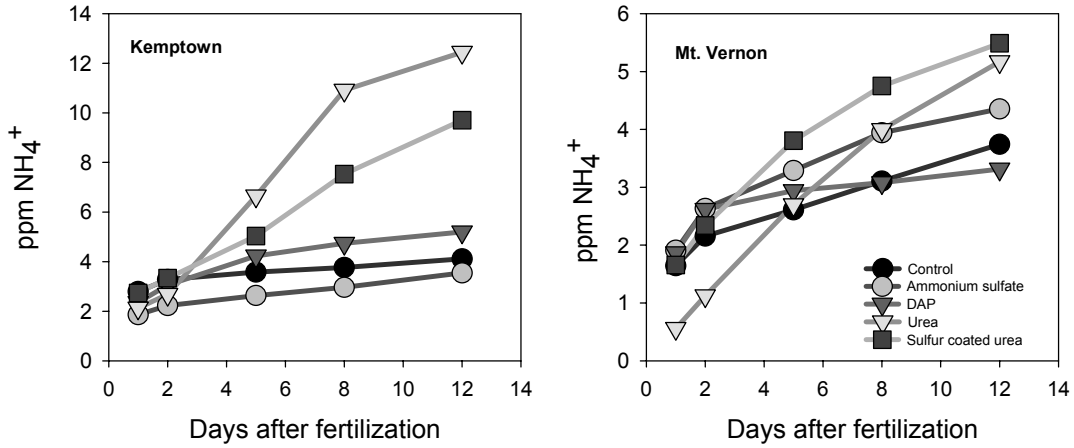

Figure 1. Cumulative volatilization rates after soil applied fertilization at two commercial wild blueberry fields located at Kemptown (NS) and Mount Vernon, PEI.

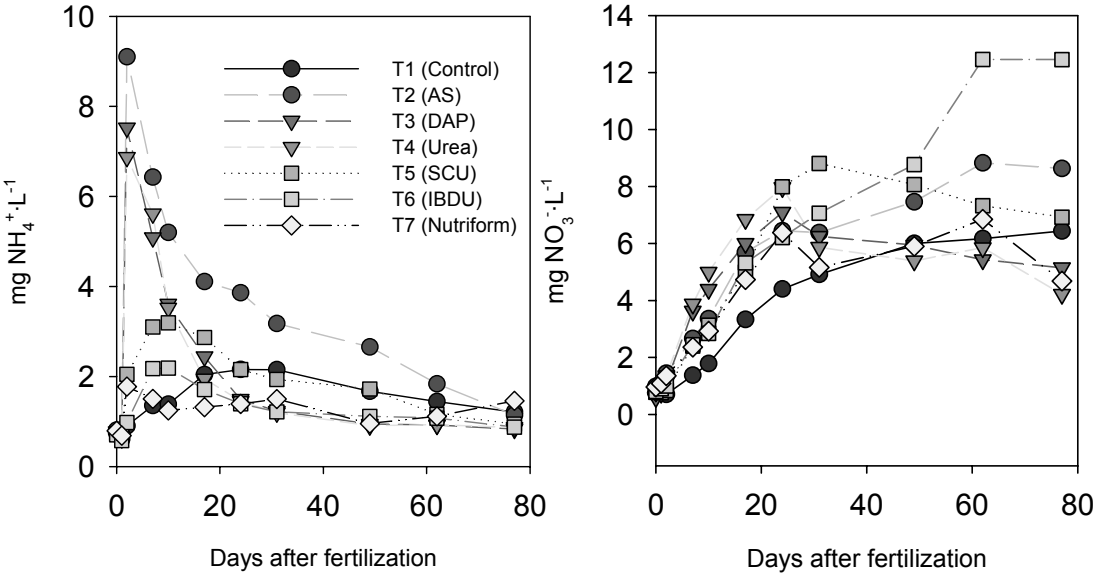

Figure 2. Leaching rates of ammonium (left) and nitrate (right) of soil applied N-fertilizer under a controlled environment using intact wild blueberry soil cores.

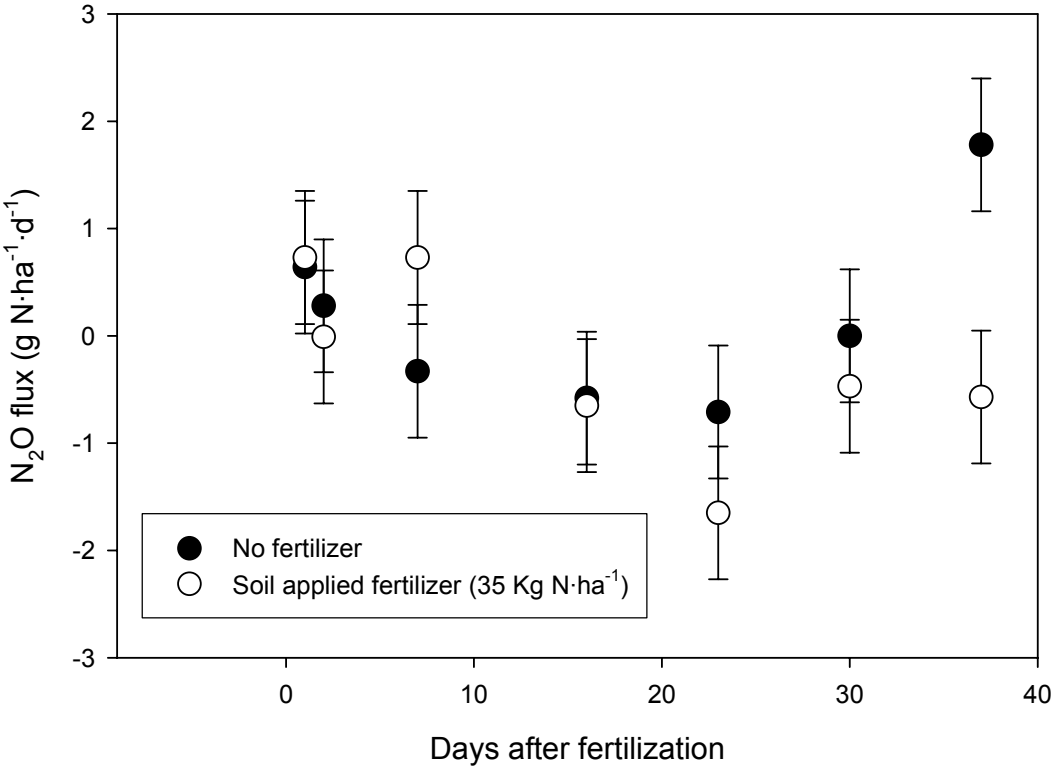

Figure 3. Nitrous oxide flux after soil applied applications of ammonia sulfate (35 kg N·ha-1) during 2005 at the Wild Blueberry Research Centre, Debert, Nova Scotia.

Effects of Raising Leaf Cu Concentration on Growth and Yield of Lowbush Blueberry

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Introduction

The lowbush blueberry (*Vaccinium angustifolium* Ait) has been more intensively managed in recent years (Smagula and Yarborough, 2006) by using better weed control, increased use of pollinators, selective pesticide usage after careful monitoring of insects and diseases (IPM), and improved fertility management based on leaf tissue analysis. The standards upon which growers base their fertilizer application were proposed by Trevett (1972). Nitrogen (N) and phosphorus (P) leaf standards have been appropriate (Smagula, et al., 2004, Smagula and Dunham, 1995, Yarborough and Smagula, 1993), but the zinc (Zn) standard was found to be too high (Smagula et al., 1999). The boron (B) standard was also shown to be too high (Smagula and Litten, 2002). Evaluation of leaf nutrient concentrations in leaf samples submitted to the Maine Agricultural Experiment Station Laboratory between 2000 and 2004 revealed that only 2% of the samples had leaf Cu concentrations at or above the 7 ppm standard. Since Cu is a component of many enzymes and is one of the electron carriers in photosynthesis, we anticipated an increase in growth and flower bud formation with a prune-year application of Cu. In this study we tested the Cu standard by evaluating growth and yield after raising leaf Cu concentrations in a commercial lowbush blueberry field characterized by plants with low leaf Cu.

Materials and Methods

2001 Study

Leaf Cu concentrations of lowbush plants in 1.8 m x 15 m treatment plots were raised by foliar sprays of 0.56, 1.12, 1.68, or 2.24 kg Cu /ha using Cu Keylate (5% Cu) (Stoller Enterprises, Inc). Ammonium sulfate was added to the solutions at 3.1 kg/ha to enhance Cu absorption. The treatments were applied in a volume of 628 L/ha. Since several growers were using a product called Micromate Calcium Fortified mix (Stoller Enterprises, Inc.) to supply secondary and micronutrients along with N and P through diammonium phosphate (DAP), it was included as an additional treatment at the rate used by the growers. Micromate is a homogeneous granule containing calcium (10%), magnesium (5%), sulfur (1%), boron (1%), iron (2%), manganese (1.5%), zinc (3%) and Cu (0.3%). Thus, a preemergent soil application of Micromate® Calcium Fortified Mix (Stoller Enterprises, Inc.) was applied at 14 kg/ha. The treatment plots received foliar sprays of Cu Keylate or the soil applied Micromate on June14, 2001. An untreated plot served as the control. Treatments were randomly assigned to treatment

plots in a randomized complete block design with 7 blocks. Composite leaf tissue samples from 50 stems were taken from each treatment plot on July 13, 2001, when the plants had stopped growing and exhibited tip dieback Trevett (1968). Leaf samples were prepared according to the methods of Kalra and Maynard (1991). Solution analysis was by plasma emission. Soil samples were taken after collecting leaf samples using a standard soil sample tube removing a 2 cm diameter core to a depth of 7.62 cm. Ten cores per treatment plot were combined and analyzed to determine pH (water) and nutrients. Stem samples from 4 randomly placed, 0.02 m^2 quadrats were collected November 6, 2001 for measurement of stem length, branching, and flower bud formation. Yield was determined August 9, 2002 by hand raking a strip 43 cm wide the length of each plot. Data were subjected to analysis of variance using the General Linear Model of SAS (Release 6.07, SAS Institute Inc., Cary N.C. 1992). Treatment effects were separated by Duncan's multiple range test at the 5% level or linear regression analysis.

2003 Study

Because 2001 leaf samples indicated that N and P were deficient and could have prevented a response to raising leaf Cu levels, the plots were maintained through another two-year cropping cycle. In 2003, the same treatments were reapplied in a split block design with Cu treatments as main plots with diammonium phosphate (DAP) applied as the sub plots to correct N and P deficiencies. The blocks were split, creating two 1.8 x 7.5 m plots. One half of each block received 448 kg DAP/ha on May 19, 2003. Cu Keyate was applied on June 17, 2003 at the rates used in 2001. Composite leaf tissue samples were taken July 22, 2003. Soil samples were taken July 29, 2003. Stem samples were collected from four 0.02m^2 quadrats per treatment plot on November 17 and 18, 2003 to determine growth characteristics and potential yield. Berry yield was taken on August 9, 2004.

Results

2001 Study

Leaf Nutrient Concentrations. Leaf N concentrations were below the standard (1.6%), ranging from 1.37 to 1.43 ppm and were not affected by any treatment. Leaf P concentrations ranged from 0.116 to 0.121 ppm, below the standard (0.125%), and were unaffected by treatments. Leaf Cu concentrations increased linearly with increasing Cu rate but Micromate at 0.05 kg Cu/ha did not affect leaf Cu concentration, compared to the control (Fig. 1). The leaf Cu concentration in the controls (3.7 ppm) indicated a deficiency. The lowest rate of Cu Keylate® (0.56 kg Cu/ha) raised the leaf Cu concentration to above the 7 ppm standard.

Soil pH and Cu concentration. The soil analysis indicated that the pH averaged 4.4 across all plots and the organic matter content (loss on ignition) averaged 9.9 %. Soil Cu concentration was not affected by any treatment and ranged from 0.041 ppm to 0.047 ppm.

Stem Characteristics. Stem density, average stem length and number of branches were not influenced by Cu treatments (Table 1). Branch length was not meaningfully affected by the Cu treatments (Table 1). Flower buds per stem and berry yield were not influenced by any treatment (Table 1).

2003 Study

Leaf Nutrient Concentrations. Foliar Cu sprays had no effect on leaf N or P concentrations (data not shown) but DAP increased both Leaf N and P concentrations (Fig. 2). The Cu treatments applied in 2003 raised leaf Cu concentrations but not to the levels observed in 2001 (Fig. 3). There was a linear increase in leaf Cu concentrations with increasing rate of foliar Cu application. The effect of DAP partially contributed to the lower leaf Cu concentrations, perhaps by stimulating more growth and larger leaves causing a dilution effect (Fig. 4). Across all Cu treatments, DAP lowered the leaf Cu concentration from 5.7 to 5.0 ppm, significant at the 1% level. A similar dilution effect was observed for iron and boron (data not shown).

Soil pH and Cu concentration. Soil pH was not affected by any of the Cu treatments but was lowered from 4.1 to 4.0 by the DAP**.** Treatments of 1.12 and 1.68 kg Cu/acre resulted in a slight increase in soil Cu concentrations of 0.1 ppm for both, compared to the control (0.07 ppm). The average soil P concentrations was 14.3 ppm in DAP treated plots compared to 12.8 for those not receiving DAP.

Stem Characteristics. Stem density, stem length, number or lengths of branches, flower buds per stem or yield were not meaningfully affected by foliar Cu treatments (Table 2). DAP did not affect the following characteristics of unbranched stems: density, length, and number of flower buds. DAP did, however, increase density, length, number of branches, and flower buds per stem of branched stems (Table3). Although DAP increased flower bud density the average yield for plots with or without DAP were about the same, 6,727 and 6,035 lbs/acre, respectively. Micromate provided insufficient amounts of Cu to raise leaf Cu concentrations above the levels found in the controls. In 2003, leaf N and P concentrations were raised by DAP at 448 kg/ha correcting the deficiency of these elements. Leaf Cu concentrations, however, were lower than in 2001 even though the same rates were applied and approached but did not reach the 7 ppm standard concentration. DAP application reduced the levels of leaf Cu in the plots receiving the foliar Cu applications and in the control plots. Cu treatments raised the leaf Cu concentrations in 2003 but did not affect growth or berry yield. Eck (1988) suggested that a deficiency would occur below 5 ppm for highbush and rabbiteye blueberry and gave a minimum of 5 to a maximum of 20 ppm as the standard range. No recommendations for Cu fertilization can be made to growers at this time; the 7 ppm standard appears to be too high and plants with concentrations of 4 ppm can produce high yields.

Acknowledgements

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Literature Cited

Kalra, Y. P. and D. Maynard. 1991. Methods manual for forest soil and plant analysis. For. Can., Northwest Reg., North. For. Cen., Edmonton, Alberta. Inf. Rep. Nor-X-319. pp 116.

Eck, P. 1988. Blueberry science. Rutgers University Press, New Brunswick, N.J.

Smagula, J. M. and S. Dunham. 1995. Diammonium phosphate corrects phosphorus deficiency in lowbush blueberry. Co-published simultaneously in Journal of Small Fruit & Viticulture 3:183-191. and in Blueberries: A Century of Research, Food Products Press, an imprint of The Haworth Press, Inc.

Smagula, J. M. and W. Litten. 2002. Correcting lowbush blueberry boron deficiency with soil or foliar application. Acta Horticulturae 574:363-372.

Smagula and Yarborough, 2006. The lowbush blueberry, p. 177-181. In: N.F. childers and P.M. Lyrene (ed.). Blueberries for growers, gardeners, promoters. Dr. Norman F. childers Horticultural Publications, Gainesville, Florida.

Smagula, J.M., W. Litten, and S. Dunham. 1999. Lowbush blueberry response to soil- or foliar-applied zinc fertilizers. HortScience 34:496.

Smagula, J. M., W. Litten, and K. Loennecker. 2004. Diammonium phosphate application date affects Vaccinium angustifolium Ait. nutrient uptake and yield. Small Fruits Review. 3:87-94.

Trevett. M. F., P.N. Carpenter, and R.E. Durgin. 1968. A discussion of the effects of mineral nutrient interactions on foliar diagnosis in lowbush blueberries. Maine Agr. Expt. Sta. Bul. 664:1-15.

Trevett, M. F. 1972. A second approximation of leaf analysis standards for lowbush blueberry. Research in the Life Sciences. Maine Agr. Expt. Sta. 19:15-16.

Yarborough, D.E. and J.M. Smagula. 1993. Fertilizing with nitrogen and phosphorus. Wild Blueberry Fact Sheet No. 225. University of Maine Cooperative Extension, Orono, ME.

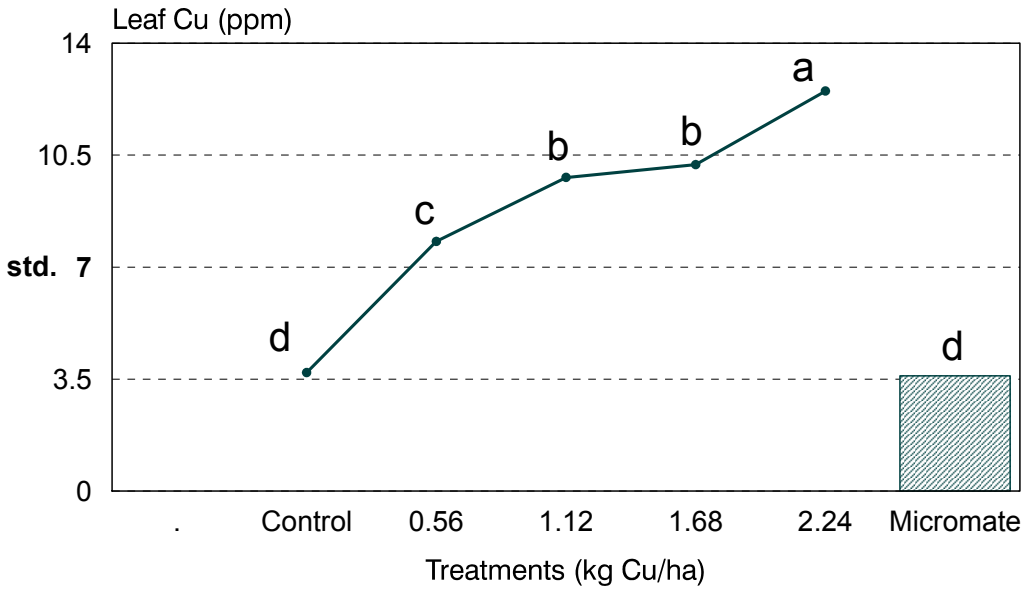

Figure 1. Effect of foliar Cu spray rates and Micromate (0.05 kg Cu/ha) on leaf Cu concentration of lowbush blueberry. Mean separation by Duncan's Multiple range test, 0.01% level. Significant linear increase in leaf Cu concentration with increasing foliar Cu rate, 0.01% level.

Table 1. Effect of 2001 foliar Cu treatments and Micromate on stem density, stem length, branching, flower bud formation and berry yield.

Treatment (kg Cu/ha)	Stem Density (stems/0.02m^2)	Stem length (cm)	Branches (no.)	Branch length (cm)	Flower buds/stem	Berry Yield (kg/ha)
0	19a[z]	10.03a	0.83a	5.85a	1.83a	4854a
0.56	21a	10.63a	1.10a	5.49ab	2.37a	4127a
1.12	18a	11.03a	0.75a	6.09a	1.83a	3974a
1.68	19a	10.33a	0.82a	6.52a	1.74a	4981a
2.24	18a	9.79a	1.15a	4.67b	2.05a	4296a
0.05 (Micromate)	19a	10.37a	1.02a	5.88a	2.80a	4337a

[z]Mean values with different letters are significantly different at the 5% level.

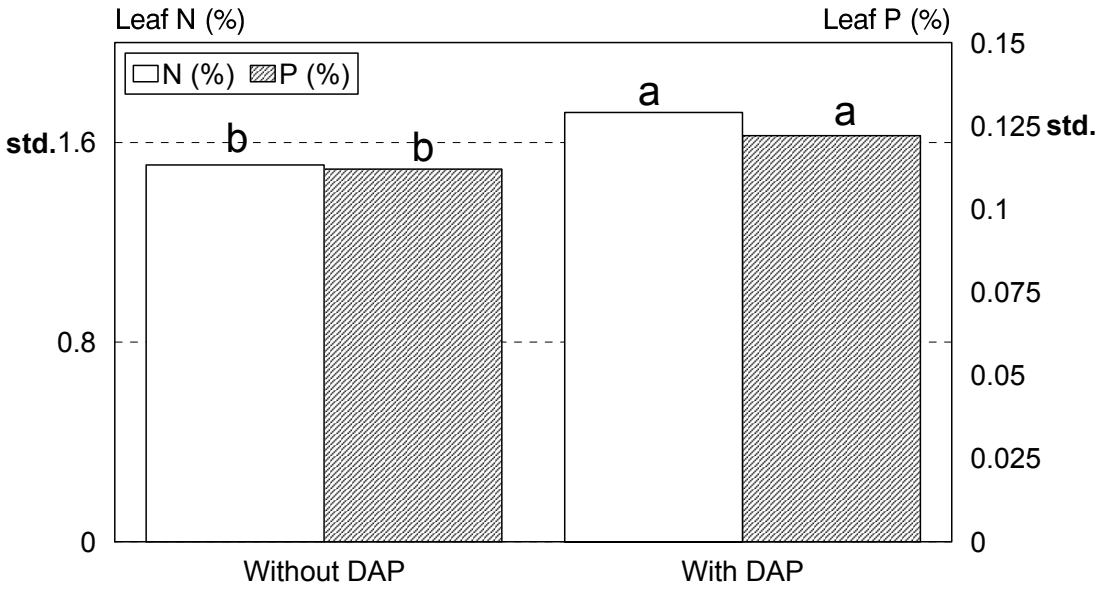

Figure 2. Effect of 2003 preemergent DAP application on leaf N and P concentrations averaged across all Cu treatments. Mean separation for N and P values by Duncan's Multiple range test, .01% level.

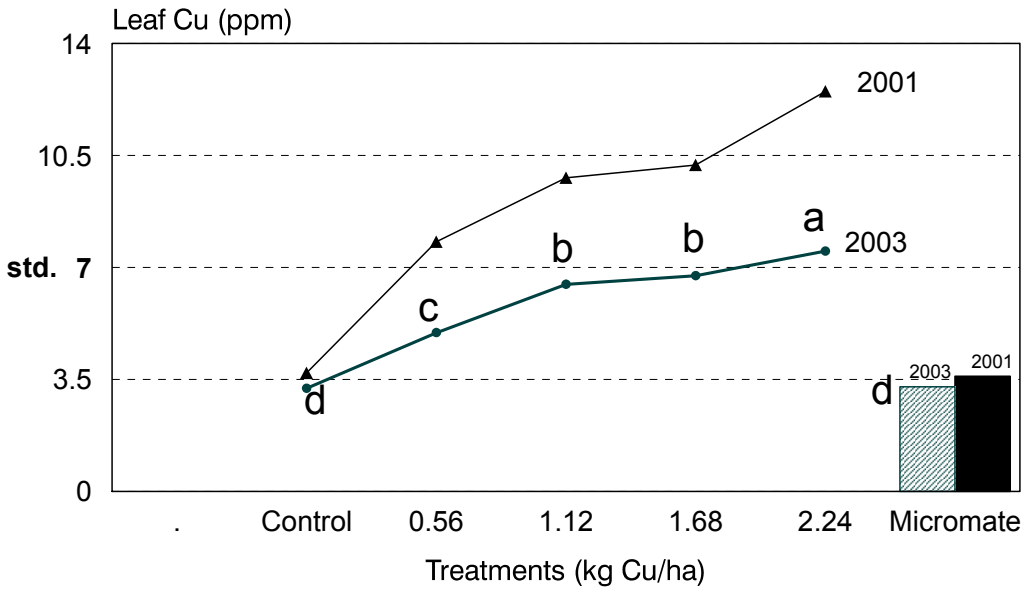

Figure 3. Effect of 2003 foliar Cu treatments and Micromate (0.05 kg Cu/ha) on leaf Cu concentrations, compared to 2001 leaf concentrations, averaged across DAP treatments. Mean separation by Duncan's Multiple range test, 0.1% level. Significant linear increase in 2003 leaf Cu concentration with increasing foliar Cu rate, 0.01% level.

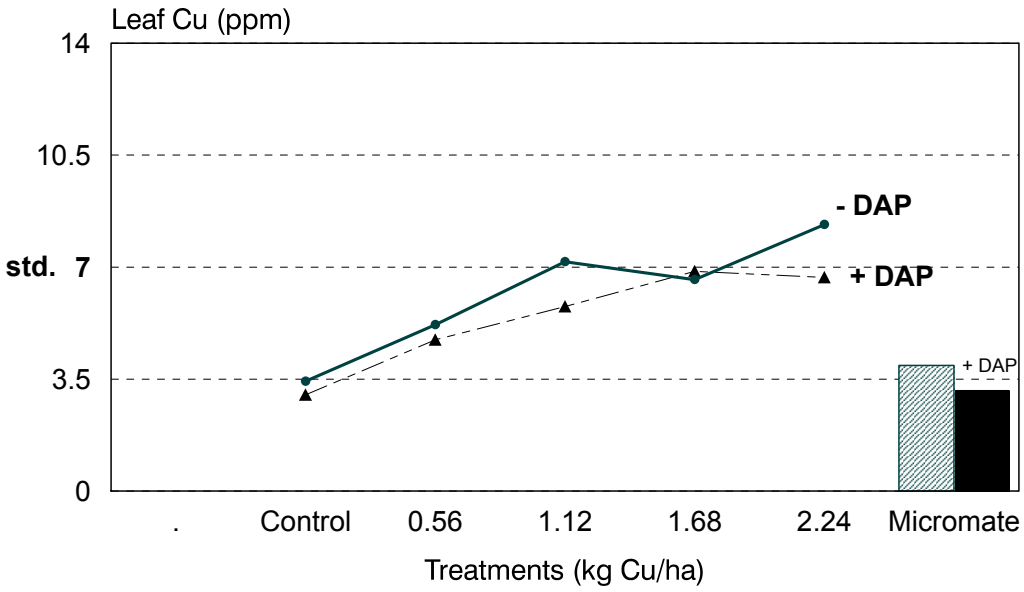

Figure 4. Depression of leaf Cu concentrations by DAP in plots receiving foliar Cu sprays or Micromate.

Table 2. Effect of 2003 Cu treatments on stem density, stem length, branching, flower bud formation and berry yield, averaged across DAP treatments.

Treatment (kg Cu/ha)	Stem Density (stems/0.02m^2)	Stem length (cm)	Branches (no.)	Branch length (cm)	Flower buds/stem	Berry Yield (kg/ha)
0	18a[z]	14.38a	2.27a	5.74a	4.47a	6968a
0.56	18a	13.31a	2.63a	5.44a	4.43a	7022a
1.12	15b	13.89a	2.50a	5.74a	4.49a	6242a
1.68	19a	13.82a	2.38a	5.92a	4.33a	8261a
2.24	17ab	13.49a	2.29a	5.21a	4.64a	7383a
0.05 (Micromate)	19a	14.25a	2.70a	5.41a	4.59a	7010a

[z]Mean values with different letters are significantly different at the 5% level.

Table 3. Effect of 2003 DAP treatment on characteristics of branched stems: density, stem length, branching, and flower bud formation, averaged across Cu treatments.

Treatment	Stem Density (stems/0.02m$^{2)}$	Stem length (cm)	Branches (no.)	Branch Length (cm)	Flower buds/stem
No DAP	4.97b[z]	13.64b	2.26b	5.56a	6.16b
DAP	6.71a	15.44a	2.66a	5.59a	7.48a

[z]Mean values within columns with different letters are significantly different at the 5% level.

Reducing Soil pH to Control Weeds in Wild Blueberries

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Introduction

Maintaining wild blueberry (*Vaccinium angustifolium*) production in Maine requires the control of a variety of grass, broadleaf, and woody weeds that reduce competition for light, nutrients and moisture. In recent years growers have become reliant on the few herbicides available. Weed shifts have been documented in wild blueberry fields indicating that weed species are adapting and there is evidence of several grasses developing resistance in wild blueberry fields in Nova Scotia (Jensen and Yarborough, 2004).

In the cranberry industry, research has been conducted to determine if lowering the soil pH can reduce the viability of some weed species. Soil pH can affect nutrient availability and therefore plant growth and development (Weaver and Hamill, 1985). Buchanan et al (1975) found that weed species vary in sensitivity to soil pH and suggested that the relative competitive ability of weeds may change with soil pH. Roper (1999) discussed how maintaining a proper soil pH would discourage the growth of some weeds in cranberry production. Patten (1996) reasoned that since some weed species occur within a limited soil pH range, soil acidification using sulfur could be a viable weed management practice in cranberry production. His work indicated the drawbacks of this approach are that the control of weeds could take years and acidification of soil is not permanent. Since wild blueberries grow in a low pH environment similar to cranberries, we decided to investigate whether lowering the soil pH of wild blueberry fields would reduce the competition from weeds. Patten (1996) also observed that when soil acidification was combined with herbicides, lower rates of herbicides could be used to control several weed species. With this in mind, we tested different rates of both the sulfur application and herbicide applications to determine if there was any interaction causing an overall reduction in weed cover.

Materials and Methods

During the period of 2000-2005, thirteen blocks were established in the non-cropping year (Table 1). One site in Whiting was discontinued and not used in the analysis. Each block has an area of 16.5 m x 22 m. Plots (5.5 x 22 m) within each block were treated with 0, 567, or 1134 kg/ha of sulfur as 80% sulfur pellets. When each block was in a non-cropping year, it was sprayed pre-emergence at a right angle to the sulfur treatments with 0, 0.5, 1, or 2 kg/ha of the herbicides Hexazinone (Velpar L) or Terbacil (Sinbar 80WP). Treatments were applied using a hand-held CO_2 propelled

boom sprayer. In August of non-cropping years, evaluation of blueberry cover, broadleaf, grass, and woody weeds were made using a Daubenmire cover class scale (Mueller-Dombois and Ellenburg, 1974). Data were transformed to percent cover and analyzed by the General Linear Model of SAS with significant means separated by a Duncans multiple range test (SAS 1995). Alpha value for significance equals 0.05 unless otherwise noted. Soil samples were taken every year on each sulfur treatment plot to determine the extent of the pH change.

Results

The response of soil pH levels to the application of sulfur varied by treatment and year. The ph level for the 0 kg/ha control ranged from 4.3 -5.2 in 2000 to 4.6 -5.1 in 2005. The pH level for the 567 kg/ha treatment (Figure 1) varied each year at each of the twelve sites. Eight sites had an initial decrease of 0.1 – 0.7 in the pH in the year following treatment, four others had no change in pH level. During the second year after sulfur application, six of the twelve sites increased in pH (0.1- 0.2), five decreased (0.1- 0.4) and one remained unchanged from the previous year's level. For the 2005 season, of the five sites initially treated in 2000, three had a lower ph (0.2-0.4), one was higher (0.1), and one was equal to the original pH. Of the four sites treated in 2001, three had lower ph levels (0.2-0.4) while one increased slightly (0.1) in 2005. Finally for the three sites treated in 2003, all three had lower pH levels (0.1-0.4) in 2005 than the original. Eleven of the twelve sites had a lower pH level after the first year of 1134 kg/ha treatment (Figure 2). The pH level decrease ranged from 0.1- 0.7. In the second year post-treatment, nine of twelve sites showed a 0.1-0.4 increase in pH from the previous year, while three showed a 0.1-0.4 decrease. In 2005, the five sites treated in 2000 had an increase in pH levels (0.1-0.5) compared to pretreatment pH. Of the four sites treated in 2001, two had a decrease in pH (0.2-0.7) and two had an increase in pH levels (0.2-0.4) in 2005. Finally, the three sites treated in 2003 had a decrease in pH of 0.2 to 0.9.

Grass, broadleaf and woody weed cover were significantly reduced by either the herbicide treatment or the sulfur treatment in several of the study years. When analyzed there was no difference between the effect of the two herbicides, Velpar and Sinbar, on the weed cover so results were combined. The herbicide treatment significantly reduced grasses in 2000, 2001, 2002 and 2004 (Figure 3). In 2000 and 2004, grasses in the all treated rates were significantly lower than the control. In 2001 the herbicide rate of 2 kg/ha had the lowest cover of grasses when alpha equals 0.10. Broadleaf weeds were significantly reduced by herbicide treatment in 2000, 2001, and 2003 (Figure 4). In 2000, 0.5 kg/ha and 2 kg/ha had the lowest cover of broadleaf weeds, while in 2001 all three treated plots had fewer weeds than the control. Woody weeds were affected by herbicide application in 2002 and 2003 (Figure 5). In both years the 2 kg/ha rate had the lowest woody weed cover. In 2004 and 2005 grass cover was reduced by the 1134 kg/ha sulfur rate, but in 2004 cover was also reduced by sulfur at the rate of 567 kg/ha (Figure 6). Though there was no statistical significance, broadleaf weed cover in plots treated with 1134 kg/ha sulfur was reduced when compared with the control during

years 2002-2005 (Figure 7). There were no significant interactions found between herbicide rate and sulfur treatment.

Discussion

Sulfur treatment reduced the pH but for some fields it took two years after treatment. The 1134 kg/ha sulfur rate reduced the pH more rapidly, resulted in the pH staying lower longer, and resulted in the greatest reduction of weed cover. The sulfur treatment decreased the competitive ability of both grasses and broadleaf weeds for several years. Although the herbicide treatments reduced weed cover, there was no significant interaction between the herbicide and sulfur treatment, though there was a greater decrease in weed cover when both were used. When comparing the pH levels three, four or five years after treatment, it appears that the pH is slowly rebounding back towards the original pH after four to five years. The difference in the rate of reduction and length of time the pH was reduced is related to differences in the organic matter and Cation Exchange Capacity. When wild blueberry producers use this technique, they will have to monitor the soil pH on their fields and retreat with sulfur every five years to maintain the lower pH levels.

Literature Cited

Buchanan, G. A., C.S. Hoveland and M. C. Harris 1975. Response of weeds to soil pH. Weed Sci. 23: 473-477.

Jensen K.I.N. and D.E. Yarborough 2004. An overview of weed management in the wild lowbush blueberry - past and present. Small Fruits Review 3(3/4): 229-255.

Mueller-Dombois, D. and H. Ellenburg 1974. Aims and methods of Vegetation Ecology. John Wiley and Sons, N.Y.

Patten, K.D. 1996. Weed management, herbicides and soil pH. Wisconsin Cranberry School Proceedings. Volume 7. Pp 23-29.

Roper, T.R. 1999. Principles of Weed Management. Wisconsin Cranberry School Proceedings. Volume 10. Pp 56-59.

SAS Institute, 1995. SAS Users Guide, Statistics. SAS Institute, Cary, NC

Weaver, S. E. and A.S. Hamill. 1985. Effects of soil pH on competitive ability and leaf nutrient content of corn (*Zea mays* L.) and three weed species.

Table 1. List of treatment blocks by year established and treated with herbicide.

Block	Year Established	Herbicide Used	Treated
Appleton	2000	Velpar	2000, 2002, 2004
West Rockport	2000	Velpar	2000, 2002, 2004
Wesley (A)	2000	Velpar	2000, 2002, 2004
Wesley (B)	2000	Sinbar	2000, 2002, 2004
Machiasport	2000	Velpar	2000, 2002, 2004
Whiting [1]	2000	Velpar	2000
Union	2001	Velpar	2001, 2003, 2005
Jonesboro	2001	Velpar	2001, 2003, 2005
Wesley (C)	2001	Velpar	2001, 2003, 2005
Wesley (D)	2001	Sinbar	2001, 2003, 2005
Eastbrook	2003	Velpar/Sinbar	2003[2]
Franklin	2003	Velpar/Sinbar	2003, 2005
Blue Hill	2003	Velpar/Sinbar	2003, 2005[3]

Note: [1] Whiting was discontinued in 2002, [2] Not treated in 2005 because of owner, [3] Owner treated whole site with 1 kg/ha Velpar.

Figure 1. The change in pH levels after one-time treatment of 567 kg/ha of sulfur pellets. Dotted line indicates general trend of pH change. A) Treated in 2000 B) Treated in 2001 C) Treated in 2003, - - - - indicates average.

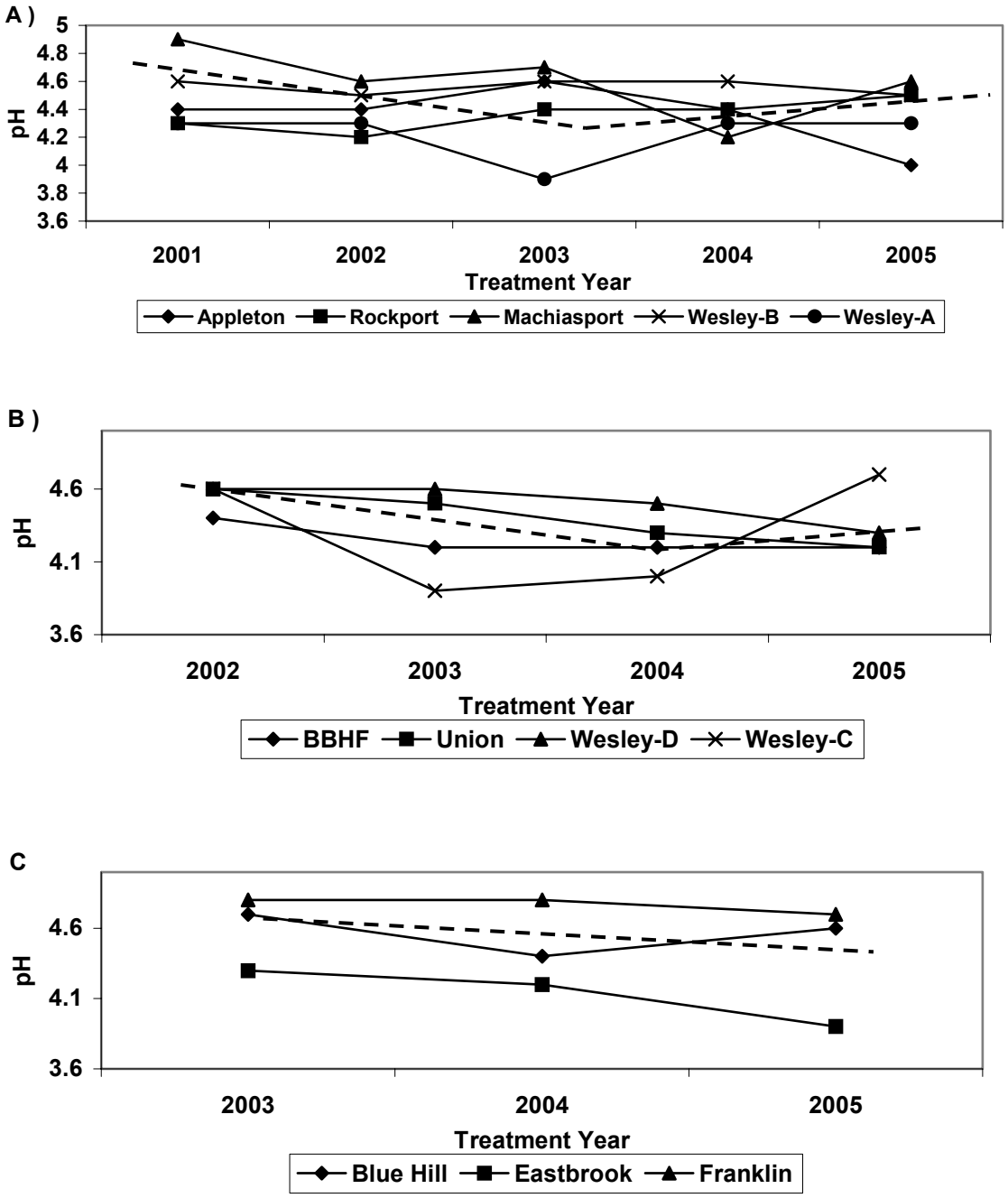
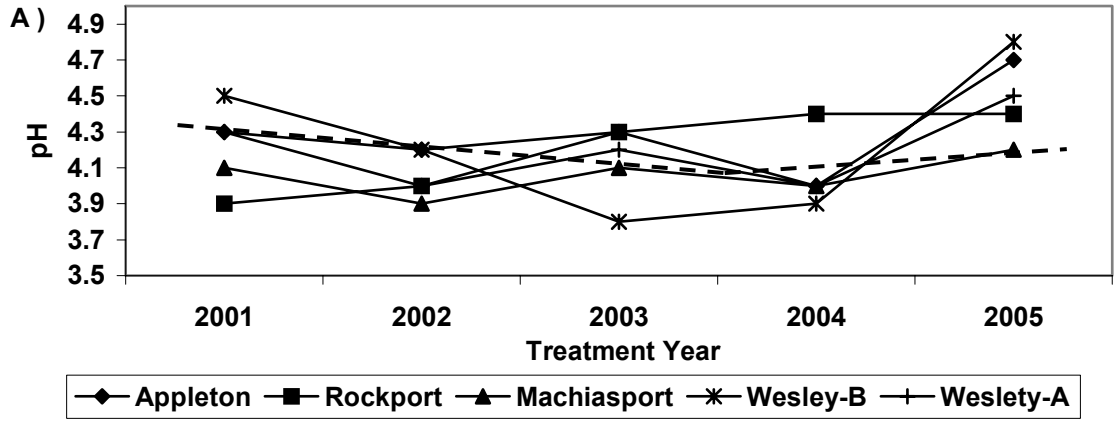
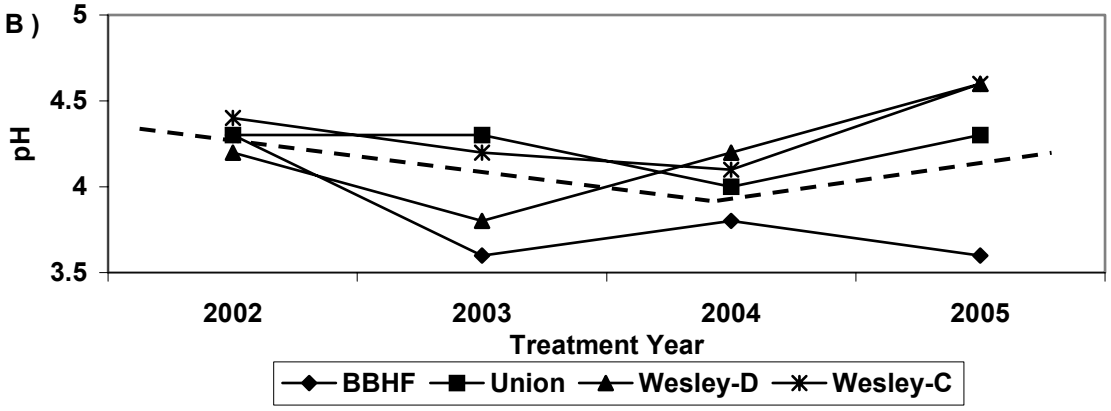


Figure 2. The change in pH levels after one-time treatment of 1134 kg/ha of sulfur pellets. Dotted line indicates general trend of pH change. A) Treated in 2000 B) Treated in 2001 C) Treated in 2003, - - - - indicates average.





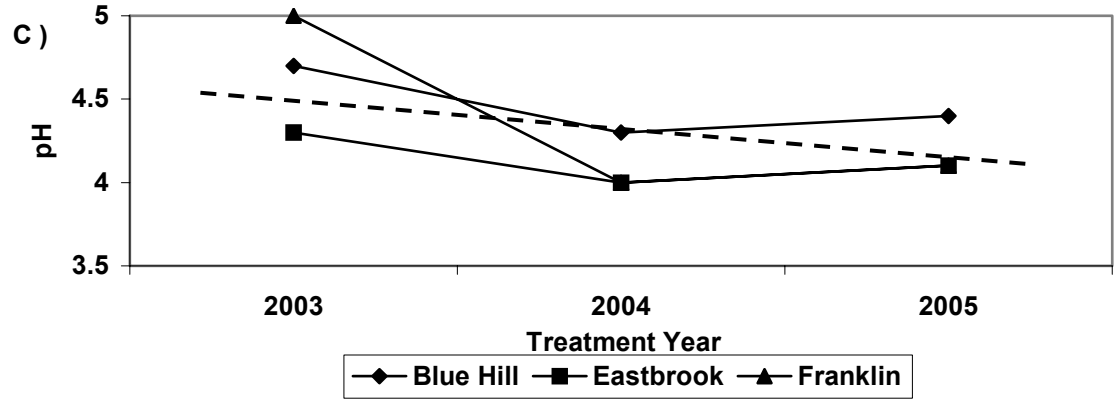


Figure 3. Average grass cover after herbicide treatment. Alpha = 0.05 except for results from 2001, when alpha = 0.10.

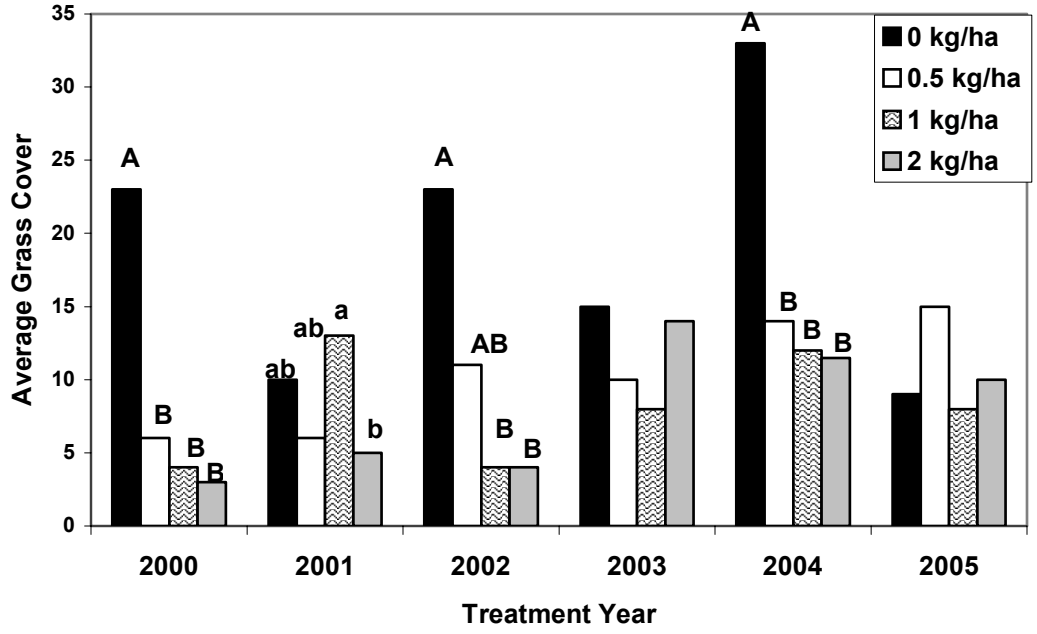


Figure 4. Average broadleaf weed cover after herbicide treatment.

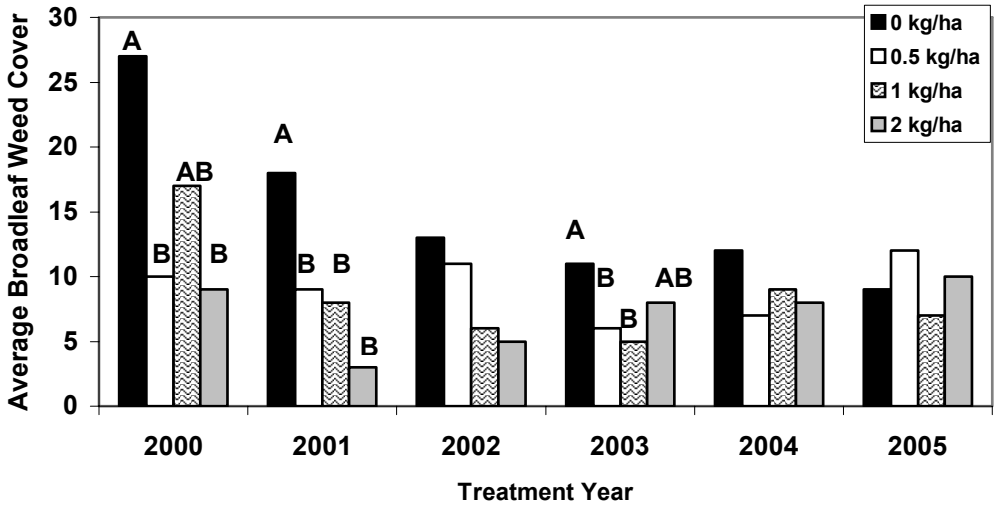


Figure 5. Average woody weed cover after herbicide treatment.

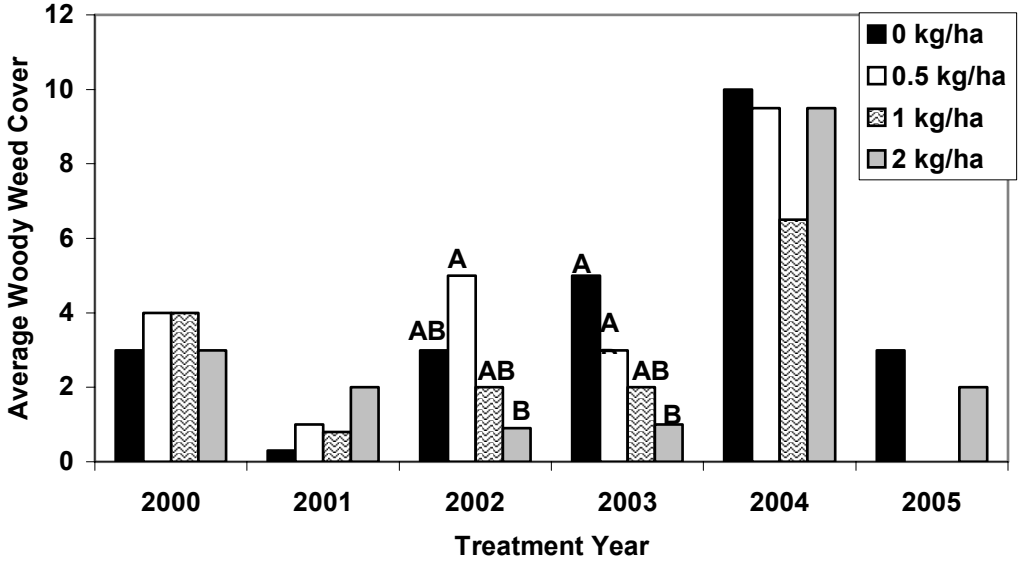


Figure 6. Average grass cover following treatment with sulfur.

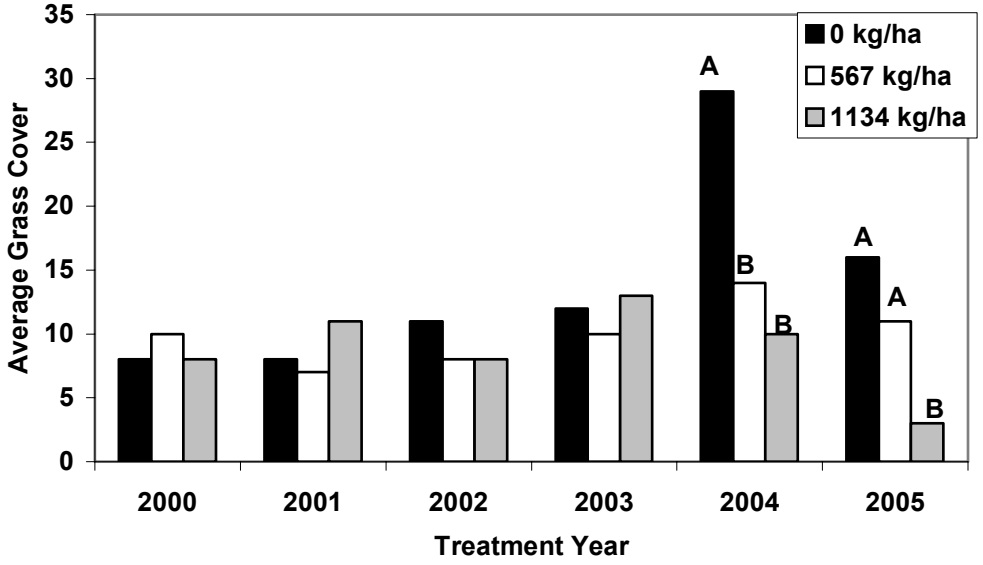
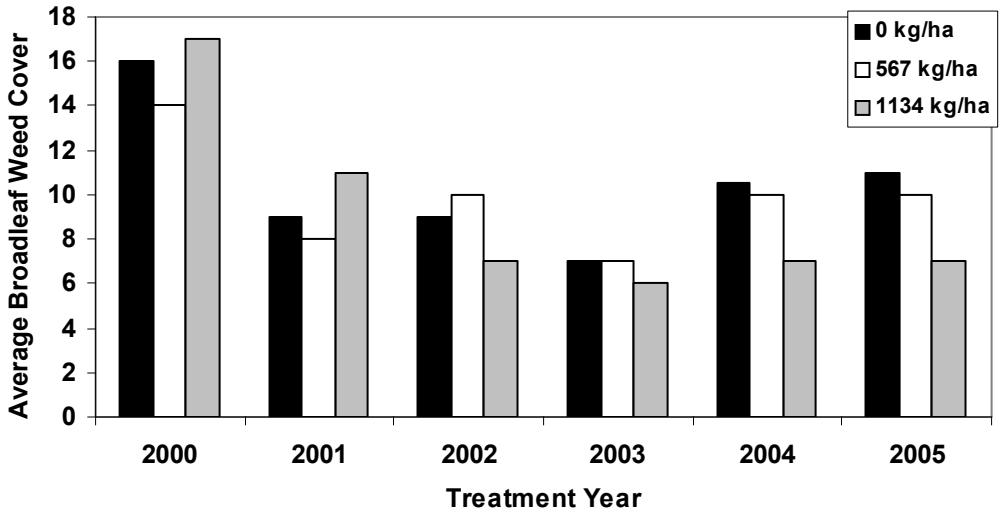


Figure 7. Average broadleaf weed cover following treatment with sulfur.



Parthenocarpic Fruit Development in Highbush Blueberry (*Vaccinium corymbosum* L.)

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Summary

During 2004 and 2005 we evaluated 20 and 41 half-sib populations, respectively, (comprised of >3000 individuals in total) segregating for the trait of parthenocarpic fruit production. Among these populations, approximately 80 parthenocarpic individuals were identified. In general, three categories of segregants have been observed: normal types, small/low seeded types, and parthenocarpic types. Initial evaluations suggest that the trait is recessive, but that it exhibits phenotypic dosage effects at the tetraploid level (e.g. small/low seeded types). The dosage effects are expected to allow easier recognition and manipulation of plants carrying higher frequencies of this allele. Crosses were made in 2005 between different classes to further investigate genetics and recovery of this trait, and to build breeding populations. The lesser vigor (in many cases) of parthenocarpic clones suggests that this material will be most useful, initially, for enhancing fruit development in heterozygous types, and in improving fruit quality by reducing seed development.

Introduction

Parthenocarpy in any fruit bearing crop is a very desirable trait because it holds the promise of freedom from pollination worries. In a cross-pollinated crop like blueberry, parthenocarpy could address at least three pollination concerns: 1) sub-optimal pollination weather during the bloom period, 2) declines of pollinators due to parasitic infections, and 3) cross-pollination versus self-pollination for optimum yield. Previously, a selection was identified by Rutgers University among USDA breeding materials that appeared to set fruit parthenocarpically. Preliminary studies suggested this trait was controlled by a single recessive gene and could be recovered in F_2 populations. This material, however, was in a poor phenotypic background and recovery in desirable clones was difficult. This study presents a detailed examination of the inheritance of this trait and an evaluation of its potential for development.

Materials and Methods

The original parthenocarpic variant (G-176) was discovered in a family of the pedigree G-105 x E-204. The female parent, G-105, was a cross of 11-93 (a 'Bluecrop' sibling) x 'Herbert'. The male parent, E-204, was a cross of E-7 ('Berkeley' x 'Earliblue') x F-72

('Wareham' x 'Pioneer'). Subsequently, G-176 was crossed to a diverse selection of clones including 'Bluetta', 'Chandler', G-172 (late ripening selection), G-303 (midseason ripening selection), G-850 (early selection), JU 62 (*V. myrsinites* x *V. angustifolium* selection), NC 2909 (*V. elliottii* derivative), 'Sunrise', 'Toro', and US 880 (*V. boreale* derivative). These families were planted to the field, and the best performing clones were selected and retained. Selected clones (based mainly on vigor) were entered into half-sib crosses and resulting progeny planted to the field. When the plants were 3 years old, they were evaluated for expression of parthenocarpy. For evaluation, each fruiting clone in a family had three fruit harvested. After initial evaluations, it was decided that three classes could be recognized: normal-seeded types, small-seeded/low seed number types (hereafter referred to as diminished-seed types), and parthenocarpic types. For evaluation, fruit was cut open equatorially and graded according to the listed categories. If a clone was found to be parthenocarpic, fruit from that clone and the clone on either side of it was recollected, and the observations rechecked to confirm the initial observation.

Results and Discussion

This character behaved as a recessive. All F_1 progeny had normal seed production and the trait segregated in F_1 x F_1 crosses. Families were evaluated under two alternative sets of assumptions: 1) that only seeded versus parthenocarpic types could be recognized and that seeded types were *P* – – – , and parthenocarpic types were *pppp*, and 2) that normal-seed, diminished-seed, and parthenocarpic types could be recognized and that normal-seed types were *PP* – – , diminished-seed types were *Pppp*, and parthenocarpic types were *pppp*. A simple recessive model with duplex (*PPpp*) F_1 parents fit the data most closely although there was considerable variation that we attributed to environmental interactions. The three phenotype model fit less well, but this may be due to subjective judgments needed to separate normal-seed and diminished-seed types. A duplex x simplex (*PPpp* x *Pppp*) model in the F_1 x F_1 generation was also evaluated. This provided a good fit for some families, but gave inconsistent results across families.

In 2004, among families with more than 105 individuals, the segregation ratios of seeded:parthenocarpic individuals ranged from 8 : 1 to 114 : 1 (7 families). The overall ratio across all families, regardless of family size was 22.8 : 1 (approximately 2100 individuals). If the "seeded" categories were subdivided into "normals" and "diminished-seed" types, the overall ratio between normal, diminished, and parthenocarpic types was 14.6 : 8.2 : 1 (compared to the expected ratio of 27 : 8 : 1). If segregation was averaged across the half-sib parents (i.e. combining crosses with a common parent), the ratios for seeded:parthenocarpic ranged from 8:1 to 162:1 (10 half-sib parents). Seven half-sib groupings had a surfeit of parthenocarpic types and 3 groupings had a deficit. In the limited number of backcrosses evaluated in 2004, the ratios for seeded:parthenocarpic progeny averaged 10:1 (2 families, 77 individuals), compared to the expected 5:1.

In the 2005 populations, there was only one family with more than 105 individuals; its ratio for seeded:parthenocarpic types was 28:1. The overall ratio across all families, regardless of family size was 5.5 : 1 (1279 individuals) (i.e. a relative surfeit of parthenocarpic types). If the seeded categories were subdivided into "normals" and "diminished-seed" types, the overall ratio between normal, diminished, and parthenocarpic types was 3.4 : 2.1 : 1 (compared to the expected ratio of 27:8:1). This ratio again represents a relative excess of parthenocarpic types. If segregation was averaged across common half-sib parents, ratios ranged from 2.4 : 1 to 34.5 : 1 (7 half-sib parents) (i.e. a relative surfeit of parthenocarpic types in every family). In the backcrosses evaluated in 2005, the ratios for seeded:parthenocarpic progeny averaged 6:1 (4 families, 86 individuals), compared to the expected 5:1.

This trait appears to be is influenced by environmental factors. Several parents were common to both years; these were US 1018 (G-850 x G-176), US 1019 (US 880 x G-176), and US 1020 (also US 880 x G-176). In half-sib groupings, these clones showed seeded to parthenocarpic ratios in 2004 and 2005, respectively, of: 13.7 & 34.5 (US 1018), 10.3 & 9.7 (US 1019), and 25.0 & 27.6 (US 1020). Thus US 1018 varied widely between years, while the other two selections varied to a lesser degree. The other likely environmental influence observed is the overall relative surfeit of parthenocarpic types in 2005, a year in which normal pollination was judged to be less than optimal.

Although the dosage effect model fit the data only moderately well, if it ultimately proves correct, the dosage effects should allow easier recognition and manipulation of plants carrying higher frequencies of this allele. Crosses were made in 2005 of diminished-seed types to standard cultivars, to other diminished-seed types, and to parthenocarpic types to further investigate genetics and recovery of this trait and to further build breeding populations. These crosses should provide a further test of this model.

Conclusion

Although segregating selections exhibit true parthenocarpy, the conditions necessary to fully trigger a widespread expression of this trait in all buds, yielding an economically competitive parthenocarpic crop are less clear (i.e. in many cases, the total set and yield was far below what might be expected if parthenocarpy were to live up to its maximum possibilities). The reduced yield of parthenocarpic clones suggests that this material may be most useful, initially, in the presumably heterozygous diminished-seed types. In this state it appears to enhance fruit development and reduce seed development, (higher pulp to seed ratios) and may allow more fruit development with minimal pollination. It should also improve fruit quality by reducing overall seed development.

Blueberry Production Increasing in Clinch County

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Situation

Clinch County is one of the largest blueberry producing counties in the state of Georgia. The introduction of a new packing, handling and shipping facility in Homerville, plus low timber prices, available high productive blueberry soils, and good blueberry prices have led to rapidly expanding acres of newly planted blueberries. Clinch county blueberry growers need different production educational programming. New growers need programs on beginning blueberry production. Experienced commercial growers need research, field trials, and grower production meetings to help them increase production and make them more efficient producers.

Extension Response

Clinch/Lanier County Agent's initial contact is one-on-one to discuss site location and take soil samples (pH and organic matter) since blueberry varieties are very site and soil specific.

Extension educational programs for new growers included field preparation, weed control, plant varieties, irrigation and equipment needs for blueberry production.

The experienced commercial producers blueberry education programs and Extension conducted in-field research demonstrations included weed control in replanted blueberries, improved methods of replanting blueberries in established fields, air blast sprayer calibration, nursery plant propagation, pruning and mechanical harvesting of Southern Highbush and Rabbiteye blueberries.

Missing or dead blueberry bushes in fields have caused reduced yields; however, replanting has been difficult due to weeds, herbicide damage, drought and poorly drained soils. Extension conducted research trials using different treatments on improved methods of replanting blueberries.

County Agent, University of Georgia Extension Horticulture Specialist, and USDA-ARS, Appalachian Fruit Research Station, Kearneysville, WV, are researching

mechanical harvesting needs to keep fruit quality high and reduce the labor cost of hand harvesting blueberries. This research is ongoing.

Impact

Extension conducted blueberry production meetings were attended by 90% of the new and experienced commercial growers. County Extension agent worked with 18 first time blueberry growers and trained 21 new private pesticide applicators. These new producers have planted 520 acres of blueberries since 2002. Experienced growers have expanded production by 580 acres. Blueberry weed control replanting trial plots were viewed on the weed control farm tour by 25 producers. Replant trials show landscape fabric as most practical and economical mulch. These additional plantings of blueberries have the potential to double the farm gate value of blueberries in Clinch County from $8 million to $16 million by 2009.

Improved Methods of Replanting Blueberries in Established Fields

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Introduction

Georgia has blueberry yields well below the national average. This is due in part to early season cultivars, freeze damage, insect and disease problems. However, a very significant part of the problem is missing bushes in the fields. Rabbiteyes have the potential to live for 50 years or more, but due to poor drainage and problems during establishment it is common to have 10-30% missing bushes after 10-15 years. Usually

the drainage problems are corrected over time, but grower replanting has been very limited due to weed and herbicide problems. Landscape fabric is a woven plastic cloth, which allows water and fertilizer to pass through, but prevents most weed growth. Some years ago, the cost was about 10 cents per square foot, rather expensive for use in blueberry fields, since a 3 by 4 foot swatch would cost $1.20. In 2003 a local manufacturer of landscape fabric was located, Geotextiles, Enigma, Ga. which manufactures and sells landscape fabric for about $.03 per square foot or $.35 for a 3 by 4 foot swatch. This discovery made use of landscape fabric feasible.

In 2004 we conducted extensive experiments in Clinch and Appling Counties, Ga. testing two plant sizes (rooted cuttings and 1 gallon plants) and many replant aids such as control released fertilizer, soil amendments and various mulches alone and in combination. On gallon size plants, landscape fabric, peat moss and controlled release fertilizer appeared to be most beneficial in replant establishment. In 2005 we proposed to test the best treatments on three sites of varying types in south Georgia.

Materials and Methods

Three farms with variable conditions were selected for the 2005 field research trials. 1. A moist, weedy site with drip irrigation, 2. A predominately dry site with moderately heavy weed press and a poor drip irrigation system in that part of the farm, 3. A non-irrigated farm with good soil, but almost weed-free from extensive diuron (Karmex) use. Experimental design was a randomized complete block with four replications of four plants per treatment per replication with the following treatments:

1. Control, no amendments
2. Landscape fabric, 3 feet by 4 feet wide, held down with pins.
3. Landscape fabric plus controlled release fertilizer in the planting hole.
4. Landscape fabric plus one gallon of wet peat
5. Landscape fabric plus controlled release fertilizer in the planting hole, plus one gallon of wet peat moss mixed in the planting hole.

Landscape fabric was purchased from GeoTextiles, Enigma, Ga. at a cost of $.35 per yard, three feet wide. It was cut into three by four foot squares, an X cut in the center and held in place with four landscape fabric pins (A.M. Leonard, Pica, OH). Treatments three and five had the addition of one gallon of wet Canadian peat moss mixed in the planting hole a rate of about 50/50 peat and soil. Degree of mixing varied with the worker. Treatment five had the addition of one tablespoon of Osmocote 17-6-12. One half was placed in the bottom of the planting hole and one half mixed with the backfill soil. One gallon size ‘Brightwell’ plants where used in the experiment. All plants were pruned to about one foot in height with a gasoline hedger. Plants where transplanted in early to mid March. Growers provided any additional fertilizer or weed control during the course of the summer. The season was very rainy until late summer and then very dry. In late September plants were measured. Measurements taken were height, width in row, width across row and survival.

Results and Discussion

Landscape fabric pinned down with four pins stayed in place on all sites despite tropical storm Dennis. On site 1 and 2 (see Table 1), with heavy weed pressure, the landscape fabric treatments provided very noticeable weed reduction in the immediate area around the plant. However, on site 1 crabgrass overgrew the landscape fabric late in the summer. On site 1 the height of plants in the landscape fabric only treatment was less than the control. There is not an obvious explanation for this anomaly. On site 1, landscape fabric plus slow release fertilizer had a significantly greater width in row, width across row and growth index than the control. On site 2, landscape fabric plus fertilizer had a significantly greater width in row than the control. On site 1, landscape fabric plus peat had a significantly greater width across row than the control. However, all other measurements were not significant due to variation. Except for one treatment in one replication, there was a trend for treatments containing landscape fabric to produce the largest plants. Also, except for one treatment in one replication, there was a trend for plant survival to be greater with landscape fabric treatments. The addition of peat and slow release fertilizer to the landscape fabric treatment did not consistently increase growth more than just the landscape fabric. Most plants received supplemental fertilization from the growers in the course of routine fertilization.

Conclusion

Landscape fabric may be beneficial for increasing the survival and growth of blueberry replants in mature field sites. Weed control, in close proximity to the plant, was improved through the use of landscape fabric on sites 1 and 2 which were known to have high weed populations. Growth measurements were significantly greater in treatments where landscape fabric was used in combination with either peat moss or slow-release fertilizer amendments. With the exception of one treatment in replication, there was a trend for landscape fabric alone to increase growth performance of replants.

Table 1. Effect of planting treatments on survival and growth of 'Brightwell' replants

Site	Treatment	Height (cm)	Width in row (cm)	Width across row (cm)	Growth index (cm)	Survival (%)
1. Moist, weedy	Control	41.8 a[z]	22.3 b	19.9 c	28.2 bc	81.3 a
	Landscape fabric	29.7 b	21.4 b	22.4 bc	24.5 c	100.0 a
	Landscape fabric & peat	44.8 a	26.5 ab	28.4 ab	33.2 ab	100.0 a
	Landscape fabric & slow release fertilizer	46.6 a	29.8 a	35.6 a	37.3 a	93.8 a
	Landscape fabric & peat & slow release fertilizer	40.8 ab	23.0 ab	27.9 abc	30.6 abc	86.5 a
2. Dry, weedy	Control	28.4 a	15.6 b	20.6 a	21.4 a	55.0 a
	Landscape fabric	37.2 a	27.5 ab	30.8 a	31.7 a	52.2 a
	Landscape fabric & peat	34.4 a	24.5 ab	28.1 a	29.0 a	78.7 a
	Landscape fabric & fertilizer	32.3 a	28.7 a	32.8 a	31.3 a	70.0 a
	Landscape fabric & peat & fertilizer	33.0 a	25.9 ab	29.7 a	29.5 a	65.0 a
3. Weed free, diuron program	Control	41.8 a	42.0 a	38.2 a	40.8 a	56.3 a
	Landscape fabric	52.1 a	43.2 a	45.6 a	46.8 a	75.0 a
	Landscape fabric & peat	45.7 a	51.3 a	51.7 a	49.7 a	68.8 a
	Landscape fabric & fertilizer	40.5 a	44.2 a	45.4 a	43.4 a	75.0 a
	Landscape fabric & peat & fertilizer	46.0 a	52.5 a	49.0 a	49.2 a	81.3 a

[z] = Means with the same letter in a column are not significantly different ($P \geq 0.05$) according to the DIFF option in PROC MIXED (SAS,2000) with Satterthwaite option on the model statement

Phytotoxicity of CPPU on Southern Highbush Blueberry in North Carolina

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Introduction

The plant growth regulator CPPU (also known as KT-30, ABG-3207, forchlorfenuron or N-(2-chloro-4-pyridynil)-N'-phenylurea) (Salzman, 2004) has been reported to improve fruit size and fruit set in rabbiteye blueberry (*Vaccinium ashei*) cultivars 'Tifblue' and 'Climax' when applied 10 to 18 days after 50% bloom (Nesmith and Adair, 2004). This study was conducted to determine whether similar results could be obtained with two specific southern highbush blueberry (*Vaccinium corymbosum*) cultivars grown in North Carolina.

Materials and Methods

Experiments were conducted in 2004 on mature (10- to 12-yr-old) bushes planted on a 4×10 ft spacing at the Horticultural Crops Research Station in Castle Hayne, NC. Plots consisted of three adjacent bushes in the same row. Randomized complete block designs were used with four replications. CPPU was applied at 15 ppm using a CO_2-powered backpack sprayer delivering the equivalent of 50 gal/A at approximately 40 psi, with a single hollow cone nozzle. A non-ionic surfactant (ABG-7011, 0.1% conc.) was used. The spray application was made 14 days after 50% bloom (17 April) on the cultivar Bladen. On the cultivar Pender, CPPU was applied at 15 ppm in three separate spray timing treatments, at 7, 13 and 20 days after 50% bloom, respectively. Dates of application on 'Pender' treatments were 17, 23 and 30 April.

Ripe berries were harvested every seven days from the center bush in each plot; 'Bladen' was completely harvested in two weeks, 'Pender' in three weeks. Total yield at each harvest, and berry weight (wt of 100) was recorded. Following harvest, all buckets were coded for anonymity of treatments, and berries were hand-sorted based on visible symptoms of injury. Where observed, injury to berries was recorded and photographed.

Results

Bladen. Significant harvest × treatment effects were observed, due to yield loss caused by crop injury (Table 1). Berry size appeared to be slightly reduced, but effects were not statistically significant. The number of berries per bush was severely reduced at the

first harvest on 24 May, and somewhat reduced at the second harvest on 1 June. Some injury was observed on leaf shoots and flowers of the treated bushes (data not recorded).

Pender. Effects on 'Pender' were mostly beneficial. Some injury attributed to the CPPU + surfactant treatment was observed on leaf shoots, flowers and fruit, but damage was so slight that effects could not be separated from injury by freeze or other causes (data not shown). Significant yield increases occurred with applications made 7 d and 20 d after 50% bloom. Yield increases are attributed to increased set, since berry size was unaffected (data not shown).

Discussion

Both positive and negative effects were seen from CPPU applications, depending on the cultivar tested. 'Bladen' showed reduced yields and injury, while two of three CPPU treatments on 'Pender' gave increased yields and little or no injury. The surfactant was not tested separately for phytotoxicity, but may have contributed to the injury; other surfactants have been reported to cause damage on blueberry (Cline and Oudemans, 2002).

Literature cited

Cline, W. O. and Oudemans, P. V. 2002. Diagnosis and description of widespread surfactant injury on blueberries in North Carolina. Acta Horticulturae 574:95-100.

Nesmith, D. S. and Adair, H. M. 2004. Rabbiteye blueberry field trials with the growth regulator CPPU. Small Fruits Review 3:183-191.

Salzman, F. P. 2004. CPPU (KT-30): Magnitude of the Residue on blueberry. IR-4 National Pesticide Clearance Protocol.

Table 1. Effect of CPPU + surfactant applied 14 days after bloom, on yield, phytotoxicity, time of ripening and berry weight. Cultivar 'Bladen', 2004 (N=4).

Treatment	Average yield per bush (g)[x]	Harvest date	Berries with visible injury (%)[y]	Total weight of ripe fruit per bush (g)[y]	Individual berry weight (g)[y]
Untreated Control	1602.5 a	24 May	4.2 ± 2.6	1628 ± 519	1.07 ± .10
		1 June	2.5 ± 1.7	1577 ± 528	1.10 ± .07
CPPU (15 ppm) + surfactant	853.5 b	24 May	69.8 ± 12.4	580 ± 395	1.05 ± .09
		1 June	42.8 ± 9.9	1127 ± 144	1.00 ± .07

[x] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD (*P*=0.05).
[y] Values are means ± standard deviation.

Table 2. Effect of application timing (15 ppm CPPU + surfactant) on yield, time of ripening and berry weight. Cultivar 'Pender', 2004 (N=4).

Application date	Days past 50% bloom	Yield (g/bush)			
		Harvest # 1 1 June 04	Harvest # 2 7 June 04	Harvest # 3 14 June 04	Average at each harvest
17 April 04	7	1421 a	974 a	534 ab	976 a
23 April 04	13	1289 a	679 ab	321 bc	763 b
30 April 04	20	1456 a	1048 a	628 a	1044 a
Untreated Check	--	1438 a	544 b	219 c	783 b

[x] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD (*P*=0.05).

Evaluation of Herbicides for Yellow and Purple Nutsedge (*Cyperus esculentus* and *C. rotundus*) and Annual Sedges Control (*Cyperus spp.*) in Young Blueberry Fields.

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Introduction

Acreage of blueberries, both rabbiteye (*Vaccinium ashei*) and southern highbush (*Vaccinium corymbosum*), have been on the increase in the Southeastern United States. When new blueberry fields are planted the most critical period for weed control is during the first two years of establishment. During this establishment period, many growers throughout the southeast experience heavy infestations of yellow and purple nutsedge (*Cyperus esculentus* and *C. rotundus*), and annual sedges (*Cyperus spp*.). At present, there are no herbicides labeled for selective postemergent sedge control during this establishment period. There are, however, several postemergent herbicides that are known to be safe to plants in the blueberry family (Ericaeae) that control sedges (e.g. halosulfuron and sulfentrazone). The goal of this study was to evaluate the safety of both halosulfuron and sulfentrazone on highbush and rabbiteye blueberries.

Materials and Methods

Georgia Sites: In Georgia, three sites were chosen for the testing. Site #1 and #2 were located in Alma, Georgia. At site #1, the southern highbush blueberries (*Vaccinium corymbosum* 'Star') were approximately 2 year old, and over-the-top applications were applied on June 23, 2005. At site #2 the rabbiteye blueberries (*Vaccinium ashei* 'Brightwell' and 'Powderblue') were approximately 1 year old and had been established for less than 6 months. Over-the-top applications to site #2 were also applied on June 23, 2005. Site #3 was located in Griffin, Georgia, liners of southern highbush blueberries (*Vaccinium corymbosum* 'Millennium', *Vaccinium c.* 'O'Neal', *Vaccinium c.* 'Windsor') were transplanted into 1 gallon nursery pots allowed to grow for approximately 2 month. Over-the-top applications were applied May 13, 2005. Treatments applied at all 3 locations were identical, and consisted of the following:

Treatment #	Treatment	Formulation	Formulation Rate
1	Spartan	75 DF	3.0 oz/A
2	Spartan	75 DF	6.0 oz/A
3	Spartan	75 DF	12.0 oz/A
4	Spartan	75 DF	24.0 oz/A
5	Spartan	4 L	3.0 oz/A
6	Spartan	4 L	6.0 oz/A
7	Spartan	4 L	12.0 oz/A
8	Spartan	4 L	24.0 oz/A
9	Sandea	75 DF	0.5 oz/A
10	Sandea	75 DF	1.0 oz/A
11	Sandea	75 DF	2.0 oz/A
12	Sandea	75 DF	4.0 oz/A
13	Control		

All sprays solutions contained the surfactant Dynamic applied at a rate of 0.25% solution volume to volume. Dynamic is 100% active propriety blend of polyalkyleneoxide modified polydimethylsiloxane, polyoxypropylene-polyoxyethylene block copolymer, and methylated vegetable oils. In both field studies, plot size was approximately 6 x 12, and contained 3 plants per treatment. Test was applied as a randomized complete block with 4 replications. Applications of the containerized tests were done as follows: seventy-two one gallon pots of each species were placed in a 6 ft. x 6 ft. area. Herbicide treatments were then applied, and pots were moved to assigned test area where they were arranged in a randomized complete block (RCB) design. All treatments were applied with a CO^2 backpack sprayer equipped with 8002 flat fan spray tips. Sprayer was calibrated to deliver 20 gallons per acre (GPA).

Results and Conclusion

At site #1 and 2, data was taken at 2, 4, 8, and 16 weeks after treatment (WAT), and at site #3 data was taken at 1, 2, 3, 4, 8, 11, and 21 WAT. Blueberry injury was taken on a (0-100 scale) and numbers represented the following:

Value	Plant Symptoms
0	No visual injury present
10-30	Minimal injury to desirable plant. Less than 10% of the plant leaf service area showing chlorosis and necrosis.
40-70	More noticeable plant injury or stunting. Greater than 50% of the leaf area showing symptoms of chlorosis and/or necrosis.
80-90	Plants severally injured. Most of the leaves and leaf surface showing signs of chlorosis and necrosis.
100	Plant appears dead. No signs of regrowth.

At site #1, significant injury to highbush blueberry 'Star' was only seen at 8 and 16 WAT. The highest recorded injury was 33% with the 4.0 oz rate of Sandea (Table 1). At site #2, injury ratings of rabbiteye blueberry 'Brightwell' and 'Powderblue'did not exceed 29%, and significant injury followed no pattern (Table 2 and 3). At site #3, highbush blueberry 'Millennium' was significantly damaged by all Sandea treatments at 8, 11 and 21 WAT (Table 4). The 4L formulation of Spartan caused significant damage to Millennium at early rating periods, but injury had dissipated to non-significant levels by 21 WAT. O'Neal was significantly damaged by all Sandea treatments at 8 and 21 WAT (Table 5). Spartan injury to O'Neal was significant only at 3 WAT, but did not exceed 23%, dissipated to non-significant levels by 21 WAT. Injury ratings to Windsor blueberries were significant with all the Sandea treatments at 8 and 21 WAT (Table 6). Although significant injury occurred with Spartan throughout the ratings of Windsor blueberries did not exceed 10% during any of the rating periods.

Injury to blueberry varieties occurred with both Spartan and Sandea. It also appears that blueberries express varietal sensitivity to Spartan and Sandea. In general Spartan damage was minimal and tended to dissipate as rating continued. Injury with the liquid formulation of Spartan tended to be worse than the dry flowable formulation. Injury with Sandea was unacceptable in the blueberry container test (site #3), but did not exceed 26% in any of the field trials (sites #1 and 2). More field testing needs to be performed to determine if Sandea could be used as an over-the-top spray or as a post directed spray on young plants.

Table 1. Highbush blueberry injury (*Vaccinium corymbosum* 'Star') injury at site #1 (Alma, Georgia) 2005.

Treatment No.	Treatment	Formulation Rate	Injury to Highbush (*Vaccinium corymbosum* 'Star')			
			2 WAT	4 WAT	8 WAT	16 WAT
1	Spartan 75 DF	3.0 oz/A	8 a	5 a	5 cd	13 def
2	Spartan 75 DF	6.0 oz/A	5 a	5 a	5 cd	13 def
3	Spartan 75 DF	12.0 oz/A	13 a	5 a	5 cd	10 ef
4	Spartan 75 DF	24.0 oz/A	14 a	5 a	5 cd	23 bc
5	Spartan 4 L	3.0 oz/A	14 a	5 a	5 cd	10 ef
6	Spartan 4 L	6.0 oz/A	8 a	5 a	5 cd	8 fg
7	Spartan 4 L	12.0 oz/A	6 a	5 a	8 bc	18 cde
8	Spartan 4 L	24.0 oz/A	14 a	5 a	6 bc	20 bcd
9	Sandea 75 DF	0.5 oz/A	6 a	5 a	6 bc	18 cde
10	Sandea 75 DF	1.0 oz/A	4 a	5 a	3 de	15 c-f
11	Sandea 75 DF	2.0 oz/A	8 a	5 a	9 b	28 ab
12	Sandea 75 DF	4.0 oz/A	5 a	5 a	14 a	33 a
13	Control		0 a	0 b	0 e	0 g
LSD			8.8	0.0	3.2	10.3

Table 2. Rabbiteye blueberry injury (*Vaccinium ashei* 'Brightwell') at site #2 (Alma, Georgia) 2005.

Treatment No.	Treatment	Formulation Rate	Injury to Rabbiteye (*Vaccinium ashei* 'Brightwell')			
			2 WAT	4 WAT	8 WAT	16 WAT
1	Spartan 75 DF	3.0 oz/A	18 a-d	26 a-d	9 a	10 bc
2	Spartan 75 DF	6.0 oz/A	9 cde	14 de	8 a	23 abc
3	Spartan 75 DF	12.0 oz/A	31 a	20 a-d	14 a	25 ab
4	Spartan 75 DF	24.0 oz/A	23 abc	25 a-d	11 a	10 bc
5	Spartan 4 L	3.0 oz/A	13 b-e	15 cde	14 a	28 ab
6	Spartan 4 L	6.0 oz/A	13 b-e	18 bcd	10 a	18 abc
7	Spartan 4 L	12.0 oz/A	20 a-d	28 abc	14 a	15 abc
8	Spartan 4 L	24.0 oz/A	26 ab	23 a-d	9 a	15 abc
9	Sandea 75 DF	0.5 oz/A	9 cde	30 ab	10 a	25 ab
10	Sandea 75 DF	1.0 oz/A	8 de	28 abc	10 a	20 abc
11	Sandea 75 DF	2.0 oz/A	6 de	18 bcd	8 a	38 a
12	Sandea 75 DF	4.0 oz/A	9 cde	33 a	11 a	15 abc
13	Control		0 e	3 e	3 a	0 c
LSD			14.5	13.4	9.4	23.4

Table 3. Rabbiteye blueberry injury (*Vaccinium ashei* 'Powderblue') at site #2 (Alma, Georgia) 2005.

Treatment No.	Treatment	Formulation Rate	Injury to Rabbiteye (*Vaccinium ashei* 'Powderblue')			
			2 WAT	4 WAT	8 WAT	16 WAT
1	Spartan 75 DF	3.0 oz/A	8 cde	11 bc	14 abc	29 a
2	Spartan 75 DF	6.0 oz/A	11 cde	5 bc	10 bc	29 a
3	Spartan 75 DF	12.0 oz/A	24 b	8 bc	8 bc	15 ab
4	Spartan 75 DF	24.0 oz/A	18 bc	15 ab	15 abc	15 ab
5	Spartan 4 L	3.0 oz/A	13 bcd	9 bc	13 abc	13 ab
6	Spartan 4 L	6.0 oz/A	10 cde	13 bc	19 abc	13 ab
7	Spartan 4 L	12.0 oz/A	11 cde	8 bc	6 bc	10 ab
8	Spartan 4 L	24.0 oz/A	39 a	15 ab	15 abc	15 ab
9	Sandea 75 DF	0.5 oz/A	14 bcd	28 a	20 ab	13 ab
10	Sandea 75 DF	1.0 oz/A	5 de	28 a	26 a	10 ab
11	Sandea 75 DF	2.0 oz/A	13 bcd	18 ab	19 abc	11 ab
12	Sandea 75 DF	4.0 oz/A	6 cde	18 ab	20 ab	13 ab
13	Control		0 e	0 c	6 c	0 b
LSD			11.3	13.1	14.1	21.9

Table 4. Injury to southern highbush blueberries (*Vaccinium corymbosum* 'Millennium') at site #3 (Griffin, Georgia) 2005.

Treatment No.	Treatment	Formulation Rate	Injury to Highbush (*Vaccinium corymbosum* 'Millennium')		
			8 WAT	11 WAT	21 WAT
1	Spartan 75 DF	3.0 oz/A	0 d	0 b	
2	Spartan 75 DF	6.0 oz/A	0 d	0 b	
3	Spartan 75 DF	12.0 oz/A	0 d	0 b	
4	Spartan 75 DF	24.0 oz/A	0 d	0 b	
5	Spartan 4 L	3.0 oz/A	0 d	0 b	
6	Spartan 4 L	6.0 oz/A	17 bcd	17 b	
7	Spartan 4 L	12.0 oz/A	7 cd	0 b	
8	Spartan 4 L	24.0 oz/A	7 cd	0 b	
9	Sandea 75 DF	0.5 oz/A	20 a-d	3 b	10 b
10	Sandea 75 DF	1.0 oz/A	40 a	40 a	20 a
11	Sandea 75 DF	2.0 oz/A	30 ab	40 a	20 a
12	Sandea 75 DF	4.0 oz/A	27 abc	57 a	20 a
13	Control		0 d	0 b	0 c
LSD			21.7	20.7	8.4

Table 5. Injury to southern highbush blueberries (*Vaccinium corymbosum* 'O'Neal') at site #3 (Griffin, Georgia) 2005.

Treatment No.	Treatment	Formulation Rate	Injury to Highbush (*Vaccinium corymbosum* 'O'Neal')		
			8 WAT	11 WAT	21 WAT
1	Spartan 75 DF	3.0 oz/A	0 d	0 c	
2	Spartan 75 DF	6.0 oz/A	17 cd	17 c	
3	Spartan 75 DF	12.0 oz/A	7 d	7 c	
4	Spartan 75 DF	24.0 oz/A	0 d	0 c	
5	Spartan 4 L	3.0 oz/A	23 bcd	0 c	
6	Spartan 4 L	6.0 oz/A	17 cd	10 c	
7	Spartan 4 L	12.0 oz/A	37 abc	17 c	
8	Spartan 4 L	24.0 oz/A	60 a	33 bc	
9	Sandea 75 DF	0.5 oz/A	37 abc	33 bc	17 a
10	Sandea 75 DF	1.0 oz/A	50 ab	33 bc	17 a
11	Sandea 75 DF	2.0 oz/A	53 a	63 ab	20 a
12	Sandea 75 DF	4.0 oz/A	57 a	83 a	20 a
13	Control		0 d	0 c	0 b
LSD			26.7	39.6	7.3

Table 6. Injury to southern highbush blueberries (*Vaccinium corymbosum* 'Windsor') at site #3 (Griffin, Georgia) 2005.

Treatment No.	Treatment	Formulation Rate	Injury to Highbush (*Vaccinium corymbosum* 'Windsor')		
			8 WAT	11 WAT	21 WAT
1	Spartan 75 DF	3.0 oz/A	0 d	0 b	
2	Spartan 75 DF	6.0 oz/A	7 d	0 b	
3	Spartan 75 DF	12.0 oz/A	0 d	0 b	
4	Spartan 75 DF	24.0 oz/A	0 d	0 b	
5	Spartan 4 L	3.0 oz/A	0 d	0 b	
6	Spartan 4 L	6.0 oz/A	0 d	0 b	
7	Spartan 4 L	12.0 oz/A	0 d	0 b	
8	Spartan 4 L	24.0 oz/A	0 d	0 b	
9	Sandea 75 DF	0.5 oz/A	27 c	17 b	13 a
10	Sandea 75 DF	1.0 oz/A	43 b	17 b	13 a
11	Sandea 75 DF	2.0 oz/A	53 a	47 a	20 a
12	Sandea 75 DF	4.0 oz/A	57 a	50 a	20 a
13	Control		0 d	0 b	0 b
LSD			9.2	23.5	7.3

Cost Benefit Analysis of Rabbiteye Blueberry Production in Georgia

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Summary

Blueberry now ranks number two most important economic crop in the state of Georgia after pecan. In 2004 Georgia blueberry industry surpassed peach by generating $48.6 million compared to $36.3 million of total farm gate value for year. Of all the various varieties of blueberries, rabbiteye blueberry (Vaccinium *ashei*) is the most important type grown in Georgia. This species is classified as a highbush blueberry type, but is distinctively different from highbush (*Vaccinium corymbosum*) in its ability to withstand high temperatures and lower organic matter soils (Krewer and NeSmith, 2002). Rabbiteye blueberries are relatively high yielding with well tended field commercial yields in the range of 5,000 to 8,000 pounds per acre typical on well maintained fields. Occasionally optimistic yields in excess of 10,000 to 12,000 pounds per acre are reported once in eight years. Fields may remain productive for thirty years or more even though only 20 years was used in calculating the compounded establishment cost in this study (Fonsah et al, 2005; Krewer et al, 2003; Westberry et al. 1995). Since there are several uncertainties involved in producing blueberries or any horticultural crop, it is important to conduct an economic feasibility study prior to getting involved in the cultivation of rabbiteye blueberries. The objective of this poster is therefore to conduct a cost benefit analysis to show whether or not growing rabbiteye blueberry in Georgia is a lucrative business venture. The result of this study will provide the badly needed information for growers in their decision making process.

New Highbush Blueberry Releases from Michigan State University

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Summary

Three new cultivars have been released from the MSU breeding program – Draper, Liberty and Aurora.

Draper is composed primarily of genes of *Vaccinium corymbosum*, but has a small contribution (< 5%) from *V. tenellum*, *V. ashei* and *V. darrowi*. It is a productive, early mid-season ripening cultivar with very high fresh market quality and probably a long storage life. It is intended for areas where northern highbush cultivars are grown successfully. Plants of 'Draper' are vigorous and upright. Canes are numerous, moderately branched and the fruit are well exposed. Its berries are moderately large, have small, dry picking scars, excellent powder-blue color, delicious flavor and excellent firmness. The size of the fruit is unusually regular and is presented in a loose cluster.

Consistent high yields at Benton Harbor and Grand Junction, MI indicate that the buds and wood of 'Draper' are tolerant to fluctuating late fall and spring temperatures. 'Draper' also has excellent winter hardiness, as it has routinely been challenged with mid-winter temperatures below - 20 C.

'Draper' appears to be about five days earlier ripening than 'Bluecrop'. In four years of trials in Michigan and Oregon, the fruit of 'Draper' have been consistently much firmer than 'Duke' and 'Bluecrop', and have been much better flavored. The firmness of its fruit suggests that it can be machine harvested for the fresh market. Its fruit load has been about equivalent to 'Duke' and slightly lower than 'Bluecrop". 'Draper' proved much more resistant to *Alternaria* and *Colletotrichum* than 'Bluecrop', and its fruit remained sound for a much longer time.

'Liberty' and 'Aurora' are productive, very late ripening genotypes with high fresh market quality. They are intended for areas where northern highbush cultivars are grown successfully. Plants of 'Liberty' and 'Aurora' are vigorous and upright. Canes are numerous, moderately branched and the fruit are well exposed. Its berries are moderately large, have small, dry picking scars, excellent powder-blue color, delicious flavor and excellent firmness. 'Liberty' has a harvest season that begins about 5 days before 'Elliott', while 'Aurora' is about 5 days later.

Consistent high yields at Benton Harbor and Grand Junction, MI. indicate that the buds and wood of 'Liberty' and 'Aurora' are tolerant to fluctuating late fall and spring

temperatures. Both also have excellent winter hardiness, as they have routinely been challenged with mid-winter temperatures below - 20.

Over four years of trials in Michigan and Oregon, ‘Liberty’ and ‘Aurora’ have consistently had better color, were more firm and had a better picking scar than ‘Elliott’. They also had improved flavor. The relative fruit rot susceptibility of all three genotypes was similar and good. ‘Liberty’ and Aurora have appeared to have a slightly longer storage life than Elliott.

Horizontal Wells: What are they, How do they work and How would they benefit us?

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Introduction

Irrigation is a vital part of producing a food and fiber crops for sell. In the 24 counties of coastal Georgia there are many operations that produce food and fiber. In recent years, over pumping of the upper Floridian aquifer has forced the Environmental Protection Division of the Department of Natural Resources to restrict the permitting and development of wells in this aquifer system. The restriction is based on the intrusion of salt water into potable water bearing strata of this aquifer system. The aquifer is the main water supply source for the coastal counties of Georgia. With this restriction, an alternative water supply system needs to be demonstrated to determine if it will be a viable means to get irrigation water for farming operations. The purpose of this demonstration is to investigate the possibility of using oil field and landslide technology to provide a reliable water supply system. The alternative technology being suggested is the horizontal well. The horizontal well can be placed at a depth that captures water from a surficial aquifer system not connected to the upper Floridian aquifer system. By removing water from a surficial aquifer, the farming operation can

be sustainable without affecting the upper Floridian aquifer and therefore not contributing to the salt water intrusion problem. The wells can also be used to recycle nutrients applied to the agricultural crops thereby reducing the need for costly nutrients and reducing the potential of polluting nearby stream systems.

What are they?

Horizontal wells were originally developed as far back as the late 1920's to 1930's for the removal of water from landslide prone areas in California and the extraction of oil from selected strata (Society of Petroleum Engineers, 2004; Welchert and Freeman, 1973). Typical applications for the use of horizontal wells includes exploitation of thin oil-rim reservoirs, avoidance of drawdown-related problems such as water/gas coning in the oil industry (Society of Petroleum Engineers, 2004), environmental remediation, water management (Park and Zhan, 2003) and the tapping of water bearing strata in rangeland areas of the arid west (Welchert and Freeman, 1973). This research and education project will adapt and use the advantages of horizontal wells to collect surficial aquifer water for the use in irrigating blueberries in two of the coastal counties in Georgia.

Horizontal wells would be an alternative water supply method in the 24 county Coastal Region of Georgia where the permitting of vertical well and the geological uncertainty of constructing irrigation ponds is restrictive. The horizontal well would also be an alternative water supply that would tap the surficial aquifer system that would not contribute to the salt water intrusion problems associated with over pumping the Upper Floridian Aquifer System. Additionally the use of horizontal wells would allow the farmer to potentially recycle nutrients in blueberry production systems.

How do they work?

Horizontal wells work in a manner that is similar to that of a French drain system. As you can see in Figure 1, the well is installed at depths from 10 – 20 feet below the soil surface in various lengths. The length of the well would be based on water availability in the subsurface strata, monetary restrictions and available length of land. Wells can be installed in single runs or can be installed in a "wagon-wheel" or multilateral formations. Installation in any formation would be driven by the available space and the requirement for higher volumes of water. The volume of flow available from the well in any formation is based on the length of run, the geology of the subsurface strata and the depth of the water table at that specific location.

One end of the well is connected to a stand pipe typically used for the pump location be it submersible of the intake hose for an above ground pump. The pipe is trenched to the desired depth and a clean-out system connected to the opposite end of the pipe or well. If multiple laterals are used then each line would have a clean-out end and the pumping end would be connected to a larger standpipe system based on the potential volumes. The operation of installing the well consist of trenching to the desired depth, installing

the pipe and associated parts and then backfilling. All of this is done by commercial installers and the three aspects of installing the well is done in one pass through the field. Once installed, pumps are either submerged in the standpipe or suction hoses are inserted and connected to standard above ground pumps.

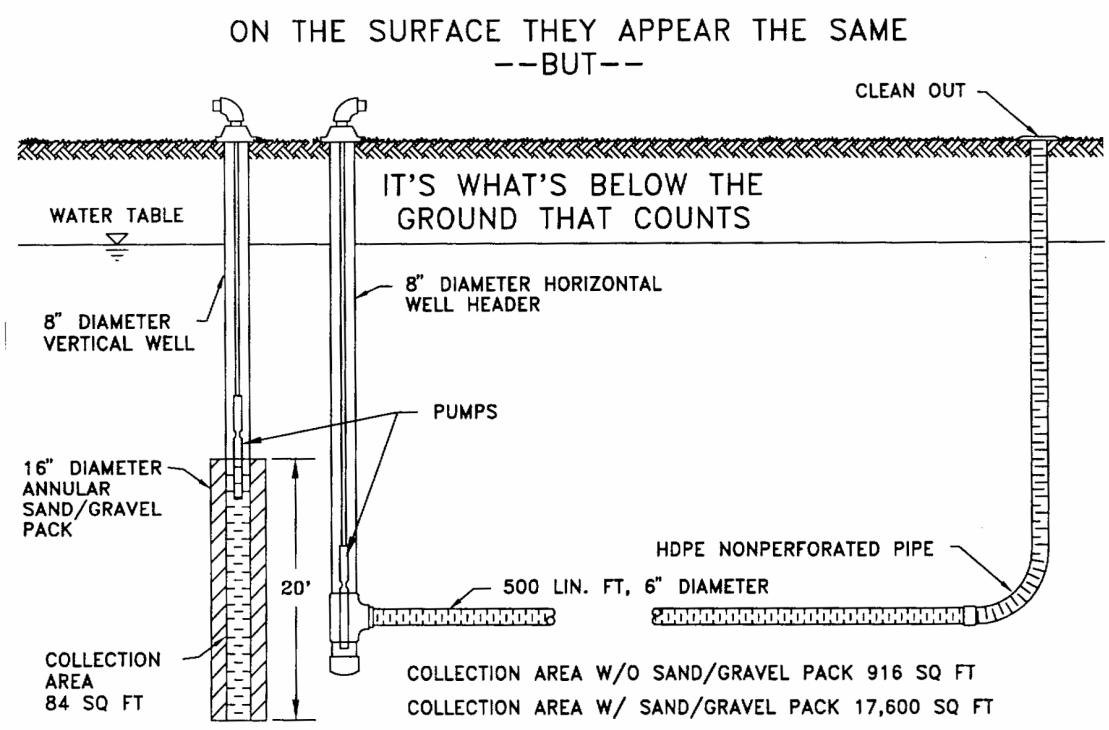

Figure 1. Schematic of a Horizontal Well as installed. Picture taken from Horizontal Subsurface System, Inc. website.

How would they benefit us?

If the geology of the interested site is determined to be suitable to produce the required amount of water, then the installation of a horizontal well could have a various benefits. These could include but may not be all inclusive. Some of the benefits would be drawing water from a zone that would not contribute to salt water intrusion, using water from a strata that has a higher water quality for the production of blueberries and the potential for recycling of nutrients.

Installation of horizontal wells have been completed in different regions of Florida and should work well on the Coast of Georgia. As stated above, one of the benefits of using this type system is that the water being used for irrigation will be extracted from levels just below the soil surface and has not come in contact with the underlying limestone which adds calcium and carbonate to the water. These addition minerals in the irrigation water increases the pH of the soil as well as adversely affects the blueberry plant itself. Unfortunately, this alternative irrigation system would still be required to

obtain a withdrawal permit from the Agricultural Pumping permitting section if the volume of water is regulated.

Summary

The horizontal well is a technology that has the potential of extracting water in the coastal region of Georgia from a level 10-20' below the soil surface. This water would be better for the blueberry plants as well as not contributing to the salt water intrusion problem being investigated by the GA-EPD. The systems potentially have a slightly higher initial cost, but cold be overcome based on the depth of pumping from a deep well and the decreased quality of blueberries from the use of water with high concentrations of carbonate. Therefore, this technology is being looked at as a demonstration in Georgia to see if a technology used in the production of Florida citrus and removal of water in the oil industry can be used in blueberry production.

Literature Cited

Park, E. and H. Zhan. 2003. Hydraulics of Horizontal wells in fractured shallow aquifer systems. Journal of Hydrology 281 (2003), pp. 147-158.

Society of Petroleum Engineers. 2004. Horizontal and Multilateral Wells. http:/www.spe.org.

Welchert, W.T. and B.N. Freeman. 1973. 'Horizontal' Wells. Journal of Range Management 26(4) pp. 253-256.

New Southern Highbush Blueberry Varieties From The University of Georgia

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Introduction

The University of Georgia (UGA) Blueberry Breeding Program has been in existence for several decades, and this long term effort has led to great improvement of the plant material that is available. Much of the cultivar development work in the past has been focused on rabbiteye blueberries, which occupy the most acreage in the Southeast. However, in recent years the increased grower interest in southern highbush blueberries has led to an accelerated effort at UGA in developing suitable new southern highbush varieties. The following is a brief description of two new southern highbush blueberry varieties that have been released by the UGA Blueberry Breeding Program.

Please note the new blueberry releases from UGA are protected varieties. For information on licenses and licensed propagators of UGA blueberry varieties, contact the Georgia Seed Development Commission in Athens (ph. 706-542-5640), or visit their web site at http://www.gsdc.com/.

Camellia Southern Highbush Blueberry

'Camellia' is an early-to-mid season southern highbush blueberry, having highly favorable fruit attributes, especially color and size, and excellent plant vigor (Fig. 1). Released by UGA in 2005, the new variety is estimated to have a similar chill hour requirement to that of other early season southern highbush, in the range of 450 to 500 hours. 'Camellia' flowers 5 to 7 days after 'Star' and 'O'Neal' and ripens 2 to 7 days after them (Table 1). 'Camellia' berries are large in size (up to 2.2 g) and are firm and flavorful. Growers desiring a high quality early-to-mid ripening southern highbush blueberry should consider trialing 'Camellia' in areas where southern highbush are successfully grown. While many southern highbush varieties are self-fertile to a degree, planting of two or more varieties together is highly recommended to facilitate cross-pollination which typically results in larger, earlier ripening fruit.

Figure 1. Camellia southern highbush blueberry fruit during ripening.

Table 1. Average ratings of fruit and plant attributes of 'Camellia', 'Star', and 'O'Neal' southern highbush blueberries over a 4-year period in test plots at Alapaha, Ga. under field conditions. Ratings (other than flowering and ripening dates) are based on a 1 to 10 scale, with 1=poorest and 10=best. A value of 6-7 (except for cropping score) is generally considered to be the minimum acceptable rating for a commercial cultivar.

Berry/Plant attribute	Variety		
	Camellia	**Star**	**O'Neal**
Flowering date	March 13	March 6	March 7
Ripening date	May 19	May 12	May 17
Berry size	9.1	7.6	7.7
Berry scar	7.6	7.7	7.5
Berry color	9.0	8.0	7.7
Berry firmness	7.5	8.0	6.8
Berry flavor	7.6	7.2	8.2
Cropping	6.8	5.7	5.5
Plant vigor	9.4	7.0	6.8

Rebel Southern Highbush Blueberry

'Rebel' is a very early season southern highbush blueberry released in 2006. Plants of 'Rebel' are very vigorous and precocious, with a slightly spreading growth habit. The new variety produces abundant fruiting wood annually and readily breaks leaf buds during or just after flowering. 'Rebel' has been productive in yield, exceeding yields of 'Star' and 'O'Neal' in 2 years of testing in south Georgia. 'Rebel' flowers approximately 3 days earlier than 'Star', while berries of 'Rebel' ripen 6 to 8 days before 'Star' (Table 2). Berries of 'Rebel' are large in size, having exceeded 2.5g per berry under good management (Fig. 2). Other important fruit characteristics, including stem scar, color, and firmness are good to excellent for 'Rebel', while flavor is only average. Growers desiring an early ripening southern highbush should consider trialing 'Rebel' in areas where southern highbush are successfully grown. The estimated chill hour requirement for the new variety is 400-450 hours.

Table 1. Average ratings of fruit and plant attributes of 'Rebel', 'Star', and 'O'Neal' southern highbush blueberries over a 2-year period in test plots in a high density bed at Alapaha, Ga and on a growers farm in Ware County Georgia under field conditions. Ratings (other than flowering and ripening dates) are based on a 1 to 10 scale, with 1=poorest and 10=best. A value of 6-7 (except for cropping score) is generally considered to be the minimum acceptable rating for a commercial cultivar.

Berry/Plant attribute	Variety		
	Rebel	**Star**	**O'Neal**
Flowering date	March 7	March 10	March 15
Ripening date	May 8	May 16	May 24
Berry size	8.6	8.3	7.8
Berry scar	8.5	8.3	7.3
Berry color	7.9	8.0	7.0
Berry firmness	7.9	7.5	6.9
Berry flavor	7.1	7.5	8.3
Cropping	7.3	5.8	5.5
Plant vigor	9.1	7.8	6.8

Figure 2. Rebel southern highbush fruit during ripening.

Response of 'Reveille' Southern Highbush Blueberry to Various Amounts of Pine Bark Incorporated into a Typical Georgia Flatwoods Soil

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Introduction

Studies have been conducted which have shown the benefit of pine bark soil amendment or mulch on the growth and yield of southern highbush blueberries (Odneal and Kaps 1990; NeSmith 2003) However, few or no studies have been conducted looking at a rate response to pine bark soil amendments. This is of fundamental importance to the blueberry industry in the Southeast since pine bark is relatively expensive and organic amendments are required for the culture of most cultivars of southern highbush blueberries in the common soils of the southeast.

Materials and methods

The experiment was conducted at UGA Alapaha Blueberry Field Station on raised beds with overhead irrigation. Soil type was an Albany loamy sand with about 1.5% organic matter and a pH of about 4.8. Previous crop was blueberries. Experimental design was a randomized complete block with five treatments with four replications per treatment and four bushes per replication for a total of 20 bushes per treatment. The plots were twenty feet long by three feet wide. Plastic root barriers were installed between treatments. Treatments were an unamended control; one inch, three inches and five inches of milled pine bark incorporated about five or six inches deep with a rotovator; and one inch of milled pine bark applied in an unincorporated layer and covered with one inch of soil. Calculated at a ten foot between row spacing with a three foot wide treated band this is equivalent to 40.3, 121 and 202 cubic yards of pine bark per acre for the one, three and five inch pine bark amendment treatments. In Feb. 2001, one gallon 'Reveille' plants were set four feet apart. Plant were fertilized and watered as needed. In years three, four and five plants received about 80-100 pounds of N per year from multiple applications of 10-10-10 or slow release fertilizer.

Plant width in row, width across row and height were measured on 5 March 2001 (starting) and after the end of the growing season in late September or October of each subsequent year. The plant growth index was calculated as mean of measures (height plus width plus width / 3). In 2004, the plants were mechanically harvested with a BEI Little Blue Tall or hand harvested on 18 May, 25 May and 3 June. Berry size was

determined by harvesting 50 berries per replication and treatment on 18 May and 25 May. In 2005, the plants were mechanically harvested with a BEI Little Blue Tall with touch up hand harvest on 1 June and 7 June.

Results and discussion

The first year plants were allowed to fruit and only a small amount of growth occurred. The second year, rapid growth occurred in the best treatments. Plant width in row and width across row was not significantly different between treatments, due to variation between plants, but there was a trend toward much greater growth index with the pine bark treatments (Table 1). Since 'Reveille' is a very upright growing plant, differences in plant width between treatments were probably minimized by the natural tendency of this cultivar to remain narrow. Five inches of pine bark incorporated significantly increased plant height compared to the control (Table 1). There was a trend for all pine bark treatments to increase plant height, but the rate of increased growth was greatest from the control to three inches of pine bark incorporated. However, best response was to the five inches of pine bark incorporated. Bush volume was 40% greater on the five inch than the three inch treatment. Control plant height was actually smaller after two years since branches of southern highbush often partially die back from disease if conditions are poor for growth. There was a trend for the one inch bark veneer treatment to increase 'Reveille' growth more than one inch incorporated.

In year three (2003), plants in amended soil made excellent growth. Plant survival was not significantly different between treatments. Compared to the control, width in row and width across row, and growth index was significantly increased by the five inch pine bark treatment (Table 2). Bush volume was 79% greater with the five inch pine bark treatment than the control. Compared to the control, height was significantly increased by the one inch pine bark veneer treatment. There was trend for higher growth indexes with increasing amounts of pine bark.

In year four (2004), compared to control, plants growing in soil amended with one inch of pine bark veneer, three inches of pine bark incorporated and five inches of pine bark incorporated had significantly greater width in row, width across row, height and growth index (Table 3). In 2004, one of the three inch pine bark plots growing on a wet end of the field was removed from the analysis due to saturated soil conditions. With these bushes removed from the analysis, the growth index of the bushes growing with three and five inches of pine bark incorporated were not significantly different. One inch of incorporated pine bark was not significantly different than the control in any of the growth measurements. In 2004, compared to the unamended control, fruit yield on the first, second and third harvest was significantly greater with the three and five inch pine bark treatments (Table 4). Total fruit yield of plants growing in the five inch pine bark incorporated was significantly greater (179% greater) than the unamended control.

In 2004, berry weight on the first and second harvest was not significantly affected by treatment, however, there was a trend toward highest berry weight with the five inch

treatment (Table 5). In 2005, compared to the unamended control, all pine bark treatments significantly increased width in row (Table 6). Width across row, height and growth index was significantly increased by the three inch incorporated, five inch incorporated and one inch veneer. Growth index in 2005 was similar between the three and five inch pine bark treatments. Mean berry weight was not significantly different between treatments, but there was a trend for larger berries with the pine bark treatments. Total yield in 2005 was not significantly different between the three and five inch incorporated and the one inch veneer. Total fruit weight of plants growing in the five inch pine bark incorporate was 275% greater than the control. Plant survival was not significantly different between treatments.

In years two, three, four and five the one inch pine bark veneer treatment had a growth index similar to the three inch pine bark treatment. Blueberry roots spread widely in this layer, however, after two and especially three and four growing seasons, some of the bark was becoming exposed. Throwing a small amount of soil on top of the bed each winter should solve this problem. It was very surprising how well southern highbush performed with such a small amount of pine bark using the veneer technique.

In 2004, the yield of plants with one inch of pine bark incorporated was almost the same as the unamended control, but yield of plants with the one inch veneer layer was over 100% higher than the control. In 2005, the yield of plants with one inch of pine bark incorporated was higher than the control, but one inch veneer was about double the yield of one inch of pine bark incorporated (Table 7). Results of this magnitude were unexpected and another experiment is now underway to further investigate pine bark veneer. From a commercial production standpoint, five inches of pine bark incorporated gave the best response in years one though four. In year five the three inch incorporated also performed well. Total yields where disappointing, birds ate significant amounts of the fruit on several occasions and the plots where mechanically harvested so some ground loss occurred. It appears at least five inches of milled pine bark should be recommended for the culture of southern highbush on a loamy sand with only 1.5% organic matter. Virgin upland pine forests (pine barrens) typically have about 2% organic matter in much of south Georgia, so this data should be applicable to these sites.

Literature Cited

NeSmith, D.S. 2003. Survival and vigor of southern highbush blueberry cultivars with and without pine bark mulch. Small Fruit Rev. 2 (2): 81-86.

Odneal, M.B. and M.L. Kaps. 1990. Fresh and aged pine bark as soil amendments for establishment of highbush blueberry. *HortScience* 25(10):1228-1229

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Table 1. Effect of milled pine bark incorporated or veneered on the growth 'Reveille' southern highbush blueberries, Spring 2001 to Fall 2002.

Treatment	Increase in growth (cm) (1 inch = 2.54 cm)			Growth index
	Width in row	Width across row	Height	
Control	9.0a[z]	14.4a	-0.2b	7.8b
One inch incorporated	17.4a	22.4a	8.3ab	16.0ab
Three inch incorporated	17.6a	27.8a	23.8ab	23.0ab
Five inch incorporated	20.7a	28.9a	27.6a	25.6a
One inch veneer	13.0a	23.3a	19.6ab	18.7ab
SE	5.0	5.8	9.0	5.6

[z]= Means with the same letter in a column are not significantly different (P>0.05) according to the DIFF option in PROC MIXED (SAS, 2000) with Satterthwaite option on the model statement.

Table 2. Effect of milled pine bark incorporated or veneered on the growth of 'Reveille' southern highbush blueberries, Spring 2001 to Fall 2003.

Treatment	Increase in growth (cm) (1 inch = 2.54 cm)			Growth Index	Survival (%)
	Width in Row	Width Across Row	Height		
Control	25.4 b[z]	44.2 b	48.5 b	35.0 b	85 a
One Inch Incorporated	35.8 ab	36.1 b	62.5 ab	44.7 ab	75 a
Three Inch Incorporated	42.4 ab	46.5 ab	77.0 ab	54.4 ab	90 a
Five Inch Incorporated	52.8 a	57.7 a	78.5 ab	62.7 a	85 a
One Inch Veneer	37.8 ab	42.2 ab	81.8 a	54.1 ab	95 a

[z] = Means with the same letter in a column are not significantly different (P≥005) according to the DIFF option in PROC MIXED (SAS, 2000) with Satterthwaite option on the model statement.

Table 3. Effect of milled pine bark incorporated or veneered on the actual width and height of 'Reveille' southern highbush blueberries, 2004.

Treatment	Total growth(cm)-(1 inch = 2.54 cm)			Growth Index	Survival (%)
	Width in row	Width across Row	Height		
Control	67.4c	62.9c	115.1b	81.8b	85a
One inch incorporated	73.6c	68.9c	131.5b	91.0b	75a
Three inch incorporated	99.2a	87.4ab	159.9a	115.5a	70a
Five inch incorporated	91.6ab	95.0a	158.9a	114.9a	85a
One inch veneer	83.0b	79.8b	155.9a	106.2a	95a
LSD	13.2	10.3	25.7	15.1	26.8

[Z]= Means with the same letter in a column are not significantly different (P≥0.05) according to the DIFF option in PROC MIXED (SAS,2000) with Satterthwaite option on the model statement.

Table 4. Effect of milled pine bark incorporated or veneered on the actual width and height of 'Reveille' southern highbush blueberries, 2005.

Treatment	Increase in growth (cm)			Growth Index	Survival (%)
	Width in row	Width across row	Height		
Control	67.7 c[z]	65.9 c	117.4 b	83.6 c	85.0 ab
1" incorporated	84.9 b	82.1 bc	138.1 b	101.7 b	70.0 b
3" incorporated	109.6 a	101.4 a	163.8 a	125.1 a	93.3 ab
5" incorporated	107.1 a	109.2 a	167.5 a	127.8 a	85.0 ab
1" veneer	93.6 ab	95.6 ab	161.0 a	116.7 ab	95.0 a

[z]= Means with the same letter in a column are not significantly different (P≥0.05) according to the DIFF option in PROC MIXED (SAS,2000) with Satterthwaite option on the model statement

Table 5. Effect of pine bark on plant yield of 'Reveille' blueberry, 2004.

Treatment	Yield (g)			
	18 May	25 May	3 June	Total
Control	125 b	91 b	60 a	276 b
1" incorporated	129 b	95 b	48 a	271 b
3" incorporated	325 a	269 a	85 a	679 ab
5" incorporated	342 a	278 a	151 a	771 a
1" veneer	250 ab	228 ab	159 a	637 ab

a = Data analyzed using Proc Mixed (SAS 9.1) with the option DDFM = SATTERTH (Satterthwaite method for computing degrees of freedom in split plots)

Between harvests within a treatment, LSD = 1.07
Between treatments within a date, LSD = 170
Between treatments for total yield, LSD = 458

Table 6. Effect of pine bark treatments on berry weight of 'Reveille' blueberry, 2004.

Treatment	Yield (g)		
	18 May	**25 May**	**Mean**
Control	1.13 a	0.94 a	1.03 a
1" incorporated	1.18 a	1.01 a	1.10 a
3" incorporated	1.09 a	0.99 a	1.04 a
5" incorporated	1.25 a	1.03 a	1.14 a
1" veneer	1.24 a	1.02 a	1.13 a
	0.14	0.14	0.14

a = Data analyzed using Proc Mixed (SAS 9.1) with the option DDFM = SATTERTH (Satterthwaite method for computing degrees of freedom in split plots)

Table 7. Effect of pine bark on plant yield of 'Reveille' blueberry, 2005.

Treatment	Yield (g)		
	1 June	**7 June**	**Total**
Control	143 b[z]	118 b	261 b
1" incorporated	240 b	222 b	462 b
3" incorporated	583 a	589 a	1172 a
5" incorporated	512 a	466 a	978 a
1" veneer	516 a	465 a	981 a
	Berry Weight (g)		
Control	1.06 a	1.02 b	1.04 a
1" incorporated	1.09 a	1.22 a	1.15 a
3" incorporated	0.99 a	1.12 ab	1.06 a
5" incorporated	1.17 a	1.17 ab	1.17 a
1" veneer	1.10 a	1.16 ab	1.13 a

[z]= Means with the same letter in a column are not significantly different (P≥0.05) according to the DIFF option in PROC MIXED (SAS,2000) with Satterthwaite option on the model statement.

Factors Influencing the Long-term Storage of Northern Highbush Blueberries

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Summary

Over the last six years we have been studying four factors that could influence the long term storage of blueberries: 1) storage atmosphere, 2) nutrition, 3) stage of fruit ripeness and average stage of ripeness on the bush (bush ripeness), and 4) cultivar. To test the influence of atmosphere on long term storage, ripe fruit from eight cultivars were stored in 1999 under ambient O_2 and CO_2 or 2 kPa O_2 and 8 kPa CO_2. After 4, 5 and 6 weeks of storage, there was little difference observed between the two treatments for soluble solids, acidity, firmness, % bruising and % decay in any cultivar.

To determine the effect of N and Ca levels on the keeping quality of blueberries, fruit were collected and stored in 1999 and 2000 from 'Jersey' bushes whose leaves had N levels ranged from 1.7 to 2.1 % and 'Bluecrop' bushes whose leaves had Ca levels ranging from 0.43 to 0.47 %. Little difference was observed in the storage quality of fruit from any of these treatments.

To measure the effect of bush ripeness on long term storage, 100 % blue fruit were picked from 'Elliott' bushes in 1999 when the bushes were 30 %, 60 % and 80 % ripe. Fruit were also picked from 'Elliott' bushes in 2000 at two stages of bush ripeness (30 % and 60 %) and sorted into three classes: 100 % blue, approximately 75 % blue and approximately 50 % blue. Bush ripeness impacted storage quality, with earlier harvested fruit being significantly better than that picked later. However, there was no significant difference in the storage quality of fruit sorted into categories of 50, 75 and 100 % blue. In 2000, we compared the storability of fruit from the first and second harvests of four cultivars and found that fruit from the first harvest had superior storage quality to that of the second.

To contrast the long term storability of some of the newer cultivar releases, fruit were collected from 'Nelson', 'Bluegold', 'Bluecrop', 'Jersey', 'Legacy', 'Brigitta' and 'Little Giant' in 1999, 2000 and 2001 and stored in ambient air at 0 C. Overall, 'Bluegold', 'Brigitta' and 'Legacy' performed the best, storing well for 4 - 7 weeks. 'Elliott', 'Nelson' and 'Little Giant' remained salable for only half as long. We also compared the long term storage and disease resistance of thirty additional highbush cultivars and advanced selections in 2002, 2003 and 2004. The genotypes with the longest storage life were 'Brigitta' and 'Draper' which averaged 9 weeks, followed by 'Aurora' and 'Toro' (8 weeks). The most resistant genotypes to *Alternaria* were

‘Aurora’, ‘Draper’ ‘Brigitta’ and ‘Elliott’, while the most resistant genotypes to *Colletrotricum* were ‘Duke’, ‘Elliott’, ‘Bluejay’, ‘Toro’ and ‘Aurora’.

Two cultivars, ‘Bluegold’ and ‘Brigitta’, performed exceptionally well. After 7 weeks of storage, nearly 80% of the ‘Bluegold’ berries were unblemished and firm, and nearly 65% of the ‘Brigitta’ berries were of similar quality. ‘Legacy’ and ‘Nelson’ performed about like ‘Elliott’, while ‘Little Giant’ deteriorated rapidly.

‘Liberty’, ‘Brigitta’, and ‘Legacy’ had the firmest fruit, showed the least internal bruising, and had the highest soluble solids at harvest. ‘Bluegold’ and ‘Nelson’ were not as firm and had lower soluble solids than the above three cultivars, but maintained good quality for 5 weeks of storage. The firmness and soluble solids of ‘Elliott’ were close to ‘Bluegold’ and ‘Brigitta’, but 'Elliott' fruit deteriorated rapidly and within two weeks, most were unsalable.

In 2001, we compared the storability of ‘Aurora,’ ‘Bluecrop’, ‘Bluegold’, ‘Brigitta’, 'Elliott', ‘Liberty’ and 'Nelson.' The extreme heat in the middle of the summer turned everything rapidly into mush, but when it cooled to normal temperatures, several genotypes stored very well. 'Bluegold', ‘Aurora’, 'Brigitta', ‘Liberty’ and 'Nelson' had the firmest fruit, showed the least internal bruising, and had the highest soluble solids at harvest. The fruit of these genotypes remained salable for up to 5 weeks of storage.

Impact of Management Practices on Blueberry Shoot Growth

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Introduction

Growth of individual shoots in blueberry is episodic and sympodial; they grow in flushes during the season accompanied by a varying number of apical abortions often called the "black tip stage" (Gough et al., 1978). The aborted shoot apex usually remains visible on individual shoots for one to two weeks, after which the necrotic area sloughs off. Two to five weeks after black-tip abscission, shoot growth typically continues from the most distal vegetative bud which assumes apical dominance preventing more proximal buds from breaking. The shoot often remains un-branched, although branched shoots may occur. The continued growth of the shoot is designated as the "second flush" or later flushes of growth.

According to Gough et al. (1976), the number of flushes of growth in blueberry shoots is dependant on cultivar and vigor, with early-ripening cultivars having more flushes than later cultivars. The length of individual shoots and the number of flushes that occur on a single shoot vary and may affect the potential number of flower buds. There has not been much published on the effect of various cultural practices on the number of growth flushes per shoot or shoot length. Since shoot growth cessation precedes flower bud development, late growth flushes may affect the number of flower buds per shoot.

Optimal growth for highbush blueberries is achieved in soils with a high organic matter, a pH between 4.2 and 5.5, and in soils with a high water holding capacity (Eck, 1988). Soil amendments are commonly used before planting in mineral soils to achieve these qualities for improved plant growth. Various studies have been completed on the effects of incorporated soil amendments in blueberry production; most have used bark (Bollen and Glennie, 1961; Odneal and Kaps, 1990) or peatmoss (Lareau, 1989). Results from these studies have been inconsistent. Research on the effect of surface mulch, either sawdust or other materials, has had more consistent results in blueberry, commonly improving growth (Clark, 1991; Lareau, 1989; Moore, 1979; Spiers, 1998).

A recent economic study conducted by Oregon State University found that establishment costs are $20,336 per hectare and over $300,000 in cash is required to establish 8 ha of blueberries (Eleveld et al., 2005). A portion of this cost comes from the incorporation of soil amendments before planting and the use of sawdust mulch and fertilizers. Most growers in western North America use fir sawdust. Incorporation of a sawdust amendment and nitrogen fertilizer when preparing a blueberry planting has an estimated cost of $4,069 per hectare while use of a sawdust mulch will add $5,632 per

hectare in the establishment years (1-6) and $930 per hectare per year, on average, for the mature production years including labor (Eleveld et al., 2005).

In this presentation (briefly summarized here), we will present information from various studies on the effect of pre-plant incorporation with sawdust, surface mulching with sawdust, in-row spacing, nitrogen fertilization rate, cultivar, and summer pruning on blueberry shoot growth.

Results

Study 1:

The number of shoots on mature 'Bluecrop' plants ranged from 249 to 382 with plants at 1.2 m having more shoots than those at 0.45 m, but there was no effect of nitrogen (N) fertilization rate (0, 100, or 200 $kg \cdot ha^{-1}$). The distribution of shoot size on plants was not much affected by in-row spacing or N rate and averaged 50% small shoots (< 10 cm long), 32% medium (10 to 29 cm), 10% large (30 to 50 cm), and 8% extra-large (> 50 cm). Plants spaced at 1.2 m in the row tended to produce more L and XL shoots than those at 0.45 m.

In-row spacing had no effect on the proportion of shoots with one, two, three, or four flushes of growth. The number of flushes of growth varied with final shoot length; 63 to 81% of S and M (small and medium) shoots had one flush of growth and these shoots never had more than two growth flushes. In contrast, L and XL shoots had either one (33 to 49%), two (42 to 63%), three (4 to 46%), or four (1 to 17%) flushes of growth, with XL shoots more commonly having four flushes than L shoots. Most shoots (61 to 73%) however, had only one flush of growth. Nitrogen fertilization, after two years, had no effect on the number of growth flushes per shoot although there was a trend for plants receiving higher rates of N to have more shoots with three or four flushes of growth.

Final shoot length (S, M, L, or XL) and in-row spacing affected the number of flower buds per shoot and percent flower bud set, but not N fertilization rate after two years. The number of flower buds per shoot ranged from 3 to 13 in S and XL shoots, respectively. Percent fruit bud set ranged from 16% in XL shoots to 46% in M shoots. Plants at 1.2 m in the row had a higher percentage of flower buds on L shoots than those at 0.45 m. It is clear that actual flower bud number would be more useful to predict potential yield as shoot number is a more important factor (and thus flower bud number) than percent fruit bud set.

More buds (floral and vegetative) were found in the first flush of growth than subsequent flushes in all shoot sizes except XL shoots were more buds were in the second and third flush. Flower buds were located in the two most distal flushes of growth. Stage of flower bud differentiation likely differs amongst growth flushes.

Study 2:

In 'Elliott', in the first year of planting establishment, the greatest shoot growth rate occurred about 2 weeks after the first fertilizer application (Figure 1). Mulch had a significant effect on growth early and late in the season, with plants in mulched plots having the greatest growth rate and total growth. Plants in un-incorporated soil with mulch and receiving the high N rate (114 $kg \cdot ha^{-1}$ compared to 22, or 68 $kg \cdot ha^{-1}$) had a peak growth rate of 0.31 $cm \cdot d^{-1}$. In comparison, plants in un-incorporated soil without mulch, receiving the medium rate of N had the lowest shoot growth rate of 0.12 $cm \cdot d^{-1}$ on the same date. There was a second, smaller flush of growth approximately 2 weeks following the second fertilizer application (Figure 1). Shoot growth differences amongst treatments followed the same trends as for the first peak. Plants in incorporated soil had little shoot growth after July 1. However, plants in non-incorporated, mulched plots that received some level of N fertilizer showed small peaks of shoot growth until the end of July; by August, all shoots had ceased to grow.

In the second year, there were three main peaks of growth that did not appear to be completely related to time of fertilizer application (data not shown). The first increase in shoot growth rate was seen approximately 2 weeks after the first fertilization. Succeeding peaks were seen 2 and 4 weeks after the first peak event. The greatest rate of shoot growth was seen on plants in non-incorporated plots. Plants in non-incorporated soil, without mulch, receiving a low N fertilizer rate had a peak growth rate of 0.6 $cm \cdot d^{-1}$. In comparison, plants in incorporated soil, with sawdust, receiving the lowest rate of N had a shoot growth rate of 0.3 $cm \cdot d^{-1}$on the same date. In the second year, on average, shoots had two times the growth rate measured in year one. All shoot growth ceased by early August.

Whips began growing in late June of both years. At the start of whip growth in year one, there was a significant incorporation by mulch interaction, with plants in non-incorporated, mulched plots having the greatest growth rate -- up to 1.2 $cm \cdot d^{-1}$ (Figure 2). The lowest growth rate, in this same time period, was observed in incorporated plots without mulch at 0.66 $cm \cdot d^{-1}$. As the season progressed, only mulch had a significant effect on whip growth rate. In year two, there was a significant interaction of incorporation by mulch and N rate at the beginning of the season, but only mulch was significant during mid-season growth (data not shown). Peak growth was seen at the beginning of the season when whips averaged 2.0 $cm \cdot d^{-1}$ -- a 166% increase over the growth rate in 2004.

Other studies:

The impact of cultivar and summer pruning on shoot growth will be presented at the meeting also.

Literature Cited

Bollen, W. and D. Glennie. 1961. Sawdust, Bark and Other Wood Wastes for Soil Conditioning. For. Prod. J. 11(1): 38-46.

Clark, J. 1991. Rabbiteye and Southern Highbush Blueberry Response to Sawdust Mulch. Arkansas Farm Research. Jan.-Feb.:3.

Cummings, G.A., C.M. Mainland, and J.P. Lilly. 1981. Influence of Soil pH, Sulfur, and Sawdust on Rabbiteye Blueberry Survival, Growth, and Yield. J. Amer. Soc. Hort. Sci. 106(6):783-785.

Eck, P. 1988. Blueberry Science. Rutgers University Press, N.J.

Eleveld, B., B. Strik, K. DeVries, and W. Yang. 2005. Blueberry economics. The costs of establishing and producing blueberries in the Willamette Valley. EM 8526. 41 pp. http://eesc.oregonstate.edu/.

Gough, R.E., R.L. Hauke, and V.G. Shutak. 1976. Growth and development of highbush blueberry. I. Vegetative growth. J. Amer. Soc. Hort. Sci. 103: 476-479

Gough, R.E., R.L. Hauke, and V.G. Shutak. 1978. Growth and development of highbush blueberry. II. Reproductive growth, histological studies. J. Amer. Soc. Hort. Sci.103 (4): 476-479.

Lareau, M. 1989. Growth and Productivity of Highbush Blueberries as Affected by Soil Amendments, Nitrogen Fertilization and Irrigation. Acta Horticulturae. 241:126-131.

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

Odneal, M. and M. Kaps. 1990. Fresh and Aged Pine Bark as Soil Amendments for Establishment of Highbush Blueberries. HortScience. 25(10):1228-1229.

Spiers, J. 1998. Establishment and Early Growth and Yield of 'Gulfcoast' Southern Highbush Blueberry. HortScience. 33(7):1138-1140.

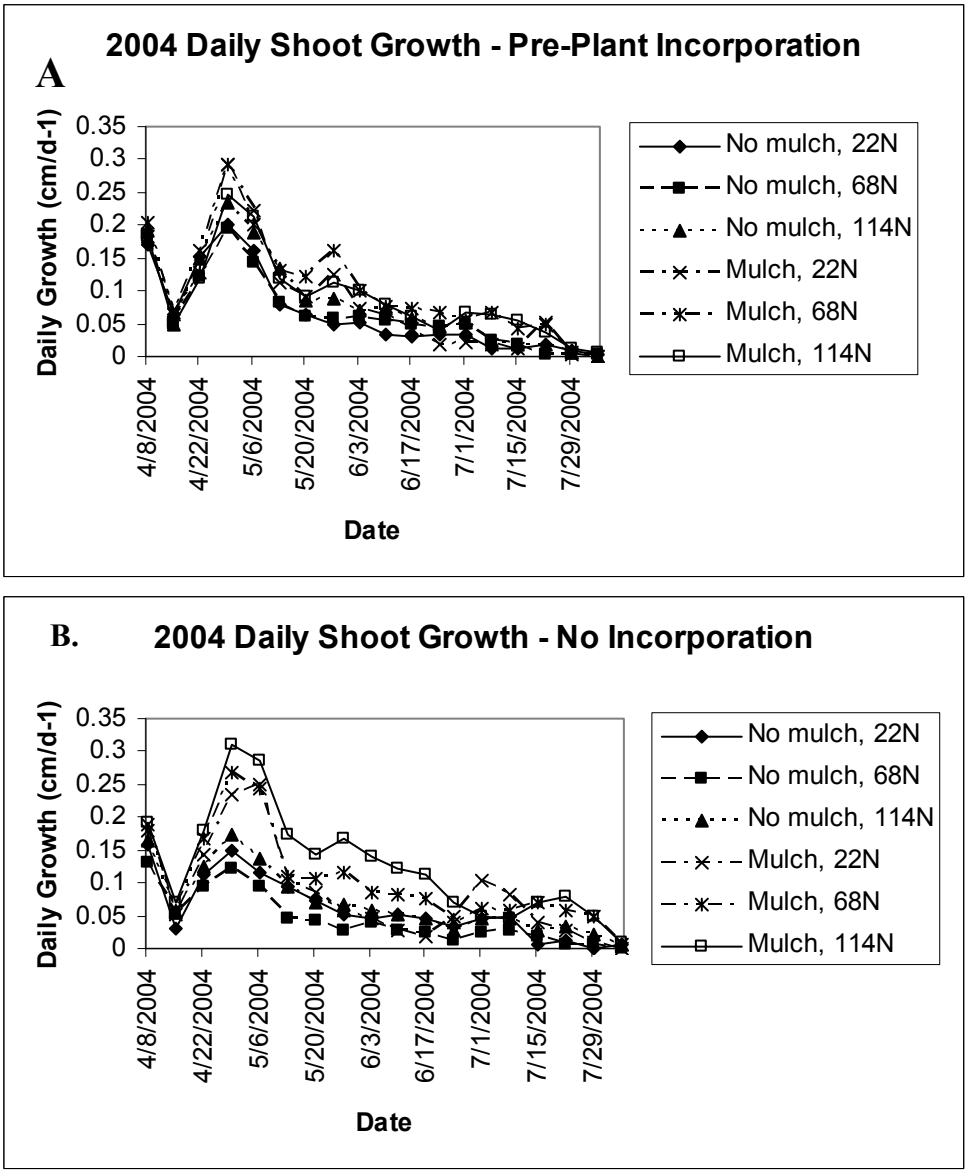

Figure 1. The effect of sawdust mulch and N fertilizer rate on daily shoot growth ($cm \cdot d^{-1}$) in year one of an 'Elliott' planting in A) incorporated with pre-plant sawdust amendments and B) no incorporation. Data points represent collection dates.

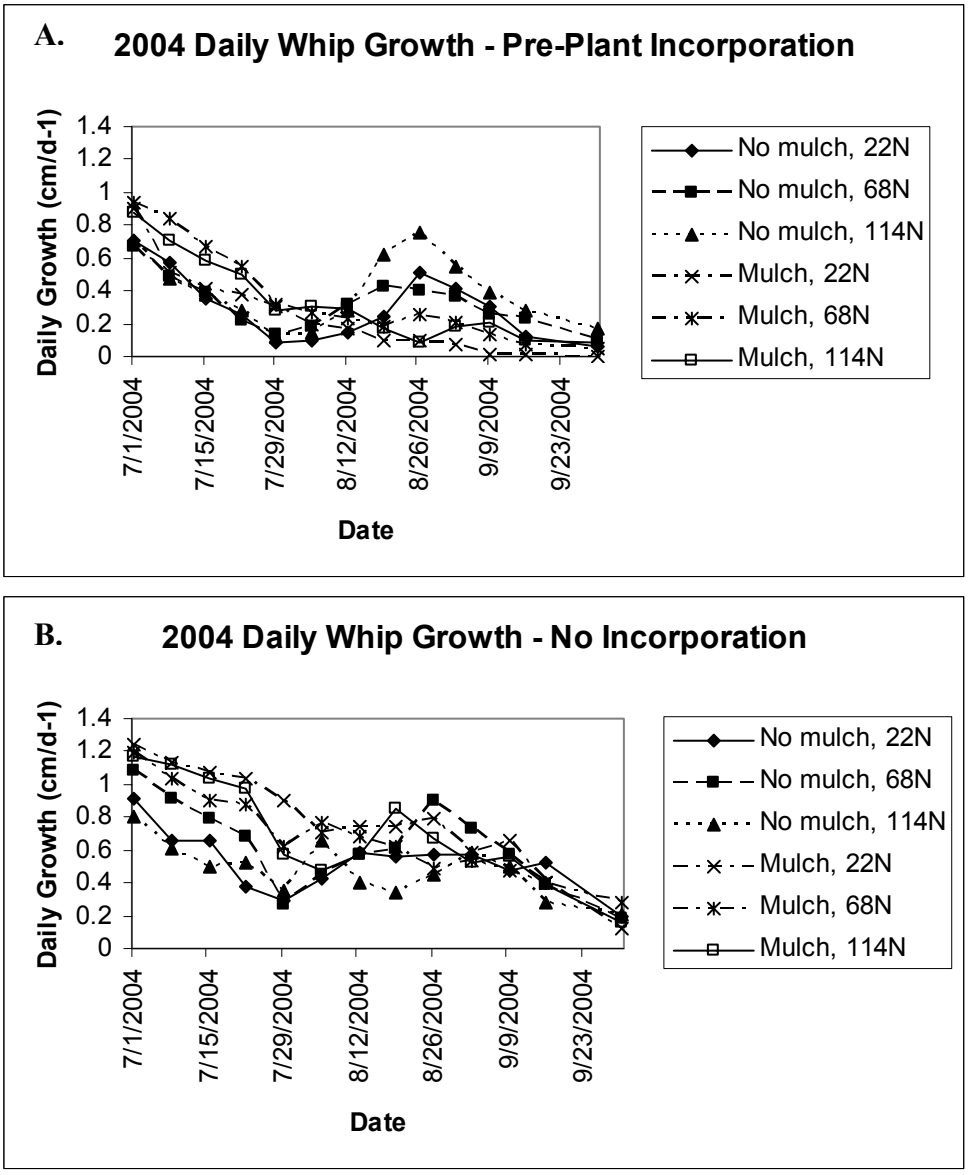

Figure 2. The effect of sawdust mulch and N fertilizer rate on daily whip growth ($cm \cdot d^{-1}$) in year two of an 'Elliott' planting in A) incorporated with pre-plant sawdust amendments and B) no incorporation.

Use of Phosphite Fungicides for Control of Blueberry Diseases in Georgia

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Introduction

Septoria and anthracnose leaf spots of blueberry, caused by *Septoria albopunctata* and *Colletotrichum gloeosporioides*, respectively, are prevalent and important leaf spots of blueberry. Surveys in 2002 and 2003 indicated that these are the primary leaf spots of blueberry in Georgia. When left uncontrolled, these diseases can cause considerable defoliation by mid-fall. Recent small-plot research has shown a significant negative effect of these diseases on both flower bud initiation and yield the following spring. As many as four fungicide applications may be required for adequate control of Septoria leaf spot; limited information has been developed relative to anthracnose control.

Control of Septoria has been largely limited to quinone outside inhibitor (QoI) products containing pyraclostrobin (Cabrio) and azoxystrobin (Abound) or the phosphonate fosetyl-Al (Aliette). More recently (2004), chlorothalonil (Bravo Weatherstik) has been utilized through a 24C (state) label developed for Georgia and Florida. Application costs for Aliette have been relatively high, and as a result, there has been strong producer resistance to use of this material. Chlorothalonil products cannot be utilized when fruit are present, due to phytotoxiciy issues. As such, additional efficacious, economical and safe rotation partners have been desired for QoI resistance management.

Phosphite, phosphate, and phosphonate materials have been previously reported to have efficacy and mode-of-action which is similar to that of Aliette, at a fraction of the cost. In addition, such materials have been purported to have activity against *Pythium* spp.,

which are often found in a root rot complex of southern highbush blueberries grown in high-density pine bark production beds, soils heavily amended with pine bark, and propagation systems (Cameron Whiting; *personal communication*). As such, testing was conducted in 2003-2005 to determine whether various phosphorous-containing materials would perform as well as Aliette for control of leaf spots, and an initial trial was performed to determine efficacy of a phosphite for control of a root rot complex, of which *Pythium* spp. are a component.

Materials and Methods

2003 dipotassium phosphonate on-farm trial for Septoria leaf spot control. In an initial on-farm trial, treatments were applied in dual strips within two varieties (Star and Premiere) at one site (Alma, GA). Treatments consisted of (a) an early-season grower standard fungicide program, without additional leaf spot control sprays, (b) Cabrio @ 14 oz/A), or (c) a dipotassium phosphonate fertilizer at 1 gal/A. Applications were made with a commercial air-blast sprayer (88 gal/acre spray volume). The leaf spot spray regimen consisted of a split block of applications, with three sprays for Septoria leaf spot (13 Jun, 5 Jul, and 21 Jul) and two sprays for anthracnose and rust diseases (4 and 18 Aug).

2004 leaf spot trial. Fungicide treatments for control of Septoria and anthracnose leaf spots of blueberry were evaluated in a commercial planting near Alma, GA (Bacon County). After harvest, four applications of either Aliette 80WDG, Biophos (20.4% dipotassium phosponate and 22.7% dipotassium phosphate by weight), ProPhyt (54.5% potassium phosphite by weight), Cabrio 20EG, Manzate 75DF, and an alternation treatment of Cabrio 20EG followed by ProPhyt (total of two applications for each product) were made to determine efficacy of these materials. Application dates were 12 Jun, 28 Jun, 12 Jul, and 27 Jul. An untreated check was included. Applications were made with a commercial air-blast sprayer (88 gal/acre spray volume). Treatments were applied to a randomized complete block design with five replications. Rows were spaced 12 ft apart, with a 6-ft spacing between plants. Each plot consisted of ten plants; the outer two plants in each plot were not utilized for disease assessment. All cultural practices were in keeping with methods commonly used in southern highbush blueberry production. For assessment of Septoria leaf spot incidence (percent infected leaves) and severity (number of lesions per leaf), at least 50 fully-expanded leaves were randomly collected from each plot on 10 Aug. Anthracnose was evaluated similarly on 20 Sep, except that disease severity was assessed as percent necrotic leaf area. Defoliation (percent leaves abscised) was determined by visual assessment on 3 Nov.

2005 leaf spot trials. Fungicide treatments for control of Septoria and anthracnose leaf spots of blueberry were evaluated in commercial ‘Star’variety plantings near Alma, GA (Bacon County) and Homerville, GA (Clinch County). After harvest, four applications of either Aliette 80WDG, Agri-Fos (45.8% mono- and dipotassium salts of phosphorous acid by weight), ProPhyt (54.5% potassium phosphite by weight), Cabrio 20EG, Procure 480SC, and an alternation treatment of Cabrio 20EG followed by ProPhyt (total of two applications for each product) were made to determine efficacy of these

materials. An untreated check was included. Application dates were 16 Jun, 30 Jun, 13 Jul, and 27 Jul for the Alma site, and 23 Jun, 7 Jul, 21 Jul, and 31 Jul for the Homerville site. Applications were made with a commercial air-blast sprayer (88 gal/acre spray volume for Alma and 34 gal/acre spray volume for Homerville). Treatments were applied to a randomized complete block design with five replications. Rows were spaced 12 ft apart, with a 6-ft spacing between plants. Each plot consisted of ten plants; the outer two plants in each plot were not utilized for disease assessment. All cultural practices were in keeping with methods commonly used in southern highbush blueberry production. For assessment of Septoria leaf spot incidence (percent infected leaves) and severity (number of lesions per leaf), at least 50 fully-expanded leaves were randomly collected from each plot on 10 Aug for both sites. Anthracnose was evaluated similarly on 29 Sep, except that disease severity was assessed as percent necrotic leaf area, and data was only collected from the Alma site. Defoliation (percent leaves abscised) was determined by visual assessment on 14 Nov, also only from the Alma site.

2005 Pythium root rot study. Fungicide treatments for control of Pythium root rot of blueberry were evaluated in a bark-bed research block at Griffin, GA. Blueberries had been grown previously in the bark bed from Fall 2003 to early Spring 2005, and new bark was not added after the initial planting was removed on 15 Mar, thereby increasing natural levels of *Pythium* species. After establishment of the second planting (variety 'Millennium') on 28 Mar, four applications of Ridomil Gold EC, Aliette 80WDG, and ProPhyt (54.5% potassium phosphite by weight) were made to determine efficacy of these materials. Application dates were 11 Apr, 11 May, 20 Jun, and 21 Jul. An untreated check was included. Ridomil Gold was applied as a drench application. Aliette and ProPhyt applications were applied to runoff with a backpack wand sprayer (57.5 gal/acre spray volume). Treatments were applied to a randomized complete block design with five replications. Each plot consisted of five plants. Rows were spaced 4 ft apart, with a 4-ft spacing between plants. All cultural practices were in keeping with methods commonly used in southern highbush blueberry production except for the use of excess irrigation. Plots were irrigated daily with ca. 0.3 to 0.4 inches of water to insure "wet" conditions in the growing media. For assessment of root rot severity, plants were rated subjectively on 7 Sep.

Results

Dipotassium phosphonate comparison strip trial. In the initial strip trial, dipotassium phosponate provided similar efficacy to that of Cabrio for control of Septoria leaf spot (Figs. 1 and 2). However, dipotasssium phosphonate did not provide control of rust, whereas Cabrio gave excellent control (data not presented). In these comparisons, both Cabrio and dipotassium phosponate treatments reduced the severity of Septoria leaf spot on the highbush blueberry cultivar Star ($P = 0.001$), while neither Cabrio nor dipotassium treatments provided disease severities which were significantly different from each other. Statistical analysis of disease incidence was not possible with this data, but both Cabrio and dipotassium phosphate provided substantially reduced Septoria leaf spot incidence, as compared to the untreated control.

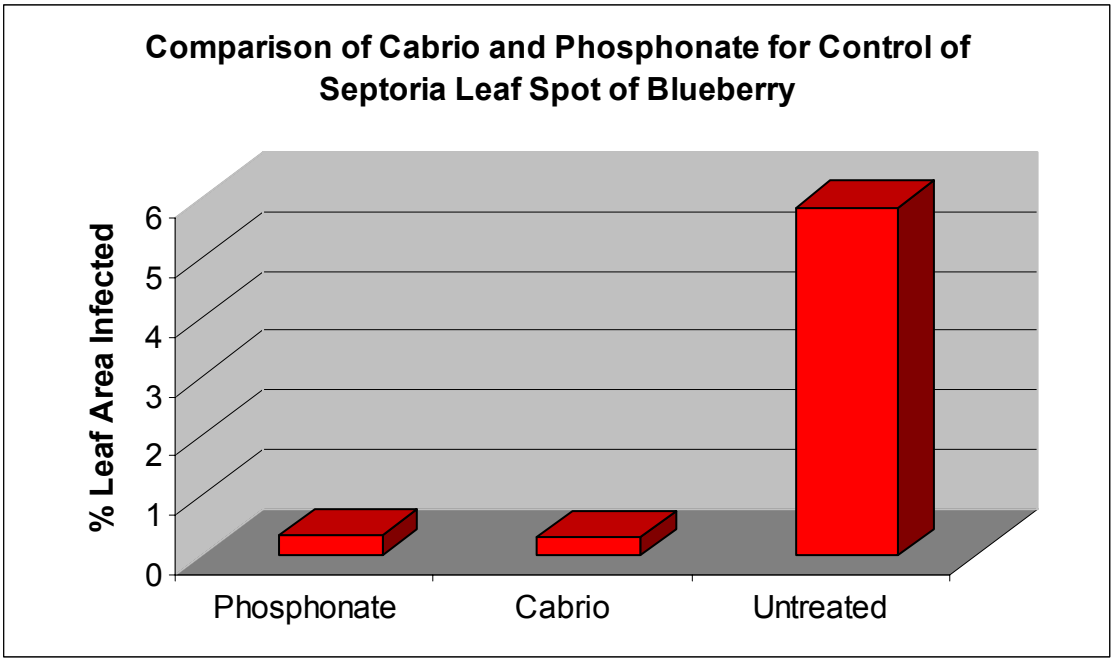

Figure 1. Septoria disease severity following treatment with Cabrio and phosphonate, as compared to an untreated control.

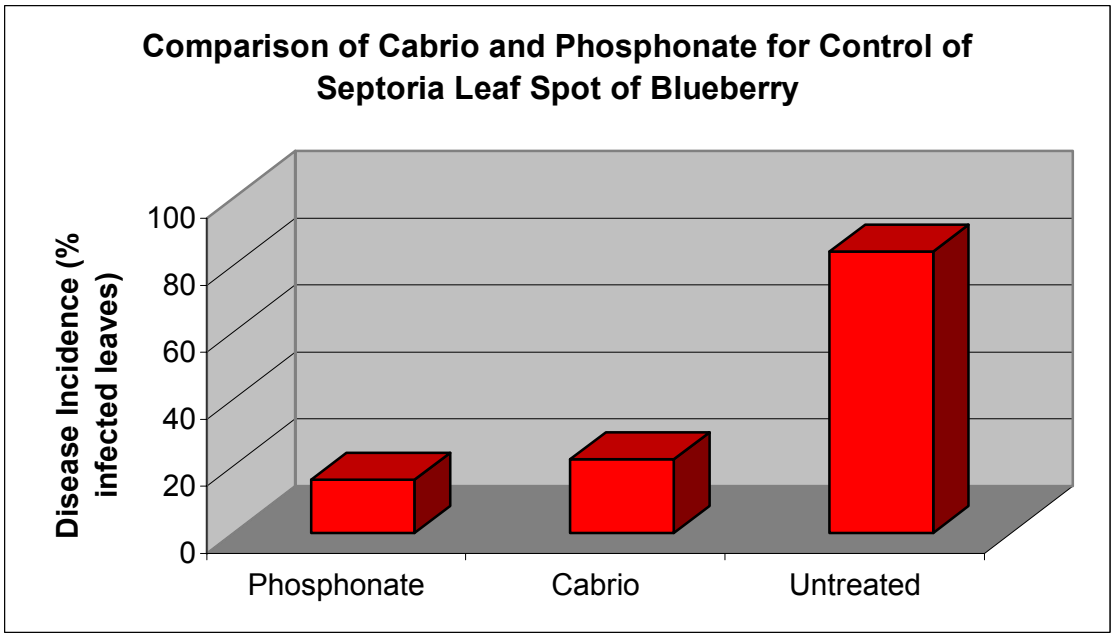

Figure 2. Septoria disease incidence following treatment with Cabrio and phosphonate, as compared to an untreated control.

2004 leaf spot trial. Septoria leaf spot, although sufficient for test purposes, did not develop to epidemic proportions observed elsewhere in Georgia in 2004. However, anthracnose was very prevalent and severe at this test site, apparently aided by a combination of adequate rainfall and overhead irrigation. All fungicide regimens, including the alternation program with Cabrio and ProPhyt, gave good to excellent control of both diseases (Table 1). Biophos, although providing substantial control of Septoria, was not as efficacious against anthracnose and in preventing premature defoliation as other materials at the rate tested.

Table 1. Comparison of Septoria and anthracnose leaf spot control when using phosphate and phosphite-containing materials (Alma, GA; 2004).

	Septoria leaf spot		Anthracnose		
Fungicide and rate/A	**Incidence[z]**	**Severity[z]**	**Incidence[y]**	**Severity[y]**	**Defoliation[x]**
1) Untreated Check	26.8 a[w]	1.3 a	66.4 a	21.9 a	60.0 a
2) Aliette 5 lb	0.0 b	0.0 b	11.6 c	2.0 bc	10.4 b
3) ProPhyt 4 pt	0.4 b	0.0 b	12.0 c	1.1 c	12.4 bc
4) Biophos 4 pt	0.4 b	0.0 b	22.4 b	3.9 b	22.0 b
5) Cabrio 20EG 14 oz	0.0 b	0.0 b	8.0 c	0.5 c	10.8 c
6) Cabrio 20EG 14 oz alternated with ProPhyt 4 pt (2 applications each)	0.0 b	0.0 b	13.2 c	1.1 c	11.6 bc
7) Manzate 75DF 3 lb	1.2 b	0.0 b	9.2 c	0.1 c	13.0 bc
LSD ($P = 0.05$)	7.8	0.4	8.2	2.2	10.9

[z]Disease incidence (percent infected leaves) and severity (average number of spots per leaf) were determined from a sample of >50 leaves per plot.
[y]Disease incidence (percent infected leaves) and severity (average percent leaf area affected) were determined from a sample of >50 leaves per plot.
[x]Defoliation (percent leaves abscised) was determined by visual assessment.
[w]Means in columns followed by the same letter are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

2005 leaf spot trials. Septoria leaf spot quickly developed to epidemic proportions at the Homerville, GA site, due to extensive rainfall throughout the test period. Trial initiation should have started as early as mid- to late May, as limited disease symptoms (spots) were observed during this timeframe. Due to the late start, incidence was high throughout the test, indicative of the importance of timely initiation of fungicide applications for effective control of this disease. All fungicide regimens, including the alternation program with Cabrio and ProPhyt, gave control that was sufficient for means separation (Table 2). Phosphorous acid generators (Aliette, ProPhyt, Agri-Fos), without

regard to specific chemical or formulation, provided disease suppression that was similar to that of the chemical standard, Cabrio. The degree of Septoria leaf spot suppression by Procure was also similar to the other treatments, but it did not exceed that of the current standard.

At the Alma site, Septoria leaf spot developed, but it was relatively less severe than observed elsewhere in Georgia in 2005, but anthracnose was very severe at this site, due to extensive rainfall. All fungicide regimens, including the alternation program with Cabrio and ProPhyt, gave good to excellent control of both diseases (Table 3). Procure, although providing substantial control of anthracnose, was once again not as efficacious against Septoria at this trial site, though no difference was observed between Procure and other fungicides relative to preventing premature defoliation. Aliette, ProPhyt, and Agri-Fos are all generally considered to be from the same chemical class, phosphonates, and activity of these materials was almost identical in this trial. Efficacy of Aliette, ProPhyt, and Agri-Fos were also very similar to that afforded by Cabrio, the chemical standard for this trial. The alternation treatment of Cabrio and ProPhyt was as efficacious as that of Cabrio alone.

Table 2. Comparison of Septoria leaf spot control when using phosphite-containing materials (Homerville, GA; 2005).

	Septoria leaf spot	
Fungicide and rate/A	**Incidence[z]**	**Severity[z]**
1) Untreated Check	86.0 a[y]	16.4 a
2) Aliette 5 lb	62.4 c	5.3 b
3) ProPhyt 4 pt	82.0 ab	7.7 b
4) Agri-Fos 5 pt	63.2 c	3.0 b
5) Cabrio 20EG 14 oz	64.8 c	5.5 b
6) Cabrio 20EG 14 oz alternated with ProPhyt 4 pt (2 applications each)	69.6 bc	5.5 b
7) Procure 480SC 16 fl oz	67.2 bc	8.2 b
LSD ($P = 0.05$)	15.8	5.9

[z]Disease incidence (percent infected leaves) and severity (average number of spots per leaf) were determined from a sample of >50 leaves per plot.

[y]Means in columns followed by the same letter are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

Table 3. Comparison of Septoria and anthracnose leaf spot control when using phosphite-containing materials (Alma, GA; 2005).

	Septoria leaf spot		Anthracnose		
Fungicide and rate/A	**Incidence[z]**	**Severity[z]**	**Incidence[y]**	**Severity[y]**	**Defoliation[x]**
1) Untreated Check	60.4 a[w]	3.3 a	67.6 a	20.5 a	43.0 a
2) Aliette 5 lb	8.4 c	0.1 b	22.8 b	2.3 b	15.2 b
3) ProPhyt 4 pt	10.8 c	0.2 b	20.0 bc	2.7 b	10.0 b
4) Agri-Fos 5 p	9.2 c	0.2 b	18.0 bc	1.7 b	12.0 b
5) Cabrio 20EG 14 oz	10.8 c	0.2 b	7.6 d	0.4 b	8.8 b
6) Cabrio 20EG 14 oz alternated with ProPhyt 4 pt (2 applications each)	5.6 c	0.1 b	10.4 cd	1.0 b	4.2 b
7) Procure 480SC 16 fl oz	31.6 b	0.8 b	13.2 bcd	1.0 b	13.8 b
LSD ($P = 0.05$)	15.2	1.5	9.7	2.7	15.0

[z]Disease incidence (percent infected leaves) and severity (average number of spots per leaf) were determined from a sample of >50 leaves per plot.
[y]Disease incidence (percent infected leaves) and severity (average percent leaf area affected) were determined from a sample of >50 leaves per plot.
[x]Defoliation (percent leaves abscised) was determined by visual assessment.
[w]Means in columns followed by the same letter are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

2005 root rot trial. Pythium root rot was observed uniformly throughout the bark-bed site. Frequent rainfall during the spring and summer coupled with the daily irrigation contributed to severe disease conditions. Control by Ridomil came as no surprise, as mefenoxam is known to be very effective against *Pythium* species. However, Aliette and ProPhyt provided equivalent control (Table 4 and Fig. 3). Although Pythium root rot of blueberry is not specified in labels for these products, both are known to control other Oomycete pathogens, such as *Phythophthora* species.

Table 4. Comparison of Pythium root root control when using phosphite-containing materials (Griffin, GA; 2005).

Fungicide and rate/A	Pythium root rot severity [z]
1) Untreated check	2.2 b[x]
2) Ridomil Gold EC 0.4 gal[w]	3.6 a
3) Aliette 80WDG 5 lb	3.9 a
4) ProPhyt 4 pt	3.7 a
LSD ($P = 0.05$)	0.4

[z]Disease severity was determined through use of a subjective visual rating scale (0 = dead plant, 1 = partial death of the plant with extreme stunting, 2 = extreme leaf discoloration (reddening and yellowing) and plant stunting, 3 = moderate reddening of leaves and plant stunting, 4 = limited symptoms and very minor plant discoloration, 5 = healthy plant.
[x]Means followed by the same letters are not significantly different according to Fisher's protected LSD test (P = 0.05).
[w]Ridomil Gold was applied as a drench (0.02 fl oz per quart final solution applied to each plant).

Figure 3. Comparisons of Pythium-active treatments as observed in a preliminary high-density bark-bed blueberry trial (Griffin, GA). Left to right, the application of Aliette, ProPhyt, or Ridomil Gold provided excellent control of root rot, resulting in substantial benefits in plant health and survival as compared to the untreated control on the right. All fungicide treatments provided near equivalent control.

Conclusions

Aliette contains aluminum tris-O-ethyl phosponate, of which the phosponate moiety may be critical to activity. Based on these trials and similar research efforts, related phosphite-containing materials, such as ProPhyt or Agri-Fos appear to have similar or identical activity to that of Aliette for control of Septoria and anthracnose leaf spots. In addition, these materials are generally as efficacious as strobilurin products such as Cabrio. Rotation partners are always required for strobilurin resistance-management programs, so these tests open up the possibility of using these less expensive materials in rotation with strobilurins for control of blueberry leaf spot diseases.

Southern highbush blueberry varieties mature during a market window that allows for high profitability, but these varieties are particularly susceptible to both leaf spot diseases and root rots. The southern highbush varieties are often poorly adapted for soils with low organic matter. As a result, high-density pine bark beds are utilized as an alternative, circumventing the organic matter issue; or, pine bark amendment is used heavily in soils. These systems have issues that have not been observed in traditional rabbiteye blueberry production. Plants often die within a relatively short period of time (1-3 years), and replants are generally necessary. Some of the causal organisms associated with this root-rot decline, and as far as we know at this time, these are unique as major pathogens to the pine bark systems; *Pythium* and *Rhizoctonia* spp. have been found in constant association with the disease, and initial tests (Cameron Whiting; *personal communication*) have shown these to be pathogenic. These pathogens are thought to act in a disease complex, with the *Pythium* spp. acting as root "nibblers," allowing for secondary infections of *Rhizoctonia* spp., as observed in cotton and other plant systems. Due to the high value of the commodity in question, extension of the productive life of plants would be of incredible value to the blueberry industry.

Since phosphites also control Septoria and anthracnose leaf spots, the added benefit of Pythium root rot control is a particularly positive prospect for the blueberry industry. If we can obtain additional data to support the use of phosphites for control of the root rot complex observed in pine bark systems, we can further incorporate these materials into an integrated management program. We would recommend early-spring applications of phosphites in alternation with strobilurins for leaf spots and Ridomil (mefenoxam) for root rot, resulting in adequate control of both leaf spots and the root rot complex. The benefit to the long-term plant health should be either additive or synergistic, since both leaf spots and root rots weaken plants, resulting in poor growth and premature mortality.

Literature Cited

Brannen, P. M., Scherm, H., and Bruorton, M. D. 2001. Use of selected fungicides for control of Septoria leaf spot of blueberry, 2000. Fungic. Nematicide Tests 56:SMF1.

Brannen, P. M., Scherm, H., and Bruorton, M. D. 2002. Fungicidal control of Septoria leaf spot of blueberry, 2001. Fungic. Nematicide Tests 57:SMF46.

Brannen, P. M., Scherm, H., and Bruorton, M. D. 2003. Fungicidal control of Septoria leaf spot of blueberry, 2002. Fungic. Nematicide Tests 58:SMF019.

Cline, W. O. 2002. Blueberry bud set and yield following the use of fungicides for leaf spot in North Carolina. Acta Hortic. 574:71-74.

Milholland, R.D. 1995. Anthracnose fruit rot (ripe rot). Page 17 in: Compendium of Blueberry and Cranberry Diseases. F. L. Caruso and D. C. Ramsdell, eds. American Phytopathological Society, St. Paul, MN.

Milholland, R.D. 1995. Septoria leaf spot and stem canker. Page 16 in: Compendium of Blueberry and Cranberry Diseases. F. L. Caruso and D. C. Ramsdell, eds. American Phytopathological Society, St. Paul, MN.

Ojiambo, P. S., Scherm, H. and Brannen, P. M. 2006. Septoria leaf spot reduces flower bud set and yield potential of rabbiteye and southern highbush blueberries. Plant Dis. 90:51-57.

On-farm Evaluation of Reduced-risk Insect Management Programs in Michigan Blueberry

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Introduction

Blueberries are host to more than 30 insect pests in their main production regions across eastern North America. The most important of these includes blueberry maggot (BBM), *Rhagoletis mendax,* Japanese beetle (JB), *Popillia japonica*, blueberry aphids (BBA), *Illinoia spp.* and *Ericaphis* spp., cranberry fruitworm (CBFW), *Acrobasis vaccinii*, obliquebanded leafroller (OBLR), *Choristoneura rosaceana*, thrips complex (*Frankliniella spp.* and *Catinathrips spp.*), and the scarab grub complex (mostly JB and oriental beetle (OB), *Exomala orientalis*) (Pritts and Hancock 1992, Polavarapu 2001). Blueberries can also be affected by a plethora of secondary pests: 292 species have been recorded on lowbush blueberries (Phipps 1930). As with many fruit and vegetable crops, the blueberry marketplace demands insect-free fruit, necessitating an intensive insect management program which in Michigan's 18,000 acres of blueberry is directed primarily at control of BBM, JB and CBFW, because of their potential for direct infestation or damage to the fruit.

Organophosphate and carbamate insecticides have been the foundation of insect pest management programs in blueberries for the past 40 years (Drummond 2000), allowing growers to meet the market's demands for insect-free fruit. Up to 90% of insecticide applications in the main production regions are broad-spectrum organophosphate and carbamate insecticides (Polk and Samoil 1993, Dill et al. 1998, R. Isaacs, unpubl.), and depending on pest pressure, variety, and market segment, between two and 12 insecticide sprays are made per season. Because some key insects pests such as JB and BBM are active in the period approaching harvest, many of the broad-spectrum insecticides are applied just before or during the harvest period that can extend for up to a month in highbush blueberry production. Blueberries may also be harvested by hand, creating a potential for worker-exposure to broad-spectrum insecticide residues.

More stringent requirements for pesticide registration in all food crops have been developed in the US in response to the Food Quality Protection Act of 1996. This is expected to restrict availability of many traditional broad spectrum insecticides for minor food crops such as blueberry. Although new insecticides are being registered, they must pass the same requirements for registration and as a result, many of these compounds are more selective than broad spectrum insecticides and require more accurate timing for optimal control. There is also concern that adoption of new reduced-risk insecticides will enable resurgence of secondary pests such as plum curculio

(*Conotrachelus nenuphar*) and tussock moth (*Orgyia leucostigma*). Transition to new insecticides may also be costly, as they tend to be more expensive than conventional insecticides, require greater effort in scouting and monitoring to apply effectively, and may need to be applied by tractor rather than by airplane. While these potential limitations suggest adoption of reduced–risk insecticides would be limited, there are also potential benefits to their adoption. Many have low toxicity to natural enemies (though see Williams et al. 2003), and in some cases they may be more active on the target pest. For example, the neonicotinoid insecticide imidacloprid was recently registered in blueberry and provides superior control of the blueberry aphid, *Illinoia pepperi,* compared to the current alternatives (Polavarapu and Peng 2000a,b). The reduced-risk insecticides registered for use in blueberry provides an opportunity to test whether implementation of an insect control program based on their use will provide the benefits expected.

Grower adoption of IPM programs that employ reduced-risk controls is much more likely if the efficacy, implications for natural enemies, and economics of such programs are measured and demonstrated in commercial agriculture settings. Without this, the perceived risk and complexity of transitioning away from broad-spectrum insecticide spray programs will limit their adoption. This project aims to measure the implications of transition to reduced-risk insecticides for blueberry growers, to provide advance knowledge of these implications before potential legislative decisions force these changes. This was done by implementing a comprehensive season-long insect pest management program appropriate to the local insect pest complex at blueberry farms in Michigan for two years. In this report, we present the results of our measurements to determine whether this change affected 1) abundance of arthropod pests, 2) levels of aphid parasitism, 3) abundance of secondary pests, and 4) cost of insecticide programs.

Materials and Methods

This project was conducted at six blueberry farms in west Michigan. In spring of 2003, two 2-4 Ha fields of *V. corymbosum*, cv. Bluecrop or Jersey, with similar insect pest pressure were selected at each farm. Both fields at each farm were scouted weekly during 2003-2005 for insect pests and natural enemies as described below. One of the fields was managed with the grower's conventional insecticide program based on broad spectrum insecticides, while the other field was managed in response to the weekly scouting results and was treated with reduced-risk insecticides (Table 1). The RAMP program included a perimeter application of Admire 2F for control of Japanese beetle grubs. The same fungicides and herbicides were applied to each field at each farm, and all applications were made by the growers using standard application technology.

Pest sampling. Each field was visited weekly and scouted intensively for the main pests listed in Table 1, using pheromone traps, yellow sticky traps and sampling of 200 fruit and vegetative tissues per field. During these samples, we also sampled for minor or secondary pests such as plum curculio, sharpnosed leafhopper, and tussock moth. Immediately before each of the three harvests in each field, a sample of 100 clusters

was taken from each field and held in the laboratory over sand. After one month, sand was sifted to determine the abundance of cranberry fruitworm hibernaculae and blueberry maggot pupariae. To sample for Japanese beetle, 25 soil cores were taken with a golf-course cup cutter in the grassy regions around each field. Samples were taken during the initial spring of this project in 2003 and in the fall of each year. Total captures of pests in traps and their abundance on bushes and in harvest samples were compared between the two management programs using ANOVA followed by post-hoc tests to compare between means or using the Kruskall Wallace test if the data did not meet the assumptions of ANOVA (Statview v 4.57, Abacus Concepts, Berkeley, CA.).

Table 1. Conventional and reduced-risk insecticides registered for use against key insect pests in Michigan blueberry fields through the growing season.

Month	Crop stage	Target Pest*	Conventional	RAMP
April	Pre bloom	Leafrollers	Lannate, Asana	Confirm
May	Bloom	CBFW	*B.t.*	Confirm
		CFW	*B.t.*	Confirm
Jun-July	Post bloom	CBFW	Guthion, Asana	Confirm
		OBLR	Imidan, Lannate	Confirm
		BBA	Lannate	Provado (foliar)
		White grubs	-	Admire (soil)
		JB	Imidan, Sevin, Asana	Provado
July-Aug	Mid-season	BBM	Malathion, Imidan	SpinTor, Provado
		BB aphid	Lannate, Provado	Provado
July-Sept	Pre-harvest	JB	Imidan, Sevin	SpinTor
		BBM	Imidan, Malathion	SpinTor, Provado

*CBFW = cranberry fruitworm, *Acrobasis vaccinii*; CFW = cherry fruitworm, *Grapholitha packardii*; OBLR = obliquebanded leafroller, *Choristoneura rosaceana*; BBA = blueberry aphid, *Illinoia pepperi*; JB = Japanese beetle, *Popillia japonica*; BBM = blueberry maggot, *Rhagoletis mendax*.

Aphid and parasitoid sampling. To measure aphid and parasitoid abundance in more detail than the general pest scouting, once the percentage of bushes with aphids present reached ~20%, colonies were intensively sampled approximately every two weeks (5 June to 7 August 2003, and 9 July to 12 August 2004). Within each of four sub-sections of the fields, we located 5 bushes infested with aphids. On each bush, the number of aphids and mummies on each branch of first-year growth was recorded. All leaves with mummies were collected and held individually in 2 oz plastic cups until a parasitoid wasp emerged. Parasitoids were identified to genus or in the case of some hyperparasitoids, to family. Mean percent aphid parasitism was calculated for each field on each sampling date and the mean number of aphids per branch and percent parasitism were compared between programs using ANOVA (Statview v 4.57, Abacus Concepts, Berkeley, CA.).

Program cost comparison. At the end of the growing season, application records from the growers were used to determine the number of insecticide sprays and cost per acre of the two management programs

Results and discussion

Pest abundance. There was no significant difference between the two programs in the degree of cranberry fruitworm infestation in either year, although the proportion of clusters infested was slightly higher in the RAMP program (Figure 1). When hibernaculae were counted, there was also no significant difference, but the number of hibernaculae was consistently lower in the RAMP program. This suggests that the growth regulator mode of action of Confirm does not work as effectively as the broad-spectrum insecticides at preventing larvae enter fruit, but the larvae are killed soon after entering the berries and do not survive to web fruit together and complete development.

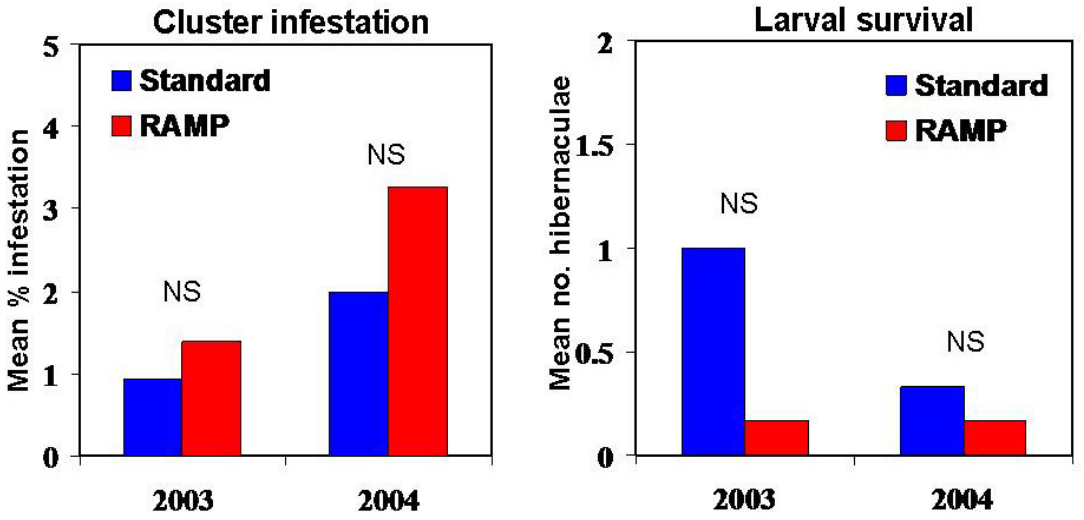

Figure 1. Proportion of clusters infested with cranberry fruitworm and the number of hibernaculae surviving in fruit collected from blueberry fields managed under conventional or RAMP insecticide programs during 2003 and 2004. NS = not significantly different, P>0.05

Across both years and both programs, no blueberry maggots were collected from fruit collected near harvest. This is despite monitoring traps trapping flies in both programs during both years. This complete lack of infestation by this important pest provides strong evidence for the efficacy of Provado and SpinTor against this insect, as these were the primary insecticides used in the RAMP program in the period prior to harvest.

Japanese beetles were seen on bushes in July and August during weekly bush sampling, and their larvae were also found during soil sampling. The number of beetles on bushes as highly variable between farms, and there was no consistent difference between programs in the season-long abundance of beetles. This is despite the high level of control provided by application of Admire to the soil around the RAMP fields. As shown in Table 2, the June application of Admire at 16 oz/acre provided over 90% control of this pest in the larval stage. The lack of a corresponding reduction in adult beetle abundance is likely due to the highly mobile behavior of this insect and the relatively small area of application of the Admire. Future research should address larval management of this pest at a larger scale if reduced adult beetle pest pressure is to be realized.

Table 2. Larval density of Japanese beetle (number/sq. ft. ± S.E.) in grassy drivelanes around blueberry fields managed under standard (no soil insecticide) and RAMP (Admire 2F in June) management programs.

Sample	Standard	RAMP	% control	*P*
Spring 2003	0.98 ± 0.42	1.24 ± 0.21	-	NS
Fall 2003	2.33 ± 0.50	0.11 ± 1.20	95.3	0.030
Fall 2004	0.39 ± 0.14	0.03 ± 0.03	92.3	0.026

Aphid parasitoids. In the first year of transition to a reduced-risk insecticide program, aphid abundance was not significantly different between programs at any sampling date ($P>0.05$ for all dates, data not shown), and the rate of aphid parasitism was also not significantly different between programs for any date (Fig. 2). Responses to the changing spray program were apparent in the aphid population in Year 2: aphid abundance was significantly lower in fields treated with the reduced-risk insecticide program (data not shown), and aphid parasitism was significantly greater in the same fields by the Aug 9 sample (Fig. 2).

Program cost comparison. On average there were slightly more sprays applied to the RAMP fields than the grower standard fields in both years (2003: Standard 5.8, RAMP 7.5; 2004: Standard 5.3, RAMP 5.5), and in both years there was some application of broad spectrum insecticides in the RAMP field around the time of the final harvest, when no more reduced-risk insecticides could be used. There was a much higher cost of the RAMP program in both years with $68.52 vs. $180.30 for the insecticides applied in 2003 and $55.31 vs. $151.11 in 2004. These cost comparisons reveal one of the greatest barriers to adoption of these practices. In future years, our focus will be on reducing the cost of the RAMP program to within the range that growers can afford, with a focus on those insecticides with improved performance over the broad-spectrum alternatives.

The Blueberry RAMP project will continue to monitor the response of pests and natural enemies to the changing insecticide program for a further two years. In addition, measuring the degree of pest control achieved by increasing populations of natural enemies should be a priority, to provide growers with confidence that the additional cost

of reduced-risk insecticides provides additional benefits above direct pest control. This research will need to be done within the context of cost-effectiveness if adoption of these reduced-risk insecticides is ever to be realized on a large scale. Because of economic constraints, we expect reduced-risk insecticides will be integrated into blueberry management programs where they are most effective and where they provide perceived improved performance compared to the currently-used conventional management program.

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Literature Cited

Dill, J.F, F.A. Drummond and C.S. Stubbs. 1998. Pesticide Use on Blueberry: A Survey. Penn State Contract No. USDA-TPSU-UM-0051-1300. Univ. ME, Orono, ME.

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

Phipps, C.R. 1930. Blueberry and Huckleberry Insects. Maine Agric. Exp. Stn. Bull. 356, 232 pp.

Polavarapu, S. 2001. Life-history of major arthropod pests infesting highbush blueberries. Proceedings of Mid-Atlantic Fruit and Vegetable Convention, Hershey, PA, Vol. II: 28-30.

Polavarapu, S. and H. Peng. 2000a. Evaluation of foliar applications of insecticides against blueberry aphids on blueberries, 1998. Arthropod Management Tests. 25: 64.

Polavarapu, S. and H. Peng. 2000b. Efficacy of soil applied insecticides against blueberry aphids on blueberries, 1998. Arthropod Management Tests. 25: 65.

Polk, D. F. and K.S. Samoil. 1993. Blueberry Pesticide use and fruit quality 1992. In Proceedings Blueberry Openhouse 1993, 8-10.

Williams, T Valle, J & Viňuela, E. (2003) Is the naturally derived insecticide spinosad compatible with insect natural enemies? Biocontrol Science and Technology 13, 459-475.

Studies on Transmissibility of Stem Canker via Cuttings From Infected Plants

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Introduction

Blueberry stem canker caused by the fungus *Botryosphaeria corticis* has historically been a major limiting factor for highbush blueberry production in North Carolina. The fungus causes swollen, fissured cankers on stems of cultivated and wild blueberry that block vascular elements and result in death of the stem above the canker. The fungus is endemic and limited to a single host genus (Farr, et al, 1989); eight cultivar-specific races have been identified (Cline & Milholland, 1988; Milholland, 1984; Milholland & Galletta, 1969). The need to produce canker-free plants was recognized over 30 years ago, and attempts were made to use chemical and heat treatments to eradicate the disease from infected, dormant hardwood cuttings, with mixed success (Beute and Milholland, 1970; Milholland, 1977). Traditionally, growers in NC have propagated using hardwood cuttings. However, since the early 1980s, the use of intermittent mist systems to propagate leafy, summer softwood cuttings has increased. Softwood cuttings are the favored method of propagating canker-susceptible cultivars, because softwood cuttings appear to be at least visibly free of disease, and plants produced in this way are thought to be less likely to carry infections to new fields. This study was initiated to 1) determine whether the stem canker fungus can in fact be recovered from plants that were rooted using infected cutting wood, and 2) compare disease incidence in softwood vs hardwood rooted cuttings from infected mother plants.

Materials and Methods

Plant propagation. All cuttings were taken from severely infected field-grown 'O'Neal' plants at the NCSU Horticultural Crops Research Station in Castle Hayne, NC. Experiments were conducted beginning in December of each year (2003-2006) with collection of visibly infected hardwood cuttings. One-year-old hardwood whips were cut into 4-5 inch sections, bundled, and stored in plastic bags at 40 ^{o}F until April, at which time cuttings were stuck 3-4 inches deep in an 8" deep rooting bed filled with pine bark. Rooting was accomplished with a combination of hand watering and intermittent mist. Plants were dug in Nov-Dec and heeled-in at 40 ^{o}F in moist sawdust. Leafy softwood cuttings, none with visible infections, were collected from the same bushes in August of each year and immediately stuck in pine bark under intermittent mist (10 sec every 5 min, 9:00 am to 6:00 pm) until rooted (approx 8 wk). Softwood cuttings were also left in the rooting beds until winter, then dug and stored at 40 ^{o}F. Where plants were grown in pots for a year prior to assay, rooted cuttings were potted in a 1:1:1 mixture of peat:sand:pine bark and maintained in an outdoor lath house.

Isolation of the fungus. Cuttings and potted plants were assayed for the presence of the stem canker fungus by isolation on acidified potato-dextrose agar (aPDA). Prior to the assay, all shoot and root growth was excised and discarded, leaving only the 1-2 yr old central stem from the original cutting. Stems were washed and surface-sterilized for 15 min in a 10% aqueous solution of household bleach (6% sodium hypochlorite), then allowed to air-dry under sterile conditions in a microvoid hood. Ten plants were assayed in each category at each date, and for each plant, multiple isolations were attempted. A scalpel was used to excise and transfer five, 3-5 mm stem pieces from each stem onto a single 150 mm culture plate containing aPDA. Where possible, isolations were made from visibly symptomatic areas. Cultures were grown under continuous fluorescent light for 7-14 days, then evaluated visually for the presence of characteristic colonies of the stem canker fungus. Colonies were counted and plates discarded; the experiment was repeated once.

Results

Using multiple isolations per plant, the stem canker fungus was readily recovered from 85-90% of both 1- and 2-yr-old plants that had been rooted from infected hardwood cuttings (Table 1). By comparison, infection was detected in only one of the plants rooted from softwood cuttings. These results show that 1) blueberry stem canker can be disseminated via infected cutting wood and 2) softwood cuttings are far less likely to be infected.

Discussion

Recovery of the fungus in 1-2 year old plants rooted from hardwood cuttings demonstrates the ease with which stem canker can travel to new fields on infected planting stock; the use of visibly infected hardwood cuttings for propagation wood seems to virtually guarantee future problems. Fields established with infected rooted hardwood cuttings, such as the ones used in this study, would have 70-100% canker incidence at time of planting, severely limiting their productivity and survival.

Incidence in plants rooted from softwood cuttings was far lower; in fact canker could not be detected in 95% of the plants tested. However, though canker was recovered in only one isolation from a single softwood plant, the fact that it was recovered at all is troubling news for growers. Even low initial incidence (5% in this case) may eventually spread throughout the planting over a period of many years. What is not known at this time is whether these infrequent and invisible canker infections on softwood cuttings will actually lead to disease. Such infections may also be far easier to eradicate with fungicides than those on hardwood cuttings.

Literature cited

Beute, M. K. and R. D. Milholland. 1970. Eradication of *Botryosphaeria corticis* from blueberry propagation wood. Plant Disease Reporter 54(2): 122-127.

Cline, W. O. and R. D. Milholland. 1988. Identification of a new race of *Botryosphaeria corticis* on highbush and rabbiteye blueberry in North Carolina. Plant Dis. 72:268.

Farr, et al. 1989. Fungi on Plants and Plant Products in the United States. APS Press, St. Paul, Minn. 1252 pp.

Milholland, R. D. 1984. Occurrence of a new race of *Botryosphaeria corticis* on highbush and rabbiteye blueberry. Plant Dis. 68:522-523.

Milholland, R. D. 1977. Histopathological effects of benomyl on blueberry stem canker development caused by *Botryosphaeria corticis*. Plant Disease Reporter 61(10) 874-878.

Milholland, R. D. and G. J. Galletta. 1969. Pathogenic variation among isolates of *Botryosphaeria corticis* on blueberry. Phytopathology 59:1540-1543.

Table 1. Detection of the stem canker fungus (*Botryosphaeria corticis*) in rooted cuttings propagated from infected 'O'Neal' bushes.

Cutting type	Age of plant [x]	Series # 1		Series # 2	
		Colonies in 50 isolations [y]	# infected cuttings	colonies in 50 isolations [y]	# infected cuttings
Hardwood	24 mo	27/50	9 of 10	26/50	9 of 10
Hardwood	12 mo	15/50	7 of 10	26/50	10 of 10
Softwood	18 mo	0/50	0 of 10	1/50	1 of 10

[x] Plant age at time of assay, measured from the time the original unrooted cutting was stuck in the propagation bed.
[y] Number of successful canker isolations / total number attempted

Effects of Cultural Practices and Chemical Treatments on Phytophthora Root Rot Severity of Blueberries Grown in Southern Mississippi

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Introduction

Phytophthora root rot, caused by *Phytophthora cinnamomi* Rands, is a serious disease of highbush blueberry (*Vaccinium corymbosum* L.) and southern highbush blueberry cultivars (hybrids between *V. corymbosum* and various blueberry species native to the southeastern U.S). Rabbiteye blueberry (*V. ashei* Reade) cultivars commonly grown in the southeastern United States are less susceptible to this disease. In areas where both highbush and rabbiteye cultivars are grown, such as North Carolina and Arkansas, Phytophthora root rot is widespread on highbush blueberry, but rabbiteye cultivars in the same area are resistant (Austin, 1994). Southern highbush cultivars are being grown in the southeastern U.S. for their early fruit production and reduced chilling requirement. In Florida, Phytophthora root rot is a major disease of southern highbush blueberry plants (Lyrene and Crocker, 1991). As the acreage of blueberries increases, the potential threat of losses due to Phytophthora root rot also increases.

Phytophthora root rot is most severe when blueberries are grown in wet soils with poor drainage. The initial infection of the roots may occur in nursery beds, in container yards when pots are set on poorly drained areas, and in fields infested with the pathogen. The causal fungus is spread by the movement of soil and water, and abundant soil moisture favors infection (Milholland, 1995). *Phytophthora cinnamomi* attacks the small feeder roots, and the infection process occurs rapidly - within 24 hours on highly susceptible highbush cultivars (Milholland, 1975). Symptoms of Phytophthora root rot are small, yellow or red leaves, lack of new growth, root necrosis, and a smaller than normal root system. Infected plants generally have fewer and poorer quality fruit than non-infected plants. This study was initiated in 2000 to evaluate the effect of drainage and fungicide treatments on Phytophthora root rot disease severity of mature infected blueberries and the effect of drainage, bed height, and fungicide treatments on Phytophthora root rot disease severity of young blueberries planted into infested soil.

Materials and Methods

Effect of drainage and chemical treatments on infected, mature blueberry plants. In February 1985 plants of the rabbiteye blueberry cultivar Tifblue were transplanted to a field with Ruston fine sandy loam soil naturally infested with *P. cinnamomi.* During the following 15 years, most of the 400 plants in this field displayed severe root rot symptoms and many died. In the fall of 1999 all plants were removed from three pairs of rows in this field, and the living plants in the remaining four rows were uniformly pruned back to a height of 1.3 m. During the summer of 2000 drainage treatments were applied to blocks of the surviving plants in each row. The treatments were (subsoil) subsoiling to a depth of 1 m on the west side of the plants using a chisel plow; (tile) installation of a 10 cm perforated drainage pipe about 0.8 m deep and 1 m to the west side of each plot; and (control) no treatment. As a split plot within each drainage treatment, three fungicide treatments were applied as a drench using 5.7 liters of water per 7.5 m^2 plot beginning on 1 March 2001. The fungicide treatments were (control) no chemical treatment, (experimental) an unlabelled test compound, and (metalaxyl) Ridomil 2E (Ciba-Geigy, Greensboro, NC) applied at the rate of 0.23 ml a.i. per plot twice a year in the spring and after fruit harvest. Each plot consisted of two plants, and all treatments were replicated five times. Irrigation was applied as needed via drip tape. Plant height and width were measured each year in July, and plant size was calculated as volume using the height and width measurements. In addition, the weight of live and dead canes was recorded for each plant at the conclusion of the study in July 2004. To confirm the presence of *Phytophthora* spp., roots were collected periodically from symptomatic plants, surface sterilized, and plated out on Tsao and Guys's PVPH+hymexozol media selective for *Phytophthora* spp. (Tsao, 1983).

Effect of drainage, bed height, and chemical treatments on young blueberry plants. 'Tifblue' blueberry plants were removed from three pairs of rows in the field described above, and a new row was prepared in the center of the space where each pair of rows was removed. In the spring of 2000 one-year-old potted plants of the southern highbush cultivar, Misty, and two-year-old plants of the rabbiteye cultivar, Tifblue, were transplanted in a split-split block design into these rows. Whole plots were bed height either flat or raised beds (0.3 m high x 0.7 m wide). Within each bed height, the first split plot was one of two drainage treatments: drainage tile and control as described above. As a second split-plot within each drainage treatment, two fungicide treatments were applied as a drench using 5.7 liters of water per 7.5 m^2 plot beginning on 1 March 2001. The fungicide treatments were (control) no chemical treatment and (metalaxyl) Ridomil 2E applied at the rate of 0.23 ml a.i. per plot twice a year before leaf emergence in the spring and after fruit harvest in the summer. Plants were spaced 1 m apart and grown consistent with standard commercial practices for rabbiteye blueberries in the southeastern U.S. Irrigation was applied as needed via drip tape. The number of surviving plants, plant height and size were determined each year in July. The southern highbush plants were removed in July 2004.

Statistical analyses. Analyses of variance were used to determine the effects of treatments on plant height, size, cane weight, and the percentage of living plants.

Means were separated by Fisher's Protected least significant difference test (SAS System, version 8.2; SAS Institute, Inc., Cary, NC).

Results

Effect of drainage and chemical treatments on renovation of infected, mature blueberry plants. In 2001 one year after drainage treatments were applied, and four months after the first chemical treatments were applied there were no differences due to drainage treatment in the height (Table 1) or size of plants (data not shown). Plants receiving the metalaxyl treatment were taller than those receiving no treatment or the experimental treatment. In 2002 plants in the subsoil drainage treatment were taller (*Pr*>F=0.06) than those in the tile treatment, and plants receiving the metalaxyl treatment were taller than the plants those receiving no treatment or the experimental treatment. In the third and fourth years there were no significant differences due to drainage or fungicide treatment in plant height or size. The study was terminated in July 2004 and the living and dead canes of each bush were weighed. Plants treated with metalaxyl had a higher total cane weight than those treated from the experimental compound, and a higher live cane weight than the untreated plants. Plants in the tile drainage treatment had a lower dead cane weight (*Pr*>F=0.10) than those in the control plots. No significant interactions occurred between the fungicide and drainage treatments in any year in the height, size (data not shown), or the final weight of living or dead canes of mature 'Tifblue' plants (Table 1).

Effect of drainage, bed height, and chemical treatments on young blueberry plants. There were no significant main effects due to bed height, drainage, or fungicide treatment in the height, size or percentage living plants among the 'Tifblue' or the 'Misty' plants (Tables 2 and 3, size data not shown). There was a significant interaction between bed height and fungicide treatment within the Tifblue plants in plant height and percentage living plants. Young 'Tifblue' plants on raised beds treated with metalaxyl were taller in 2004 and 2005 and had a greater percentage of living plants in 2003 and 2004 than plants grown on untreated flat beds.

Discussion

Phytophthora root rot is a serious disease of commercially grown rabbiteye and southern highbush blueberries in the southeastern United States. As the acreage of blueberries has steadily increased, so has the number of plants infected with Phytophthora root rot. Growers are now faced with the decision of trying to renovate infected bushes, removing infected bushes from the field and replanting new bushes in the same field, or replanting a new field. This study was initiated to help determine to what degree drainage and chemical treatments applied to mature 'Tifblue' plants infected with *P. cinnamomi* would reduce Phytophthora root rot disease severity. The greatest increase in plant height and weight of live canes following renovation of mature infected plants was a result of twice a year treatments with the fungicide

metalaxyl. The effect of drainage and raised beds on reducing disease severity was disappointing. The renovated mature 'Tifblue' plants receiving the subsoil treatment were taller than those in the untreated control plots two years after drainage treatments were applied and the total cane weight of plants in the subsoil treatment was greater at the end of the study than that of the plants in the tile treatment.

When young blueberry plants were transplanted into a field from which Phytophthora root rot infected plants had been removed, there were no significant differences in plant height, size or percentage living plants due to drainage, bed height, or fungicide treatment among the young 'Misty' southern highbush plants. Drainage and bed height only had a small impact on disease of young 'Tifblue' rabbiteye blueberry plants as indicated by a greater percentage of living plants among those planted on raised beds and treated with metalaxyl compared to those grown on flat beds receiving no fungicide treatment.

In a previous study conducted at Poplarville in a field adjacent to the one used in this study (Smith, 2002), root rot symptoms were evident on blueberry plants throughout the field after two years growth in *Phytophthora* infested soil, but there were no differences in disease severity or plant vigor due to bed height or fungicide treatment. After five years only 21% of plants drenched with metalaxyl and 16% of plants grown on raised beds were very vigorous compared to 14% of plants grown in untreated soil and 9% of plants grown on flat beds. The results of these two studies indicate that in soils similar to those in the Poplarville trails, blueberry growers should replant in new fields with no history of root rot rather than trying to renovate old infected blueberry plants or replanting into fields from which infected plants were removed.

Literature Cited

Austin, M.E. 1994. Rabbiteye Blueberries. AgScience, Inc. Auburndale, FL.

Lyrene, P.M. and T.E. Crocker. 1991. Commercial blueberry production in Florida. Fla. Coop. Ext. Ser. Handbook SP 179, University of Florida, Gainesville.

Milholland, R.D. 1975. Pathogenicity and histopathology of *Phytophthora cinnamomi* on highbush and rabbiteye blueberry. Phytopathology 65:789-793.

Milholland, R.D. 1995. Phytophthora Root Rot. Pages 7-8 in: Compendium of Blueberry and Cranberry Diseases, ed. F.L. Caruso and D.C. Ramsdell.

Smith, B.J. 2002. Susceptibility of southern highbush blueberry cultivars to Phytophthora root rot. Acta Horticulturae 574:75-79.

Tsao, P. 1983. Factors affecting isolation and quantitation of *Phytophthora* from Soil. Pages 219-236 in: Phytophthora, Its biology, taxonomy, ecology and pathology, ed. D.C. Erwin, S. Bartnicki-Garcia and P.H. Tsao, APS Press, St. Paul, MN.

Table 1. Height of mature 'Tifblue' blueberries following treatment for root rot beginning in 2000, weight of live and dead canes in July 2004, lsd values and probabilities of greater F.

Treatment	N	Plant Height (cm)				Cane Weight (grams)		
Drainage		2001	2002	2003	2004	Live	Dead	Total
Subsoil	31	177	185 A[z]	178	172	5462	2268 AB	7730 A
None	31	176	180 AB	168	183	4162	2831 A	6993 AB
Tile	28	162	165 B	166	163	4008	1658 B	5666 B
Lsd		16	17	19	19	1924	1060	1911
Pr > F		0.1493	0.0628	0.4203	0.1197	0.2597	0.0962	0.1016
Fungicide								Total
Metalaxyl	28	188 a	191 a	182	174	5983 a	2307	8290 a
Check	32	170 b	179 a	164	174	3647 b	2740	6387 ab
Experimental	30	159 b	161 b	167	170	4082 ab	1697	5779 b
Lsd		16	17	19	19	1925	1061	1912
Pr > F		0.0050	0.0030	0.1438	0.9363	0.0452	0.1713	0.0342
Pr > F Interaction Drainage x Fungicide		0.8315	0.4496	0.1811	0.5741	0.9760	0.5233	0.7076

[z]Within each column and each main effect, values followed by the same letter are not statistically different, according to Fisher's Protected least significant difference test; $P = 0.05$ (small letters) or $P = 0.1$ (capital letters).

Table 2. Average height by year and percentage of plants surviving due to main effects of root rot treatments in young 'Tifblue' rabbiteye blueberry planting.

Treatment	N	Plant Height (cm)					% Alive	
Bed Height		2002	2003	2004	2005		2003	2004
Raised	43	63.21	77.48	98.21	121.76		97.67	88.37
Flat	43	62.28	77.85	98.72	117.94		93.02	83.72
Pr > F		0.8652	0.9530	0.9509	0.5402		0.2838	0.5238
Drainage								
Tile	46	60.83	75.50	96.85	117.50		95.65	86.96
None	40	64.95	80.16	100.35	122.74		95.00	85.00
Pr > F		0.4538	0.4639	0.6729	0.4131		0.8803	0.7888
Fungicide								
Metalaxyl	45	62.04	77.23	100.49	125.54	a[z]	97.78	96.67
None	41	63.51	78.16	96.20	113.63	b	92.68	85.37
Pr > F		0.7848	0.8380	0.6373	0.0568		0.2202	0.8327
Pr > F Interactions								
Bed * Drainage		0.7815	0.3686	0.2466	0.6217		0.2507	0.4943
Bed * Fungicide		0.8770	0.4894	0.0807	0.0425		0.0261	0.0438
Drainage * Fungicide		0.9131	0.5778	0.8303	0.6381		0.2191	0.1808
Bed * Drainage * Fungicide		0.9329	0.8530	0.6647	0.2422		0.7823	0.7171

[z]Within each column and each main effect, values followed by the same letter are not statistically different, according to Fisher's Protected least significant difference test; $P = 0.1$.

Table 3. Average height by year and percentage of plants surviving due to main effects of root rot treatments in young 'Misty' southern highbush blueberry planting.

Treatment	N	Plant Height (cm)			% Alive	
Bed Height		2002	2003	2004	2003	2004
Flat	47	58.28	97.55	103.24	89.36	78.72
Raised	44	58.73	74.44	95.77	88.64	77.27
Pr > F		0.9344	0.3563	0.4183	0.9084	0.9084
Drainage						
Tile	44	60.75	99.22	98.19	93.18	84.09
None	47	56.38	73.30	101.27	85.11	72.34
Pr > F		0.4256	0.2956	0.7483	0.2031	0.0955
Fungicide						
Metalaxyl	46	58.78	97.00	97.16	91.30	82.61
None	45	58.20	75.03	102.55	86.67	73.33
Pr > F		0.9409	0.4395	0.5668	0.4943	0.2078
Pr > F Interactions						
Bed * Drainage		0.5770	0.4335	0.9344	0.4849	0.5410
Bed * Fungicide		0.4528	0.4694	0.9293	0.9589	0.9494
Drainage * Fungicide		0.7326	0.4717	0.9064	0.1297	0.3857
Bed * Drainage * Fungicide		0.4133	0.5733	0.7157	0.5529	0.6141

Mummy Berry Disease of Southern Blueberries: What Have We Learned During the Past 10 Years?

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Introduction

Mummy berry disease, caused by the ascomycete *Monilinia vaccinii-corymbosi*, is one of the most prevalent and most damaging diseases of blueberry in North America. While pathogen biology and disease management have been studied extensively on highbush blueberry (*Vaccinium corymbosum*) in northern production areas (Hildebrand *et al*. 1995), important knowledge gaps exist with regard to epidemiological patterns of the disease on rabbiteye blueberry (*V. ashei*) in the Southeast. In 1997, we initiated field and laboratory research on various aspects of mummy berry disease to provide the scientific basis for improved disease management. This paper briefly summarizes some of the lessons learned during this 10-year period.

Survival of Pseudosclerotia

Pseudosclerotia (mummified fruit) on the ground are the sole survival structure for oversummering and overwintering of *M. vaccinii-corymbosi*. Field observations in Georgia suggested unexpectedly low survival of these structures between summer and late fall, perhaps owing to the fact that most pseudosclerotia formed on rabbiteye blueberry are still immature when fruit drop occurs in the summer. To investigate this phenomenon further, the oversummer survival of pseudosclerotia of varying initial maturity was investigated relative to soil surface temperature, soil moisture content, shading, and ground cover (Cox and Scherm 2001). Survival was greater for cool soil temperatures, soils drier than field capacity, and pseudosclerotia containing mature fungal entostroma. In the field, shading or grass ground cover did not affect survival significantly; instead, survival was related solely to initial maturity of pseudosclerotia and was greatest for pseudosclerotia containing mature entostroma. Since the proportion of mature entostroma in infected fruit can vary considerably among blueberry cultivars (Savelle and Scherm 2005), there may be cultivar-related differences in survival (and hence disease potential the following year) among cultivars that show similar levels of fruit infection at harvest.

Tillage Effects on Pseudosclerotia

Since pseudosclerotia are the only source of primary inoculum, their burial may provide an effective means of disease management. The vertical distribution of pseudosclerotia

in the topsoil profile following soil cultivation with various tillage implements was characterized and the effect of depth and time of burial on carpogenic germination of pseudosclerotia assessed (Ngugi *et al*. 2002b). Pseudosclerotia or faceted plastic beads (used as a surrogate for pseudosclerotia) were placed on the soil surface before tillage with either a rototiller, a disc harrow, or two types of in-row tillers. They were recovered with a custom-made sampling device that allowed precise removal of soil layers at fixed depths. In a separate experiment, the number of apothecia emerging from pseudosclerotia buried at various depths was counted to determine the critical depth of burial. Considerable and consistent differences in vertical distribution profiles were observed among tillage implements. The greatest incidence of carpogenic germination was observed in pseudosclerotia buried between 0 and 1.5 cm below the surface, while no germination occurred at or below 3 cm. Thus, disease risk can vary considerably following commonly used soil cultivation practices, depending on the vertical distribution profile of pseudosclerotia resulting from these practices. Information from this study is being used to optimize selection of tillage implements on commercial blueberry farms for reducing primary infection by *M. vaccinii-corymbosi*.

Predicting Apothecium Emergence

Primary infection in the mummy berry pathosystem occurs via ascospores released from apothecia formed on pseudosclerotia in late winter/ early spring. Thus, the timing of apothecium emergence represents a key event in the disease cycle. Pseudosclerotia that had received different levels of natural or artificial chilling were allowed to germinate in the laboratory or in the field. Accumulation of chill-hours and heating degree-days was monitored. The number of chill-hours needed for development of viable apothecia was found to be <100, a value much lower than the 900 to 1,200 chill-hour minimum reported from North Carolina (Milholland 1977); this indicates effective adaptation of the pathogen to the low-chill environment of the Georgia blueberry belt. There was a negative relationship between the number of chill-hours received and the number of degree-days needed for apothecium production. Thus, pseudosclerotia are well adapted to form apothecia following cold winters (high chill-hours, low degree-days) as well as warm winters (low chill-hours, high degree-days). A model was developed to predict apothecium emergence based on simultaneously monitoring of chill-hour and degree-day accumulation (Scherm *et al*. 2001). This model is being evaluated to improve scouting programs for germinating pseudosclerotia and to target management tactics against primary infection more accurately.

Spore Dispersal and Infection Periods

The mummy berry fungus produces two spore types: sexual ascospores which cause primary infection of young, expanding vegetative tissues to cause a leaf and shoot blight; and asexual conidia which infect open flowers through the stigma and style, leading to mummification of the developing fruit. Field studies to monitor apothecium emergence, spore dispersal periods, leaf and flower bud phenology, and disease development revealed several unexpected results with important implications for disease management:

- Apothecia collected from early-flowering and late-flowering blueberry cultivars emerged at approximately the same time. This contrasts with earlier apothecium formation on pseudosclerotia from early-flowering cultivars as reported from highbush blueberry in New Jersey (Lehman and Oudemans 1997, 2000). The observed lack of adaptation of the timing of pathogen and host life stages may be because rabbiteye blueberries are always grown in mixed stands, involving cultivars that differ in bloom time; hence, the selection pressure for adaptation of pathogen phenology to host phenology is reduced.
- An association between rainfall and ascospore release was noted, whereby ascospores were released predominantly on rainy days. This contrasts with studies in Michigan where an association of ascospore release with relative humidity but not with rainfall was reported (Ramsdell *et al*. 1974, 1975). In Georgia, therefore, fungicidal protection is especially important during rainy periods.
- Ascospore and conidial dispersal periods were protracted and tended to overlap. In contrast, dispersal periods of the two spore types were distinctly separated in Michigan (Ramsdell *et al*. 1974, 1975). The protracted nature of spore dispersal is a complicating factor in the accurate timing of management tactics.

Management of Secondary Infection

In collaboration with county extension faculty, various host phenology-based fungicide application schedules, differing in the number of pre-bloom and bloom sprays and in the type of fungicide, were evaluated (Scherm and Stanaland 2001). Pre-bloom sprays contributed little to reduction in fruit infection, presumably because of the early onset of bloom of most rabbiteye blueberry cultivars relative to the date of leaf bud break. During the flowering period, it was important to maintain fungicidal protection through the end of bloom as a large number of the infections leading to fruit mummification occurred toward the tail end of bloom. These findings have led to a widespread shift in fungicide application timing away from pre-bloom applications and toward protection throughout the entire flowering period.

Still, determining the optimal fungicide timing in relation to bloom progression remains a challenge. In favorable weather, bloom progresses rapidly and a large percentage of flowers open within a few days. Thus, numerous new infection courts (the stigmas of newly opened flowers) become exposed to fungal conidia within a relatively short time. In blueberry flowers, fungicide active ingredients that are considered highly systemic in leaves showed little apparent translocation in the pistil, and flowers treated as short as 1 day prior to anthesis were not protected from subsequent infection by *M. vaccinii-corymbosi* (Tarnowski 2005). This suggests that producers need to compensate for the limited systemic activity of fungicides in flowers by making more frequent applications, especially in conditions that favor rapid progression of bloom.

Effective management of mummy berry disease is a major problem for the fledgling organic blueberry industry in the Southeast. Therefore, a research program on biological control of the disease was initiated in 2002. Initial experiments *in vitro* and on detached flowers demonstrated excellent efficacy of a biofungicide formulation based on the

Gram-positive bacterium *Bacillus subtilis* (Scherm *et al*. 2004). However, using conventional spray application equipment in field conditions, it has been difficult to achieve sufficient coverage of the minute and ephemeral stigmatic surface of blueberry flowers where the infection leading to fruit mummification takes place (Scherm and Stanaland 2001). In collaboration with colleagues in the Department of Entomology, we showed that honey bees, used widely for pollination in commercial blueberry production, consistently vector the biocontrol agent from bee hive-based dispensers to open blueberry flowers in the field, with associated suppression of mummy berry disease (Dedej *et al*. 2004). It was further documented that the deliberate deposition of *B. subtilis* on the stigmatic surface had no negative impacts on pollination and fruit set (Ngugi *et al*. 2005), an important prerequisite for recommending application of this biocontrol agent in commercial conditions. The most recent line of research to optimize application of the biofungicide to stigmatic surfaces involves the use of electrostatic spray equipment. This approach increased deposition of *B. subtilis* on the flower stigma by a factor of 4.5 compared with conventional spray application at the same rate (Law and Scherm 2005).

Biological Interactions During Secondary Infection

A more basic research project elucidated biological interactions during the flower infection process (via stigma and style into the ovary) by *M. vaccinii-corymbosi*. Initially, aspects investigated included the potential for competition or facilitation between pollen and conidia (both of which use the same pathway into the pistil), the impact of the amount and quality of stigmatic exudate on infection, and testing of the hypothesis of a "shut-down" of the infection pathway through early pollination (Ngugi *et al*. 2002a). More recently, efforts have focused on characterizing recognition processes in blueberry flowers following inoculation with pollen vs. conidia of *M. vaccinii-corymbosi*. Our principal hypothesis is that this highly specialized pathogen has evolved the ability to utilize the adhesion signals involved in pollen tube guidance as beacons for its own ingress through the pistil into the ovary (Ngugi and Scherm 2006b). Similar to blueberry pollen tubes, conidial germ tubes of *M. vaccinii-corymbosi* were found to adhere selectively to imprints of stylar transmitting tract tissue on nitrocellulose membrane, with adhesion in both cases occurring at the tips of the tubes. Using monoclonal antibodies, the presence of epitopes of certain pectins and of arabinogalactan proteins (AGPs), which have been implicated in adhesion and pollen tube guidance in other plant species, was documented on blueberry pollen tubes *in vitro*. Epitopes of AGPs were also localized on conidia and hyphae of *M. vaccinii-corymbosi*. Microscopic observation of inoculated pistils showed that similar to pollen tubes, hyphae of *M. vaccinii-corymbosi* tracked the lobes of the stylar lumen, grew directionally (i.e., with very limited branching) in close proximity to cells of the inner epidermis of the style and to one another, and were surrounded by extracellular matrix (Ngugi and Scherm 2004). These results provide evidence of specialized opportunism by *M. vaccinii-corymbosi*, whereby fungal hyphae mimic host pollen tubes and take advantage of an infrastructure intended to support host reproduction in order to facilitate infection of the ovary.

Postharvest Research

Fruit infected by *M. vaccinii-corymbosi* are unfit for commercial use because of their hardened texture. Fruit loads exceeding the tolerance level for mummy berry are appraised at lower quality grades, resulting in severe economic penalties to producers. In the late 1990s, we completed studies to improve the protocol for detecting and enumerating mummy berry incidence in fruit loads accurately and precisely.

Two methods to detect and enumerate disease incidence were evaluated using fruit samples with known numbers of infected fruit (Scherm and Copes 1999). The first method, which was used by graders at that time, involved processing of the samples in a blender; the resulting blueberry puree was passed through a series of screens and the number of pseudosclerotia retained on the screens assessed tactilely. The second method consisted of visual symptom assessment of intact fruit using a newly developed pictorial key. The visual method was considerably more accurate and more precise than the blender method. In a second step, a sequential sampling plan was derived based on a large number of fruit loads assessed visually in commercial packinghouses to calculate the minimum number of fruit samples needed to determine disease incidence with defined statistical properties (Copes *et al*. 2001).

Conclusions

Although mummy berry disease is still very prevalent in the southeastern blueberry belt, the threat of the disease has been reduced considerably during the past 10 years, in part through the collaborative research described above. As knowledge gaps have been filled and improved disease management recommendations and tools developed, our focus within this unique pathosystem has broadened from pathogen ecology and epidemiology to host-pathogen interactions during the flower infection process and to the biology of flower-infecting fungi in general (Ngugi and Scherm 2006a). Nonetheless, there certainly remains a sufficiently large number of practical challenges and basic questions in relation to *M. vaccinii-corymbosi* to occupy this researcher for at least another 10 years.

Literature Cited

Copes, W. E., Scherm, H., and Ware, G. O. 2001. Sequential sampling to assess the incidence of infection by *Monilinia vaccinii-corymbosi* in mechanically harvested rabbiteye blueberry fruit. Phytopathology 91:348-353.

Cox, K. D., and Scherm, H. 2001. Oversummer survival of *Monilinia vaccinii-corymbosi* in relation to pseudosclerotial maturity and soil surface environment. Plant Disease 85:723-730.

Dedej, S., Delaplane, K. S., and Scherm, H. 2004. Effectiveness of honey bees in delivering the biocontrol agent *Bacillus subtilis* to blueberry flowers to suppress mummy berry disease. Biological Control 31:422-427.

Hildebrand, P. D., Milholland, R. D., and Stretch, A. W. 1995. Mummy berry. Pages 11-12 in: Compendium of Blueberry and Cranberry Diseases. F. L. Caruso and D. C. Ramsdell, eds. American Phytopathological Society, St. Paul, MN.

Law, S. E., and Scherm, H. 2005. Electrostatic application of a plant-disease biocontrol agent for prevention of fungal infection through the stigmatic surfaces of blueberry flowers. Journal of Electrostatics 63:399-408.

Lehman, J. S., and Oudemans, P. V. 1997. Phenology of apothecium production in populations of *Monilinia vaccinii-corymbosi* from early- and late-maturing cultivars. Phytopathology 87:218-223.

Lehman, J. S., and Oudemans, P. V. 2000. Variation and heritability of phenology in the fungus *Monilinia vaccinii-corymbosi* on blueberry. Phytopathology 90:390-395.

Milholland, R. D. 1977. Sclerotium germination and histopathology of *Monilinia vaccinii-corymbosi* on highbush blueberry. Phytopathology 67:848-854.

Ngugi, H. K., Dedej, S., Delaplane, K. S., Savelle, A. T., and Scherm, H. 2005. Effect of flower-applied Serenade biofungicide (*Bacillus subtilis*) on pollination-related variables in rabbiteye blueberry. Biological Control 33:32-38.

Ngugi, H. K., and Scherm, H. 2004. Pollen mimicry during infection of blueberry flowers by conidia of *Monilinia vaccinii-corymbosi*. Physiological and Molecular Plant Pathology 64:113-124.

Ngugi, H. K., and Scherm, H. 2006a. Biology of flower-infecting fungi. Annual Review of Phytopathology 44, doi: 10.1146/annurev.phyto.44.070505.143405.

Ngugi, H. K., and Scherm, H. 2006b. Mimicry in plant-parasitic fungi. FEMS Letters 257:171-176.

Ngugi, H. K., Scherm, H., and Lehman, J. S. 2002a. Relationships between blueberry flower age, pollination, and conidial infection by *Monilinia vaccinii-corymbosi*. Phytopathology 92:1104-1109.

Ngugi, H. K., Scherm, H., and NeSmith, D. S. 2002b. Distribution of pseudosclerotia of *Monilinia vaccinii-corymbosi* and risk of apothecial emergence following mechanical cultivation. Phytopathology 92:877-883.

Ramsdell, D. C., Nelson, J. W., and Myers, R. L. 1974. An epidemiological study of mummy berry disease of highbush blueberry. Phytopathology 64:222-228.

Ramsdell, D. C., Nelson, J. W., and Myers, R. L. 1975. Mummy berry disease of highbush blueberry: Epidemiology and control. Phytopathology 65:229-232.

Savelle, A. T., and Scherm, H. 2005. Colonization of and pseudosclerotial development in rabbiteye blueberry (*Vaccinium ashei*) fruit infected by *Monilinia vaccinii-corymbosi*. (Abstr.) Phytopathology 95(Suppl.):S93.

Scherm, H., and Copes, W. E. 1999. Evaluation of methods to detect fruit infected by *Monilinia vaccinii-corymbosi* in mechanically harvested rabbiteye blueberry. Plant Disease 83:799-805.

Scherm, H., Ngugi, H. K., Savelle, A. T., and Edwards, J. R. 2004. Biological control of infection of blueberry flowers caused by *Monilinia vaccinii-corymbosi*. Biological Control 29:199-206.

Scherm, H., Savelle, A. T., and Pusey, L. P. 2001. Interactions between chill-hours and degree-days affect carpogenic germination in *Monilinia vaccinii-corymbosi*. Phytopathology 91:77-83.

Scherm, H., and Stanaland, R. D. 2001. Evaluation of fungicide timing strategies for control of mummy berry disease of rabbiteye blueberry in Georgia. Small Fruits Review 1(3):69-81.

Tarnowski, T. L. B. 2005. Blueberry flower infection by *Monilinia vaccinii-corymbosi*: Systemic activity of fungicides and development of a cDNA synthesis protocol from inoculated and pollinated pistils. M.S. thesis. University of Georgia, Athens.

Propagating and Managing Orchard Mason Bees, *Osmia* spp. (Hymenoptera: Megachilidae) for Pollinating Cultivated Blueberry

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Summary

The following is a brief overview of our bee trap-nesting study as well as information about propagating and managing mason bees for blueberry pollination, especially the bee species *Osmia ribifloris* **(Fig. A).**

Southern blueberry cultivars experience more pollination problems than any other blueberry crop. They bloom so early that few native bee species are flying and honey bee colonies are at their weakest, a situation made more dire on larger acreages with an overwhelming volume of bloom. Most rabbiteye blueberry flowers are visited at least once and set fruit 80% of the time when foraging densities of honey bees and native bees exceed an upper threshold of 5.0 bees per 10^3 open flowers (Cane 1993, 1997, Cane and Payne 1993, Sampson and Spiers 2002, Sampson et al. 2004). Fruit set becomes increasingly erratic (30 – 70%) below this threshold. If native bee densities should fall even further, below a density of 1.0 bee per 10^4 flowers, which frequently occurs in larger fields (10 - 100 ha), fruit set drops sharply to 30% or less (Danka and Sampson unpublished data). Depending on baseline foraging densities of wild pollinators, approximately 600-1200 bees per hectare of reliable native bees of any manageable species are needed to satisfy commercial levels of blueberry pollination (Sampson et al. 2004).

We are developing a management system for both imported and native solitary bee species. These species emerge early enough to pollinate southern blueberries and have the potential for commercial-scale propagation (Eaton and Murray 1994). The more

promising are cavity-nesting megachild bees especially *Osmia ribifloris* **(Figs. A-G)**. This bee prefers as floral hosts *Arctostaphylos*, *Vaccinium* (Ericaceae), *Berberis* and *Mahonia* (Berberidaceae) and can secondarily use *Diospyros* (Ebanaceae), *Rosa* (Rosaceae), *Cercis* and *Sophora* (Fabaceae) (Cripps and Rust 1985, Rust 1986). Two other potentially manageable blueberry pollinators were trap-nested on eleven Texas and Mississippi farms: *Osmia lignaria* and *O. chalybea* (Mitchell 1962, Torchio 1990, Javorek et al. 2002, Sampson, personal observation 2006). The sale of surplus *Osmia* pollinators and associated trap-nesting equipment will provide a secondary source of revenue for southern blueberry growers.

It is sometimes necessary to monitor and make some minor adjustments to the developmental and wintering conditions of *Osmia* bees, if bees are to emerge on time and pollinate blueberry bloom. *O. ribifloris* normally develops from an egg to an adult in 2 - 3 months. Cocooned adults **(Fig. F)** are dormant by autumn and early winter, at which time they can be safely removed from their nest tubes **(Fig. G)**, packed in leak-proof ice packs and promptly shipped. *O. ribifloris* is currently trap-nested at drier, elevated sites in Texas, Arizona, Utah and California and shipped eastward for blueberry pollination research in the US Gulf Coast region (Sampson et al. 1995, Sampson and Cane 2000). Breaking dormancy before late winter or early spring cannot easily be done and only after brood fully satisfied their 90-120 day chilling requirement at 5-7^{o}C (41 - 45^{o}F). Since larval bees deplete fat reserves more quickly at higher summer temperatures (25-30^{o}C) in the Southeast, reliable and humidified refrigeration at lower winter temperatures (4-5^{o}C) will help reduce winter mortality. Because *Osmia ribifloris* also develop and deplete their fat bodies faster in warmer climates they also winter earlier. As a result, male emergence occurs a month early and stretches from late January - early March, and from April – May in colder climates (Krombien 1967, Stubbs et al. 1994). A one-year delay in emergence can sometimes occur when the accidental and premature chilling of *O. ribifloris* brood prevents mature larvae from pupating, forcing them to extend larval dormancy for the first winter until they can again resume development the next spring (Bosch and Kemp 2003, 2004).

Varying incubation conditions for *O. ribifloris* can improve the synchronization of bee emergence, courtship, foraging and nest provisioning with the onset of blueberry bloom, resulting in more days for bees to pollinate and provision nest cells. Warmer incubation from 20 – 29^{o}C under bright illumination can greatly accelerate emergence, especially for male brood. Males exit cocoons first and set up patrols over bushes and at nest entrances where they are likely to begin encountering the earliest receptive females in about 3 days. Female *O. ribifloris* have a long receptivity period and probably mate multiple times. Copulation attempts by males are always preceded by tactile displays of buzzing, antennal flicking and wing flexing lasting between 20 - 90 minutes (Torchio 1990). Although male bees are perhaps more limited in their individual efficacies as blueberry pollinators, they make up for it somewhat with greater numbers during courtship and early flowering (♂♂:♀♀ ratio = 3:1). It normally takes 10 or more days after removal from winter sleep before female bees are ready to begin foraging and pollinating blueberries. Calculations based on rates of foraging and nest provisioning over a female's lifetime, as well as resulting fruit set show 5 or 6 marketable blueberries

are set for each minute she spends foraging for pollen and nectar to feed her brood (Cane 1997, Sampson et al. 2004). Female *O. ribifloris* are peculiar blueberry pollinators. They do not sonicate flowers to extract pollen like bumblebees and blueberry bees and never rob flowers of nectar as do carpenter bees and a majority of honey bees. *O. ribifloris* instead legitimately remove nectar and pollen via their long tongue and rapid leg movements, respectively.

Although *O. ribifloris* normally nest gregariously in blocks and shelters made of weathered or lacquered wood (**Figs B-E**), they also have a natural instinct to leave their natal area in search of mates and new nest sites. There are four management actions that can be taken to limit female dispersal. First, allow adult bees to eclose from their natal cocoons originally placed in a nest shelter. Insecticides toxic to bees cannot be used anytime during or after this time. Residues even from evening insecticide applications repel adult bees and might potentially harm larvae if absorbed through the cuticle from contaminated nesting material (i.e. leaf pulp). Second, caging pollinators with flowering blueberry bushes is a more expensive, but a foolproof method for preventing adult dispersal in smaller "starter" populations. Inside a large cage or screenhouse, stock a simple plywood shelter with softwood blocks made from untreated lumber (4 x 9 x 15 cm or 9 x 9 x 15 cm, **Fig. B**). Holes drilled into wood blocks can be optionally lined with hollow tubes made of cardboard or paper and tightly sealed in the rear by durable metal tape or a thin layer of wood **(Fig. C)**. Tubes ranging in interior diameter from 6 – 9 mm (1/4 - 3/8") and 10-15 cm (4-6") deep provide appropriately sized nest cavities. Plastic nest blocks made from polyvinylchloride (PVC) or polystyrene can be desirably cheaper and lighter. But compared with fiber-based products (e.g. wood, particleboard and laminated cardboard) females find nest tubes crammed into plastic containers less attractive. An *O. ribifloris* female typically fills 1 or 2 tubes with a total of 11 nest cells **(Fig. E)**, laying female eggs on pollen masses in the innermost cells and male eggs in the outermost cells **(Fig. G)**. Even more straws per female will be required to accommodate any possible nest competitors. Otherwise, poor nest availability can lead to excessive nest usurpation or secondary nest occupation, which promotes out-of-sequence brood and perhaps higher brood mortality (Eickwort 1975, McCorquodale and Owen 1994, Tepedino and Torchio 1994). Third, providing female bees with high quality nesting habitats should in theory shorten the dispersal distances of female bees. Any bees that do disperse might be rounded up by trap-nests placed along the periphery of the farm. Blocks become more attractive when they are firmly affixed to vertical wood supports, 1.0 – 1.5 m from the ground, and placed in calm sunny spots, **(Figs. C-E)** sheltered from rain and the hot midday sun by trees, hedgerows or eaves of old wood buildings. Moving active nests is not advised and never beyond 100m from a shelter's original position. If relocating bees and nests is unavoidable, it is best accomplished at night. The next morning, a relocated female bee will make several zigzag flights to help pinpoint her nest. A wood block painted white provides more warmth to a basking bee and encourages an earlier pre-flight warm up. Random or systematic patterns **(Fig. B)** painted on a surface of blocks will aid a female bee in more quickly locating her nest. Finally, a female might have trouble finding suitable leaf material for fashioning entrance plugs **(Fig. E)** and nest cell partitions **(Fig. G)**. Female *O. ribifloris* prefer mature, waxy leaves, especially those of roses (*Rosa*) and blueberries. Oak (*Quercus*),

sumac (*Rhus*) and blackberry (*Rubus*) leaves are sometimes used. Growing or placing these leaf sources near a shelter should help encourage nesting in the shelter.

Pressure from disease, predation and parasitism will increase with pollinator population size (Tscharntke, et al. 1998). X-ray analyses, visual inspection and incubation under quarantine conditions can identify cocoons containing the broods of natural enemies. A native natural enemy of *O. ribifloris*, a widespread cleptoparasitic wasp *Sapyga pumila* was extracted from host cocoons by isolating each adult in a 000-sized gelatin capsule and eliminating it before bee release. No other parasites or diseases were detected in 9 years. However, the wetter conditions of the Southeast may spur the reproduction and dispersal of harmful mold and *Chaetodactylus* mites. These mites are common nest associates of other closely related *Osmia* species and plausibly injure eggs and larvae (Griffin 1993). There is no truly effective ways of killing or removing all of the mites. However, after removing all paper tubes containing bee brood, the wood blocks can then be flame-treated to kill any encysted mites. Encysted hypopi on cocoons can be removed with a stiff brush or bathing cocoons in a very mild bleach solution. Dense reddish masses of hypopi are also carried on the bodies of adult bees in places inaccessible to grooming such as the coxae, upper thorax and propodeum. Therefore, a soft fine haired paint brush is safe for removing many of these hypopi from chilled adults. A sheath of chicken wire projecting over nest holes, very fine mesh wire placed over sealed entrances and tanglefoot barriers could offer brood greater protection from mites, parasitoids, predators and scavengers. Heavier cardboard liners or dry hollow reeds protect bee cocoons from the stings of parasitoid wasps such as *Monodontomerus*.

The only steps to complete before commercial delivery of *O. ribifloris* are 1) obtaining and rearing enough bees for field-scale pollination 2) refine a management system using lighter weight and cheaper fiber-based materials and 3) increase grower awareness of the economic value of mason bees. The monetary value of individual female *O. ribifloris* as pollinators of southern blueberries is roughly equivalent in value on a per bee basis to the native southeastern blueberry bee *Habropoda laboriosa* (Cane 1997). Currently, blueberry crop production practices are compatible with *O. ribifloris* and pesticide use on blueberries is minimal in the region.

Literature Cited

Bosch, J., and W. P. Kemp. 2003. Effect of wintering duration and temperature on survival and emergence time in males of the orchard pollinator *Osmia lignaria* (Hymenoptera: Megachilidae): Environ. Entomol. 2003, 32: 711–716.

Bosch, J., and W. P. Kemp. 2004. Effect of pre-wintering and wintering temperatures on weight loss, survival, and emergence time in the mason bee *Osmia cornuta* (Hymenoptera: Megachilidae): Apidologie. 35: 469–479.

Cane, J. H. 1995. Nesting biology and mating behavior of the southeastern blueberry bee, *Habropoda laboriosa* (Hymenoptera: Apoidea): J. Kans. Entomol. Soc. 67: 236–241. 1995.

Cane, J. H. 1997. Lifetime monetary value of individual pollinators of the bee *Habropoda laboriosa* at rabbiteye blueberry (*Vaccinium ashei* Reade): Acta Hortic. 446: 67–70. 1997.

Cane, J. H., and J. A. Payne. 1993. Regional, annual, and seasonal variation in pollinator guilds intrinsic traits of bees (Hymenoptera: Apoidea) underlie their patterns of abundance at *Vaccinium ashei* (Ericaceae): Ann. Entomol. Soc. Am. 86: 577–588. 1993.

Cripps, C., R. W. Rust. 1985. Biology and subgeneric placement of *Osmia pikei* (Hymenoptera, Megachilidae). Entomological News. 96: 109-113.

Dickman, G. Orchard Bees. Brochure. Pp. 1-12.

Eaton, L. J. and J. E. Murray. 1997. Relationships of pollinator numbers in blueberry fields to fruit development and yields. Acta Hort. (ISHS) 446:181-188.

Eickwort, G. C. 1975. Gregarious nesting of the mason bee *Hoplitis anthocopoides* and the evolution of parasitism and sociality among megachilid bees. Evolution 29:142-150.

Gorchov D. L. 1985. Fruit Ripening Asynchrony is Related to Variable Seed Number in *Amelanchier* and *Vaccinium*. American Journal of Botany. 72:1939-1943.

Griffin, B. L. 1993. The Orchard Mason Bee. Knox Cellars Publishing. Bellingham, WA.

Javorek S. K., K. E. Mackenzie, S. P. Vander Kloet. 2002. Comparative Pollination Effectiveness Among Bees (Hymenoptera: Apoidea) on Lowbush Blueberry (Ericaceae: *Vaccinium angustifolium*). Annals of the Entomological Society of America 95: 345–351.

Krombein, K. L. 1967. Trap-nesting wasps and bees, life histories, nests and associates. Smithsonian Press, Washington. DC.

McCorquodale D. B. and R. E. Owen. 1994. Laying sequence, diploid males, and nest usurpation in the leafcutter bee, *Megachile rotundata* (Hymenoptera: Megachilidae) Journal of Insect Behavior. 7: 731-738.

Mitchell, T. B. 1962. Bees of the eastern United States. Volume 2. Technical Bulletin, North Carolina Agricultural Experiment Station. 152: 557 pp.

Rust, R. W. 1986. Biology of *Osmia* (*Osmia*) *ribifloris* Cockerell (Hymenoptera: Megachilidae). Journal of the Kansas Entomological Society 59: 89-94.

Sampson, B. J. and Cane, J. H. 2000. Pollination efficiencies of three bee (Hymenoptera: Apoidea) species visiting rabbiteye blueberry. J. Econ. Entomol. 93(6): 1726-1731.

Sampson, B. J., J. H. Cane and J. Neff. 1995. Blue bees for blueberries. Ala. Agric. Exp. Stn. Auburn Univ. Highlights Agric. Res. 42: 12, 13, 15.

Sampson, B. J. and J. M. Spiers. 2002. Evaluating Bumblebees as pollinators of 'Misty' southern highbush blueberry growing inside plastic tunnels. Acta Hort. 574:53-61.

Sampson, B. J., R. G. Danka and S. J. Stringer. 2004. Nectar Robbery by Bees *Xylocopa virginica* and *Apis mellifera* Contributes to the Pollination of Rabbiteye Blueberry. Journal of Economic Entomology. 97: 735-740.

Sampson, B.J., S. J. Stringer, J. H. Cane, J. M. Spiers. 2004. Screenhouse Evaluations of a Mason bee *Osmia ribifloris* (Hymenoptera: Megachilidae)as a Pollinator for Blueberries in the Southeastern United States. Small Fruits Review. 3: 381-392.

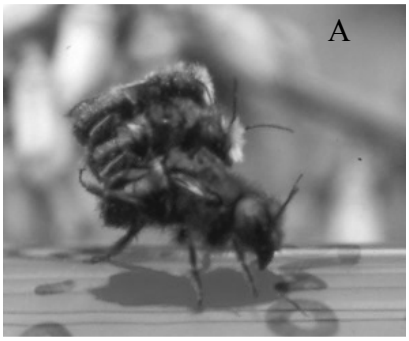
Shepherd M., S. L. Buchmann, M. Vaughan and S. H. Black. 2003. Pollinator Conservation Handbook. Xerces Society. Portland, OR. 145 pp.

Stubbs, C. S., F. A. Drummond, and E. A. Osgood. 1994. *Osmia ribifloris biedermannii* and *Megachile rotundata* (Hymenoptera: Megachilidae) introduced into lowbush blueberry agroecosystems in Maine: J. Kans. Entomol. Soc. 67 173–185.

Tepedino, V.J., P. F. Torchio. 1994. Founding and usurping: Equally efficient paths to nesting success in *Osmia lignaria propinqua* (Hymenoptera: Megachilidae). Annals of the Entomological Society of America. 87:946-953.

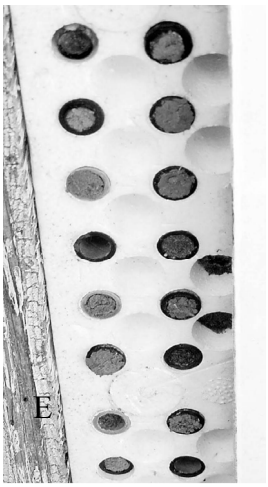
Torchio P. F. 1990. *Osmia ribifloris*, a native bee species developed as a commercially managed pollinator of highbush blueberry. J. Kansas Entomol. Soc. 63: 427–436.

Tscharntke T., A. Gathmann, I. Steffan-Dewenter. 1998. Bioindication using trap-nesting bees and wasps and their natural enemies: community structure and interactions. Journal of Applied Ecology. 35: 708-719.


A


B


D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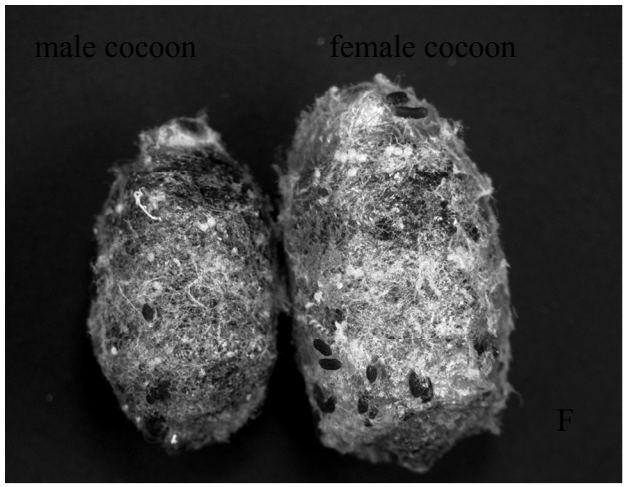
male cocoon
female cocoon
F

A Recent History of Insecticide Use in NJ Blueberry Production

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Background

New Jersey blueberry growers manage their fields for over a dozen insect pests. Most of the New Jersey crop in intended for fresh market consumption, with a portion going into frozen storage as processing fruit. Depending on the year, anywhere from 10 to 30% is exported to the Canadian market. In all cases, there is "0" tolerance for direct pests. These direct pests include cranberry fruitworm, *Acrobasis vaccinii* Riley; plum curculio, *Conotrachelus nenuphar* (Herbst); blueberry maggot, *Rhagoletis mendax* Curran; Japanese beetle, *Popillia japonica* Newman; cranberry weevil, *Anthonomus musculus* Say, and to some extent the cherry fruitworm, *Grapholita packardi*. There are several species of leafrollers that can be economic pests, particularly during bloom. These include the redbanded Leafroller, *Argyrotaenia velutinana* Walker, obliquebanded leafroller, *Choristoneura rosaceana* (Harris), various spanworms and fruitworms, and sometimes gypsy moth.

There are also a number of indirect pests, several of which are known vectors of virus or mycoplasma like diseases. These include the sharpnosed leafhopper, *Scaphytopius magdalensis* (Provancher) that transmits blueberry stunt disease, and several species of aphids, including *Illinoia pepperi, Ericaphis* spp, *Myzus persicae* (Sulzer) and other spp. While aphids are known to devitalize plant growth, it is their ability to transmit blueberry scorch virus (BBScV) that results in significant amounts of insecticide use in NJ. Of the 6 species found in NJ blueberries, of prime importance is the fact that 3 species are known to act as vectors for BBScV. One aphid (*Illinoia pepperi*) can also transmit shoestring virus.

Implications of FQPA on blueberry pest management

Organophosphates and carbamates have served as the principal tools of blueberry pest management programs for the past 40 years (Drummond 2000). Historically, our data has shown that ca. 90% of insecticide applications in NJ have been with broad-spectrum organophosphate and carbamate insecticides (Polk and Samoil 1993).

Because blueberries involve a high degree of hand harvesting, and handling in processing plants, worker exposure to broad-spectrum insecticide residues is a major concern among regulators implementing FQPA. These changes will impact the blueberry industry disproportionately compared to other crops because of the limited range of products registered due to the minor crop status of blueberry, zero tolerance for insect pests, the high potential for insect infestation, and quarantine and contamination concerns. The recent EPA Interim Reregistration Eligibility Decision (IRED) for azinphos-methyl proposes to phase out this product in blueberry. Blueberry is now in a "group 3 time limited use" category. In the interim, the re-entry interval (REI) was extended from 3 to 7 days in highbush blueberries, and the preharvest interval (PHI) was maintained at 7 days, with a 2 application maximum per season. These changes, particularly the REI changes, will virtually eliminate use of azinphos-methyl for control of blueberry maggot in the critical periods just prior to harvest. For phosmet, the PHI and REI is now 3 days. The EPA is also currently considering the re-registration of Diazinon (IRED – 1 appl/yr) and Endosulfan (changes in REI, label rates, mixing and application methods) in blueberries. As use patterns for organophosphates and carbamates become more restrictive, newer practices and pesticide products will be used, however, some control gaps may appear.

New insecticide options recently registered

Several insecticides have been developed in recent years that offer alternatives to broad-spectrum insecticides. Tebufenozide is labeled for use in blueberry against lepidopteran pests. The Naturalyte spinosad recently received federal registration for blueberry, and is effective against blueberry maggot, leafrollers, and cranberry fruitworm, blueberry flea beetle, and blueberry spanworm. A new formulation of spinosad, GF-120 Fruit Fly Bait, which was developed for control of tephritid fruit flies was registered in 2002 for uses in blueberries. Imidacloprid (Provado and Admire) is newly registered for several insects including aphids, Japanese beetle, leafhoppers and blueberry maggot. Admire is used for control of Oriental beetle grubs. The IGR, pyriproxyfen (Esteem) was registered in 2003 for cranberry fruitworm and scale, and the neonicotine, thiamethoxam (Actara) was registered in 2005 for aphids and leafhoppers.

Method of data collection and analysis

Grower pesticide use records were collected at the end of each growing season from participating growers in the Rutgers Cooperative Extension Fruit IPM Program. Spray records were input in an Access© database with a four-level grower model (grower, farm, block, and trap station) allowing for the storage of data collection records on each level. Incorporated in the database is Material Model (with pricing and AI composition), a Crop Model which includes phenology data as well as a master variety list of all blueberry varieties in NJ, and an Observation Model comprising the pests under evaluation and the observation methods. Pesticide use records were entered for

each year starting in 1998 through the present. Queries were done for each year to summarize statewide pesticide use. The queries summarize: a) number of growers on record, b) the number of grower farms with pesticide records (some growers have more than one farm location), c) number of acres covered by the records on file, d) active ingredient, e) brand name, f) total amt. used per acre, g) average rate per application per acre or rate per acre, h) average number of applications per unit (acre), and i) percent of crop acreage where the pesticide was applied. The data in the accompanying tables and graphs summarizes parameters f through i. Pesticide use defined as "Total AI/A, Avg Rate/Ac, and Avg # of Ap/A" were all derived from the actual acreage where that particular product was used, as opposed to the entire surveyed grower acreage, which may have had significant acreage where the product was not used. "% A Used" or the percent crop acreage where the product was applies at least once, was derived from the entire database of surveyed growers. All data is in lb AI.

Survey Data

Data is from 8 years of grower surveys with the following sample sizes for each year:

Year	Growers	Farms	Ac
1998	19	38	2695
1999	23	48	3054
2000	25	51	3162
2001	25	56	3417
2002	30	62	3808
2003	29	61	3809
2004	36	74	4282
2005	33	69	4273

Levels and Emerging Trends of Insecticide Use

In most cases, the rate per acre(A) did not change during the 8 years. Two exceptions are the uses of diazinon and Lannate. Use rates for those products increased in 2002 for

improved control of aphids. These are the principal products that were used for aphid control prior to the labeling of Provado, which was used under section 18 labels from 1999 to 2003. The per acre use rate of Provado also steadily increased in part to achieve better aphid control, and to include control of blueberry maggot. Tebuzenozide has been used for leafroller control during bloom, and therefore was only used during years of higher leafroller activity (2000, 2001, 2002). It was also used for cranberry fruitworm at petal fall. Various species of thrips have been a concern for growers during the last several years. With the labeling of Spintor in 2002, targeting thrips and leafrollers, it largely replaced tebufenozide, but timed at petal fall, and has seen an increased use since it's labeling.

OP Use: The 4 main OP insecticides have been azinphos-methyl, phosmet, diazinon, and malathion. In terms of the % crop acreage treated, since 2000, azinphos use has shown a declining trend. Diazinon use has increased slightly due in part for leafhopper control, and to supplement imidacloprid use for aphids. Phosmet and malathion have shown no increasing or decreasing trends. In terms of the total AI use per acre, and the number of applications used, a decreasing trend was seen for azinphos-methyl.

An increased use of pyrethrum was seen in 2005, and likely reflects the increased interest in organic blueberry production.

Literature Cited

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

Polk, D. F. and K.S. Samoil. 1993. Blueberry Pesticide use and fruit quality 1992. In Proceedings Blueberry Openhouse 1993. pp.8-10.

Blueberry Insecticide Use - 1998

AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	0.42	0.41	1.03	13.96
Bt	0.08	0.08	1.00	19.76
carbaryl	1.44	1.19	1.20	12.94
diazinon	2.08	0.97	2.14	80.29
esfenvalerate	0.04	0.04	1.00	10.20
malathion	2.28	1.53	1.49	14.37
methomyl	1.84	0.78	2.37	85.63
phosmet	1.01	0.85	1.19	32.49
petroleum oil	31.62	31.62	1.00	0.82
2695 Ac, 19 Growers, 38 Farms				

Blueberry Insecticide Use - 1999

AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	0.79	0.51	1.54	24.15
Bt	0.07	0.08	1.00	2.12
carbaryl	2.45	1.42	1.72	40.51
diazinon	1.18	0.98	1.20	44.73
esfenvalerate	0.05	0.04	1.17	36.00
imidacloprid	0.06	0.04	1.51	74.46
malathion	2.77	1.51	1.83	18.69
methomyl	1.09	0.72	1.50	46.10
phosmet	1.66	0.91	1.82	73.75
3054 Ac, 23 Growers, 48 Farms				

Blueberry Insecticide Use - 2000

AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	1.30	0.58	2.24	24.86
Bt	0.10	0.10	1.00	2.61
carbaryl	2.55	1.94	1.31	38.76
diazinon	1.47	0.89	1.65	28.18
esfenvalerate	0.03	0.03	1.13	10.49
imidacloprid	0.08	0.06	1.31	57.23
malathion	3.00	1.67	1.80	15.26
methomyl	1.24	0.68	1.83	58.39
phosmet	1.64	0.88	1.86	55.59
tebufenozide	0.23	0.23	1.00	2.40
3162 Ac, 25 Growers, 51 Farms				

Blueberry Insecticide Use - 2001

AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	0.89	0.48	1.85	42.01
Bt	0.11	0.11	1.00	24.21
carbaryl	2.37	1.92	1.23	33.26
diazinon	1.11	0.89	1.24	25.60
esfenvalerate	0.01	0.01	1.11	10.81
imidacloprid	0.09	0.06	1.50	56.30
malathion	2.28	1.27	1.80	12.36
methomyl	1.80	0.88	2.05	61.34
phosmet	1.61	0.90	1.80	57.70
tebufenozide	0.15	0.15	1.00	2.62
petroleum oil	39.52	39.52	1.00	0.12
3417 Ac, 25 Growers, 56 Farms				

Blueberry Insecticide Use - 2002

AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	0.92	0.51	1.79	46.85
carbaryl	1.42	0.93	1.53	16.63
diazinon	1.34	1.23	1.09	30.43
esfenvalerate	0.03	0.03	1.00	12.78
imidacloprid	0.11	0.06	1.96	38.67
malathion	2.06	1.21	1.71	10.26
methomyl	1.32	0.77	1.71	84.74
phosmet	1.88	0.88	2.13	66.79
spinosad	0.11	0.09	1.29	5.40
tebufenozide	0.23	0.23	1.00	4.82
3808 Ac, 30 growers, 62 farms				

Blueberry Insecticide Use - 2003

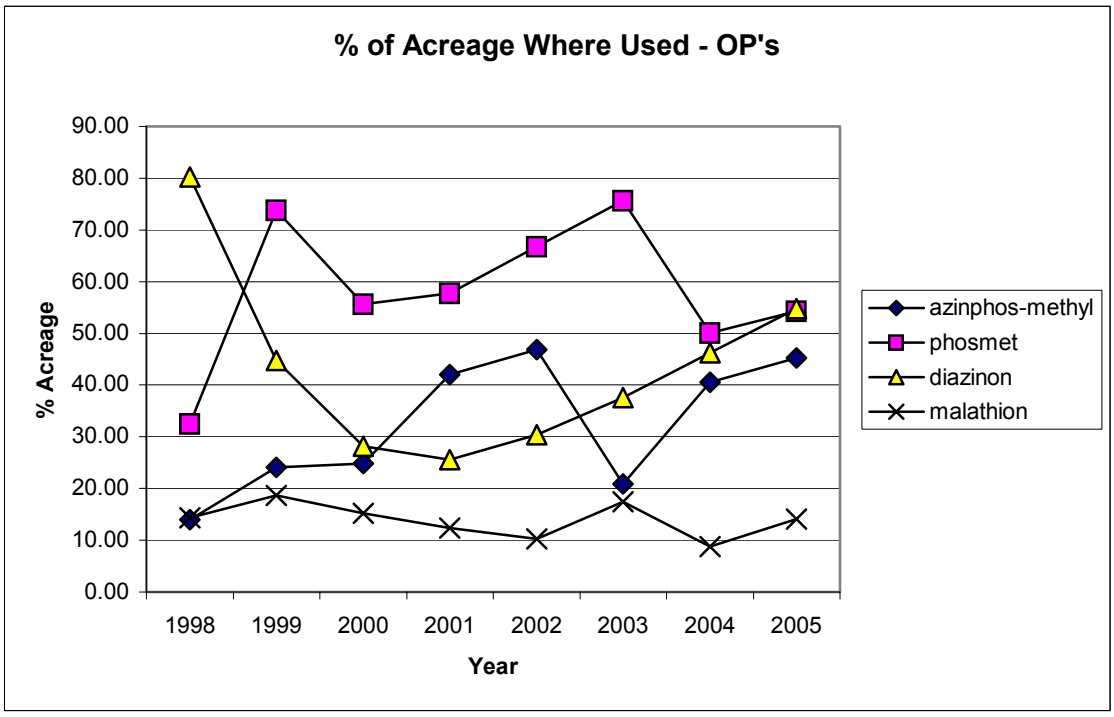
AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	0.88	0.56	1.59	20.89
carbaryl	1.31	0.93	1.42	22.18
chlorpyrifos	0.90	0.90	1.00	0.25
diazinon	1.34	0.95	1.41	37.58
esfenvalerate	0.00	0.00	1.00	6.29
imidacloprid	0.11	0.08	1.35	63.32
malathion	1.66	1.33	1.25	17.42
methomyl	1.17	0.66	1.78	53.81
phosmet	1.95	0.90	2.15	75.63
spinosad	0.10	0.09	1.10	2.73
3809 acres, 29 growers, 61 farms				

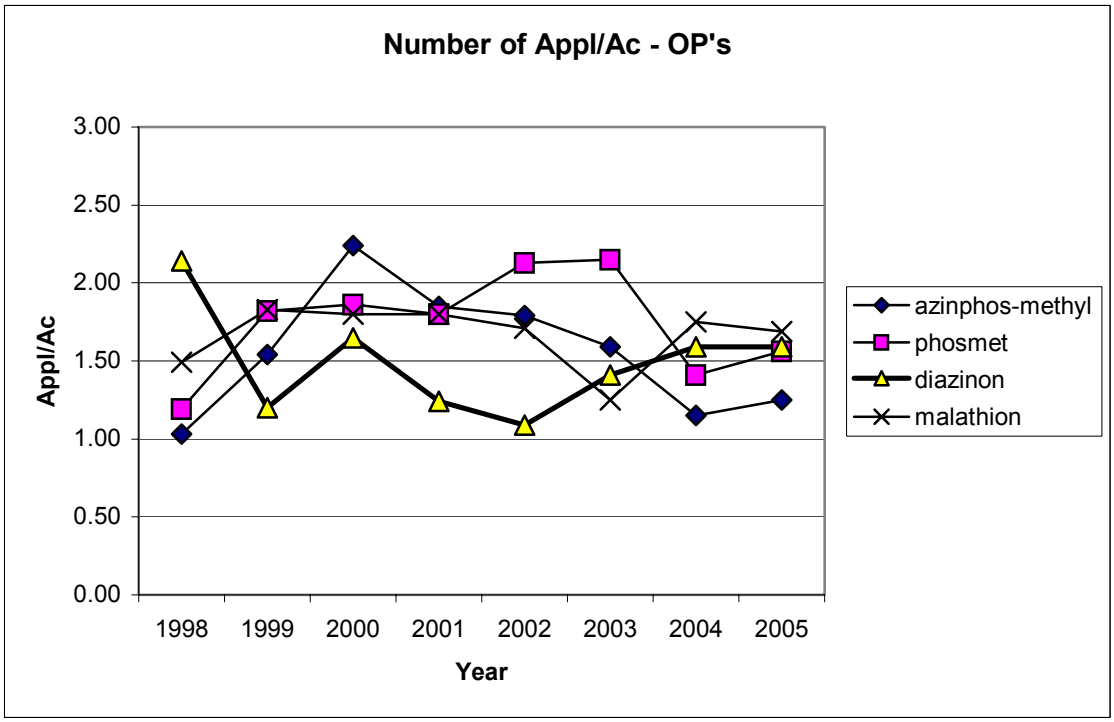
Blueberry Insecticide Use - 2004

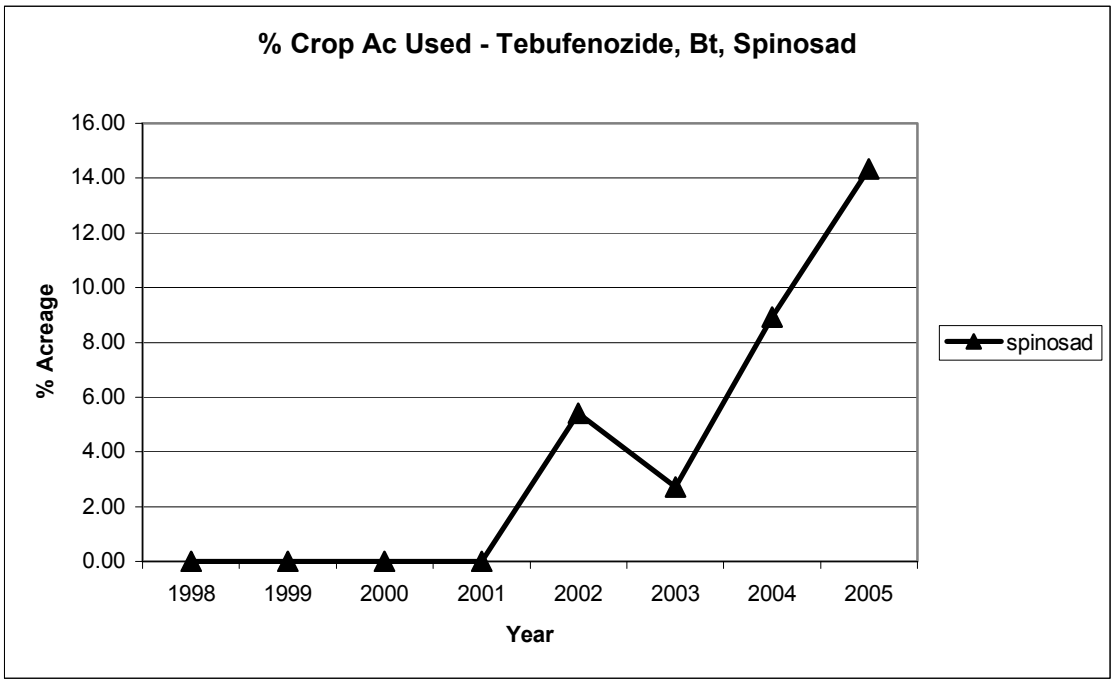
AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	0.64	0.55	1.15	40.53
Bt	0.54	0.54	1.00	0.15
carbaryl	1.43	0.90	1.60	10.11
diazinon	1.48	0.93	1.59	46.22
esfenvalerate	0.03	0.03	1.00	21.65
imidacloprid	0.17	0.13	1.28	54.59
malathion	2.73	1.56	1.75	8.82
methomyl	1.27	0.77	1.64	41.02
phosmet	1.23	0.87	1.41	50.03
pyrethrins	0.03	0.03	1.00	0.08
pyriproxyfen	0.01	0.01	1.09	5.23
spinosad	0.10	0.09	1.15	8.92
4282 Ac, 36 growers, 74 farms				

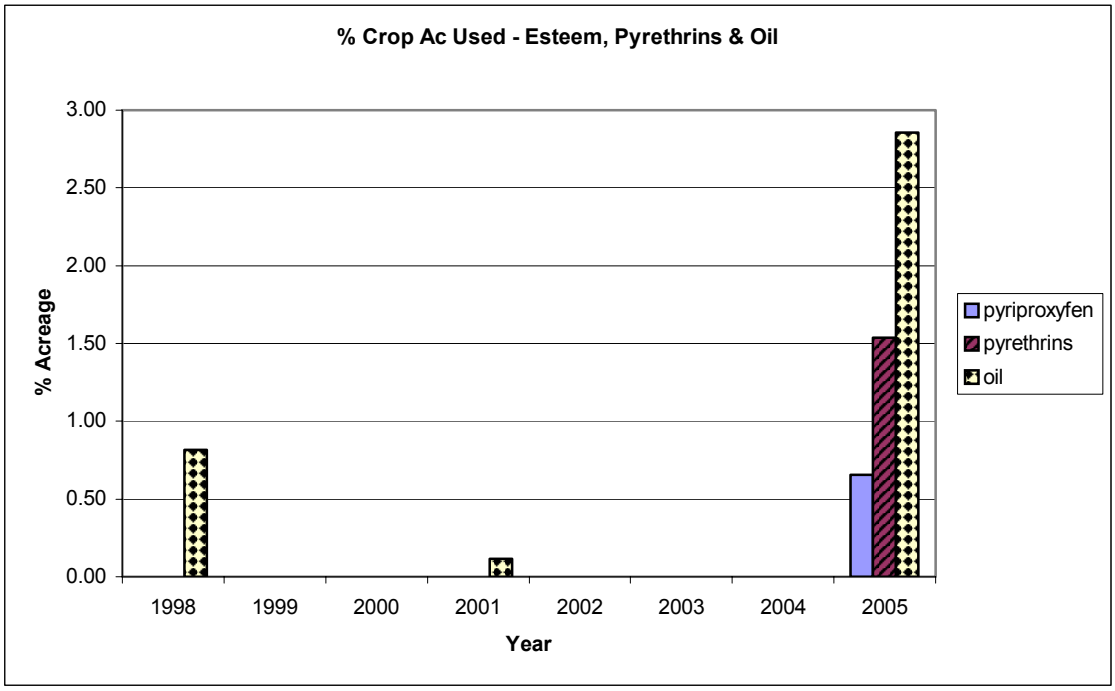
Blueberry Insecticide Use - 2005

AI	Total AI/A	Avg Rate/A	Avg # Ap/A	% A Used
azinphos-methyl	0.77	0.61	1.25	45.28
Bt	0.47	0.47	1.00	2.52
carbaryl	1.09	0.89	1.22	9.59
diazinon	1.44	0.97	1.47	54.72
esfenvalerate	0.03	0.03	1.24	13.96
imidacloprid	0.08	0.07	1.19	49.73
malathion	2.31	1.37	1.69	14.09
methomyl	1.10	0.69	1.60	47.57
petroleum oil	23.71	23.71	1.00	2.86
phosmet	1.40	0.90	1.56	54.23
pyrethrins	0.02	0.02	1.21	1.54
pyriproxyfen	0.01	0.01	1.00	0.66
spinosad	0.08	0.07	1.14	14.33
4273 acres, 33 growers, 69 farms				


% of Acreage Where Used - OP's
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
% Acreage
1998
1999
2000
2001
2002
2003
2004
2005
Year
azinphos-methyl
phosmet
diazinon
malathion


Number of Appl/Ac - OP's
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Appl/Ac
1998
1999
2000
2001
2002
2003
2004
2005
Year
azinphos-methyl
phosmet
diazinon
malathion


% Crop Ac Used - Tebufenozide, Bt, Spinosad
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
% Acreage
1998
1999
2000
2001
2002
2003
2004
2005
Year
spinosad


% Crop Ac Used - Esteem, Pyrethrins & Oil
3.00
2.50
2.00
1.50
1.00
0.50
0.00
% Acreage
1998
1999
2000
2001
2002
2003
2004
2005
Year
pyriproxyfen
pyrethrins
oil

Fiber Content of Two Rabbiteye and Two Southern Highbush Blueberry Cultivars

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Summary

A two-year study was conducted on the cell wall structural component content of two rabbiteye ('Tifblue' and 'Premier') and two southern highbush ('Pearl River' and 'Magnolia') blueberry cultivars. Rabbiteye blueberries were found to have a significantly higher concentration of neutral detergent fiber than southern highbush. Neutral detergent fiber comprises cellulose, hemicellulose, and lignin, three of the major components of cell walls, and it is the method of choice for analysis of dietary fiber in cereal.

Introduction

The interest in functional foods and health benefits is ever increasing. Nutritional aspects of foods are becoming more and more important as consumers become increasingly aware of the effect of foods on their bodies. Hippocrates, "the father of medicine," once suggested that we let food be our medicine. Over the last 2,000+ years, considerable evidence has proven how true Hippocrates words of wisdom are. Over many centuries plants have provided natural medicines to heal many ailments. There is now considerable research showing that diets containing less fat and higher fiber to be healthy (Marckmann, et al. 1993). The advantages of high fiber diets have been well documented (Wolk, 1999, Marlett et al., 2002). A diet containing 25 g of dietary fiber per day is generally recommended (Pilch 1987). Blueberries contain a several phytochemicals that can improve heart function, memory, eyesight as well as block bacterial attachment to bladder walls (www.blueberry.org). These small fruit pack a lot of punch and are proving to be a powerful medicine, and they are good tasting, too.

Materials and Methods

Fruit samples of both ripe and purple (not completely ripe) blueberries were collected from two rabbiteye and two southern highbush cultivars in 2002 and 2003. Four replicates of 100 g (80–100 berries) fruit samples were freeze-dried for fiber analysis. We separated cell wall components successfully by use of a neutral detergent, Na-lauryl sulfate, EDTA, pH 7.0, and an acid detergent, cetyl trimethyl ammonium bromide in 1N H_2SO_4 (Van Soest, 1963). Neutral detergent fiber (NDF) allowed us to quantify hemicellulose, cellulose, and lignin collectively, and acid detergent fiber (ADF) allowed us to quantify cellulose and lignin. Acid detergent fiber, neutral detergent fiber, and lignin analysis were run using an ANKOM Technology fiber analyzer at Mississippi State University plant analysis laboratory.

Results and Discussion

The greatest difference found in fiber content was found between rabbiteye and southern highbush blueberry types (Table 1). Rabbiteye blueberries contained a higher concentration of NDF than did southern highbush blueberries. In 2002 we also found a significant difference in the percent NDF and ADF recovered between cultivars within the rabbiteye and southern highbush blueberry types.

A significantly greater concentration of fiber was recovered in the purple fruit from all cultivars (Fig. 1). A decrease in fiber from purple to ripe fruit suggests an enzymatic reaction during the ripening process. This enzymatic process breaks down the components of the cell walls, which decreases the NDF and ADF recovered. This corresponds to a decrease in dietary fiber content as the fruit ripens to maturity.

Literature Cited

Hippocrates. On Ancient Medicine in Great Books of the Western World, Volume 10, Robert Hutchins (ed.), Encyclopedia Bitannica, 1952.

Marckmann P, B. Sandstrom, and J. Jespersen. 1993. Favorable Long-term Effect of a Low-fat/High-fiber Diet on Human Blood Coagulation and Fibrinolysis. Arterioscler. Thromb. Vasc. Biol. 13: 505-511.

Marlett, J., M.I. McBurney, J.L. Slavin. 2002. Health Implications of Dietary Fiber. J. Am. Diet. Assoc. 102:993-1000.

Pilch S. 1987. Physiological Effects and Health Consequences of Dietary Fiber. Bethesda, MD: Life Sciences Research Office, Federation of American Societies for Experimental Biology.

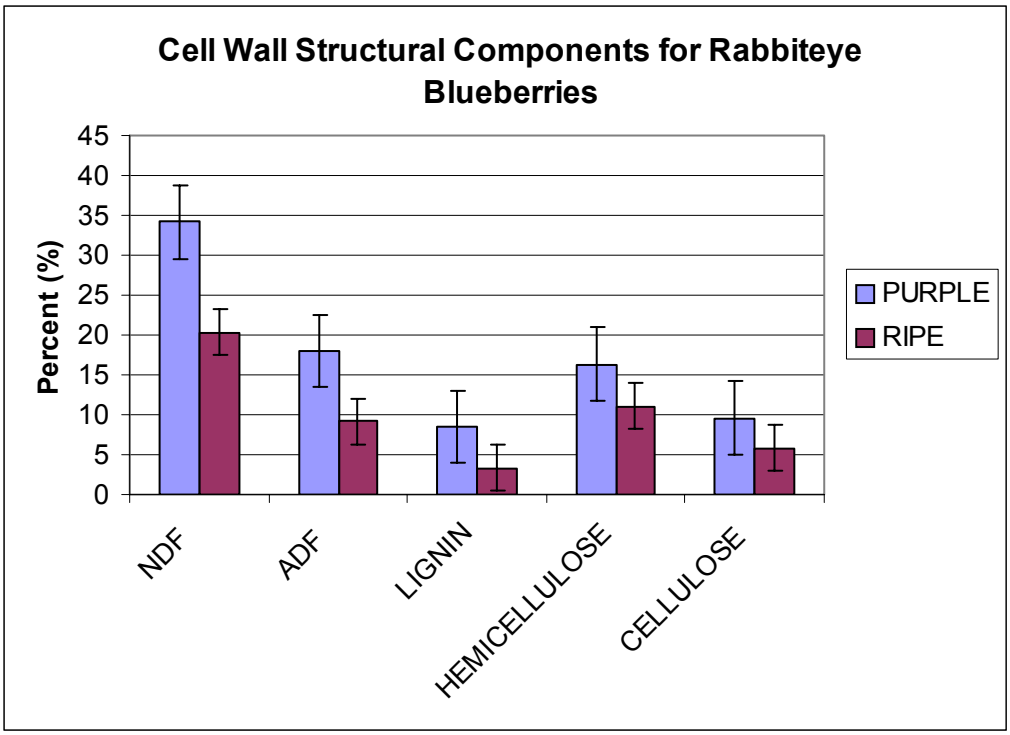
Van Soest, P. J. 1963. Use of Detergents in the Analysis of Fibrous Feeds. II. A rapid Method for the Determination of Fiber and Lignin. J. Ass. Offic. Agr. Chem. 46:829–35.

Wolk A., J. E. Manson, M. J. Stampfer, G. A. Colditz, F. B. Hu, F. E. Speizer, C. H. Hennekens, and W. C. Willett. 1999. Long-term Intake of Dietary Fiber and Decreased Risk of Coronary Heart Disease Among Women. JAMA, 281(21): 1998-2004.

Table 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF) content of commercially ripe rabbiteye and southern highbush blueberry cultivars.

Variety	2002		2003	
	NDF %	**ADF %**	**NDF %**	**ADF %**
Tifblue (Rabbiteye)	17.5 b[z]	8.7 b	20.8 a	9.1 a
Premier (Rabbiteye)	23.7 a	13.6 a	19.8 a	9.2 a
Pearl River (Southern highbush)	6.9 d	4.3 c	11.3 b	5.8 b
Magnolia (Southern highbush)	8.3 c	4.6 c	13.2 b	6.6 b

[z]Means separation within columns by LSD at $P \leq 0.05$.



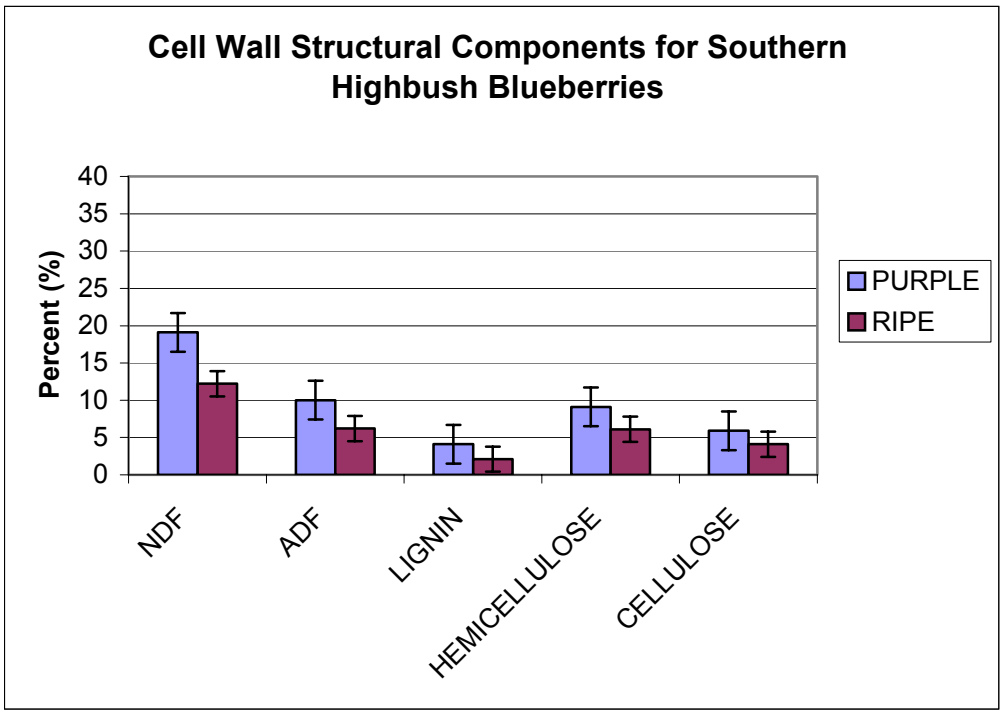


Figure 1. Percent of cell wall structural components for purple and ripe stages of rabbiteye (A) and southern highbush (B) blueberries. 2003. Differences in letters indicate a statistically significant difference in data for each individual component (LSD $P \leq 0.05$).

Development and Implementation of Reduced-Risk Pest Management Programs for Blueberries in New Jersey

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Introduction

After implementation of the Food Quality Protection Act (1996), the use of several key broad-spectrum insecticides has been prohibited or will likely be restricted. As broad-spectrum insecticides are replaced by more selective, 'reduced-risk' insecticides, there is the potential for several unintended consequences for blueberry insect pest management. First, blueberries contain a plethora of secondary pests that have been kept below injury levels by broad-spectrum insecticides. Second, the reduced-risk options do not generally have the same level of contact toxicity and environmental persistence compared to the current options, thus the risk of control failure is greater, resulting in more frequent applications and greater cost. Furthermore, abundance of natural enemies is expected to be greater under a management program that relies more on reduced-risk products and less on broad-spectrum insecticides.

A study was initiated in 2003 to develop and implement reduced-risk insect pest management programs for blueberries in New Jersey. Our specific objectives were to: 1) compare the effects of reduced-risk vs grower standard programs on insect pests populations; 2) compare the effects of reduced-risk vs grower standard programs on natural enemy populations; And 3) compare the differences in number of applications and costs between the two programs.

Materials and Methods

The study was conducted in five commercial blueberry farms in Burlington County (1 site) and Atlantic County (4 sites), New Jersey. Each site consisted of 8 to 16 acres (Table 1). All contained the variety 'Bluecrop'. Each site was divided into two paired plots: one plot was designated as a grower standard (GS) and the other as reduced-risk (RR). In the RR plots, we made decisions on which insecticides were sprayed using insect scouting data. Growers were advised not to use the same spraying schedule in the GS plot as in the RR where feasible; instead, the spraying regimen in the GS plot was to be such that it would be representative of all other plots on their farm.

A variety of methods were used to sample and monitor insect pests and their natural enemies during the season. In New Jersey, cranberry fruitworm, oriental beetle, blueberry maggot, and aphids are considered major pests. Secondary pests include: leafrollers and spanworms, leafminers, leafhoppers, thrips, tipworms, and weevils. Pheromone traps were used to monitor male obliquebanded leafroller, redbanded

leafroller, cranberry fruitworm, oriental beetle, and blueberry leafminer. Traps were also placed for monitoring sharpnosed leafhopper, thrips, and blueberry maggot. Traps for different insects were evenly spaced throughout each plot and checked at weekly intervals. Ten clusters were checked on ten bushes, for a total of 100 clusters sampled per plot. Each week in April, May, and June half of the clusters were flower/fruit and half were vegetative. Expected insect pests included: caterpillars (i.e., fruitworms, leafminers, leafrollers, spanworms), aphids, leafhoppers, and beetles (i.e., weevils). In each plot, 20 bushes were selected for sampling using beating trays. Five canes on a bush were beaten five times into a tray (28 cm x 21 cm). Surveys occurred weekly in each monitoring unit, from April through June. This method was used to sample insect pests that were often concealed (i.e., thrips and weevils), as well as more visible pests. In addition, ten tender vegetative clusters were checked in the lower 1/3 of ten bushes, for a total of 100 clusters sampled in each plot. This method was used to sample aphids. Surveys were conducted weekly from mid-May until the first week of August.

Numbers of beneficial insects included lacewings, ladybeetles, and spiders were counted from cluster, new shoot growth, and beating tray samples as described above. In addition, six pitfall traps were placed in each plot at each farm. The traps consisted of a plastic cylinder (473 ml, 12 cm in diameter) that contained 25 ml of 1:1 solution of ethylene glycol to water. A wooden platform (15 cm x 15 cm) was erected over the partially buried cylinder to prevent rain and irrigation water from entering into the trap. A total of 8 samples were collected, which ranged from one to four weeks of field exposure. The first sample was in mid-April and the last was in mid-August. Pitfall traps were used to sample natural enemies, such as ground beetles (Carabidae), rove beetles (Staphylinidae), ants, and spiders.

Results

Between 2003 and 2005, almost twice as many insecticide sprays were made in GS than RR plots. The cost of program did not differ between plots (Table 2).

There were not differences between the GS and RR programs in the numbers of obliquebanded leafroller, cranberry fruitworm, sharpnosed leafhopper, oriental beetle, thrips, blueberry maggot, and leafminer in traps (Fig. 1). However, higher numbers of redbanded leafroller in pheromone traps were collected in the GS plots compared to the RR plots. Number of oriental beetle adults in traps was lower in 2005 compared to 2003 and 2004. In contrast, the number of thrips in traps increased in 2005 compared to 2003.

In cluster samples, the total number of leafrollers, cranberry fruitworm, spanworm, leafminer, and cranberry weevil larvae, as well as number of larvae and adult thrips and tipworm damage, was not different between GS and RR plots (Fig. 2). However, cranberry fruitworm larval populations were higher in 2005 compared to 2003 and 2004, whereas numbers of leafminer larvae were higher in 2004 compared to 2003 and 2005 (Fig. 2). Similar to trap counts, fewer thrips were found in cluster samples in

2003 and 2004 compared to 2005. Tipworm damage was higher in 2004 compared to 2005 (Fig. 2). Tipworm damage was monitored in 2004 and 2005 only.

In beating tray samples, the total number of cranberry weevil adults, plum curculio adults, spanworm and leafroller larvae, aphids, and thrips was not different between GS and RR plots (Table 3). However, populations of weevils were higher in 2005 compared to 2003 and 2004, whereas numbers of aphids and thrips in beating tray samples were higher in 2003 compared to 2005 (Fig. 2). Results of thrips counts in beating trays contradict those from traps and cluster sampling where numbers of thrips were higher in 2005 compared to 2003.

The season number of aphids in new shoot growth was not different between GS and RR plots (Fig. 3). Similar to beating samples, the numbers of aphids in new growth samples were higher in 2003 compared to 2005 (Fig. 3).

There were no differences in the numbers of carabids and spiders in pitfall traps between GS and RR plots (Fig. 4). There were, however, differences between GS and RR plots in the number of adult lady beetles (Fig. 5). As predicted, numbers of adult lady beetles in new shoot growth were higher in RR plots compared to GS plots. No differences between plots were found for spiders and syrphid files (Fig. 5). Numbers of syrphid larvae new growth samples were higher in 2003 compared to 2004 and 2005. This decline in the number of flower fly larvae might be explained by the sudden decline in aphid populations (Fig. 3). In contrast, the numbers of lady beetle adults in new shoot samples were higher in 2005 compared to 2003. Greater abundance of lady beetles coincides with an increase in numbers of several secondary pests (Fig. 1 and 2; Table 3). Similarly, abundance of spiders, another generalist predator, in new shoot samplings was greater in 2005 compared to 2003.

Conclusions

After 3 years of grower-standard (GS) and reduced-risk (RR) spray programs, there were little-to-no significant differences for numbers of at least ten insect pests: leafrollers, cranberry fruitworm, spanworm, leafminer, cranberry weevil, plum curculio, leafhopper, aphids, blueberry maggot, thrips and tipworm. The lack of differences in pest abundance indicates that both spray programs achieved a similar level of pest control.

The most noticeable was the difference in number of insect pests among years (2003-2005). Some major pests such as aphids and oriental beetle decreased in numbers since 2003, while abundance of several secondary pests (oblique banded leafroller, cranberry fruitworm, thrips, cranberry weevil and plum curculio) increased.

Another noticeable difference was the average number of insecticide sprays in GS and RR spray programs, which was 3.9 and 2.2, respectively. In 2005, the GS program cost 20% less than the RR program, primarily because of the higher cost of RR insecticides.

This differs from 2003 and 2004 where the cost of the GS program was greater than the RR program.

Contrary to our expectations, little-to-no significant differences were found for the numbers of natural enemies in the GS spray or the RR spray program. Only lady beetle adults were found in higher numbers in RR plots compared to GS plots. As with insect pest populations, numbers of natural enemies have changed over the years. Numbers of flower flies, that prefer to prey on aphids, declined since 2003. This decline coincides with a sudden drop in aphid populations, possibly caused by an increase use of Provado for aphid control. In contrast, numbers of lady beetles and spiders increased since 2003, which coincides with an increase in numbers of several secondary pests.

Acknowledgements

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Table 1. Study sites.

		Acreage		
Site	**County**	**Grower Standard**	**Reduced-Risk**	**Total**
1	Burlington	5	4	9
2	Atlantic	5	5	10
3	Atlantic	7.8	8	15.8
4	Atlantic	4	4	8
5	Atlantic	5	4.9	9.9

Table 2. Insecticide spray record.

	Grower Standard	**Reduced-Risk**
Average cost of spays		
2003	$ 62.40	$ 37.24
2004	$ 71.74	$ 20.40
2005	$ 60.53	$ 69.54
Average no. of sprays		
2003	4.6	2.4
2004	3.4	1.4
2005	3.8	2.8

Table 3. Seasonal number of insects in beating trays.

	2003		2004		2005	
Insect[1]	**GS**	**RR**	**GS**	**RR**	**GS**	**RR**
Cranberry weevil	9.6	16	24.2	42.8	69.2	61.6
Plum curculio	0.4	0.4	1	0.8	4	4.2
Spanworm	3	2.6	2.2	2.2	0.8	1.4
Redbanded leafroller	0	0.2	0	0	0.8	0.4
Aphids	140.8	161.2	0.2	0	1	0.4
Thrips	63.2	55.6	31.6	26	24.4	24.6

[1] Numbers indicate means per farm. GS = grower standard; RR = reduced-risk

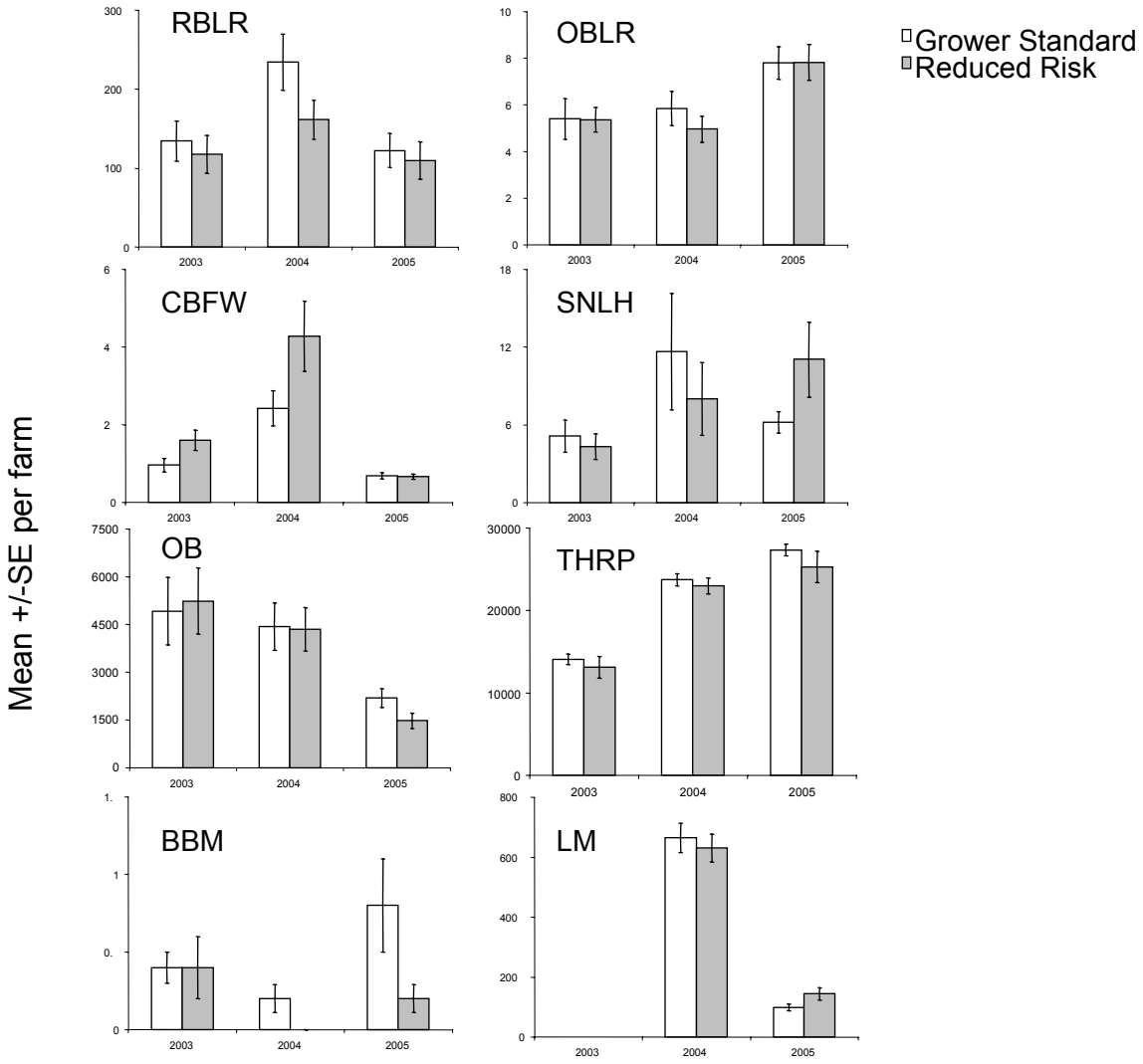

Figure 1. Mean seasonal number of insects caught in traps. RBLR = redbanded leafroller; OBLR = obliquebanded leafroller; CBFW = cranberry fruitworm; SNLH = sharpnosed leafhopper; OB = oriental beetle; THRP = thrips; BBM = blueberry maggot; and LM = leafminer.

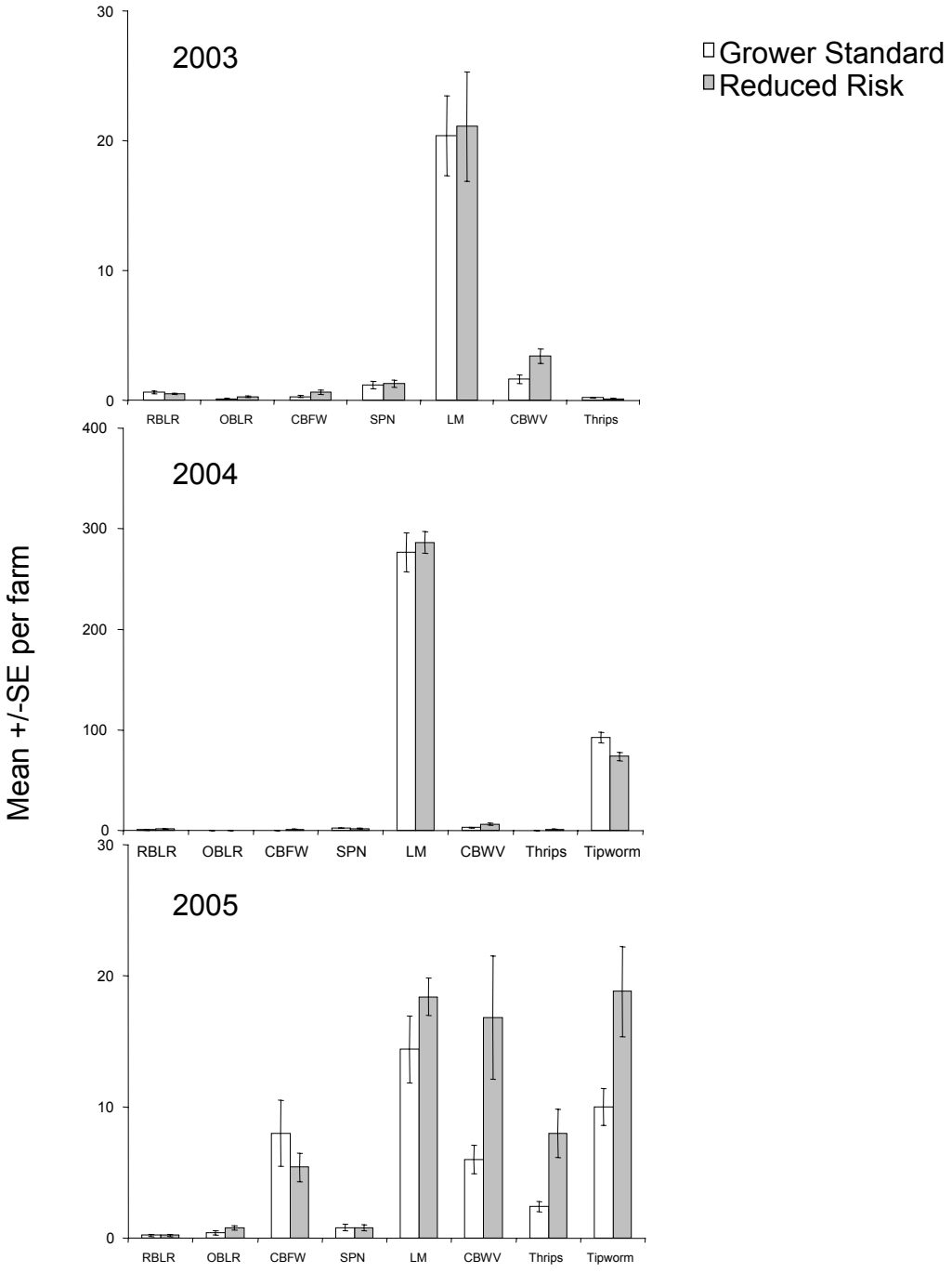

Figure 2. Mean seasonal number of insects in cluster samples. RBLR = redbanded leafroller; OBLR = obliquebanded leafroller; CBFW = cranberry fruitworm; SPN = spanworm; CBW = cranberry weevil; and LM = leafminer.

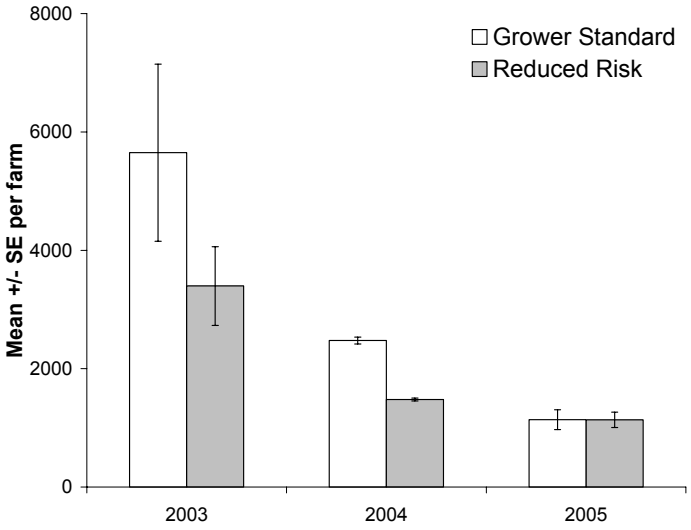

Figure 3. Mean seasonal number of aphids in new growth samples.

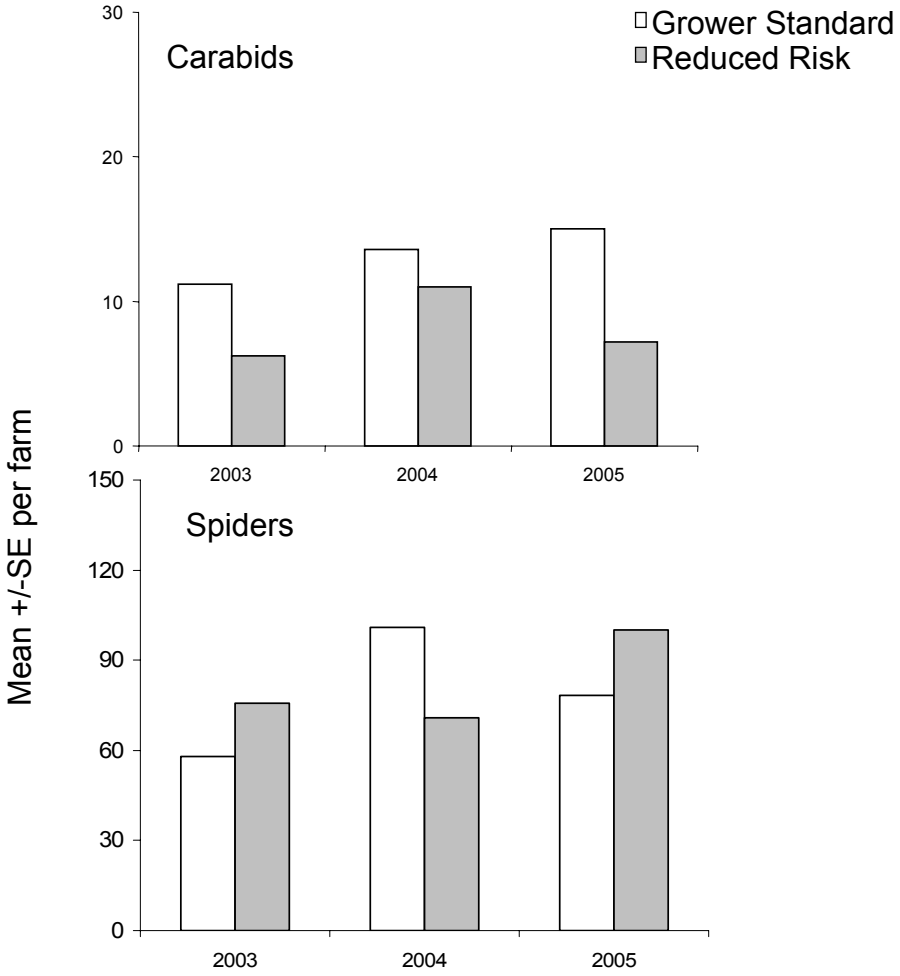

Figure 4. Mean seasonal number of natural enemies in pitfall traps.

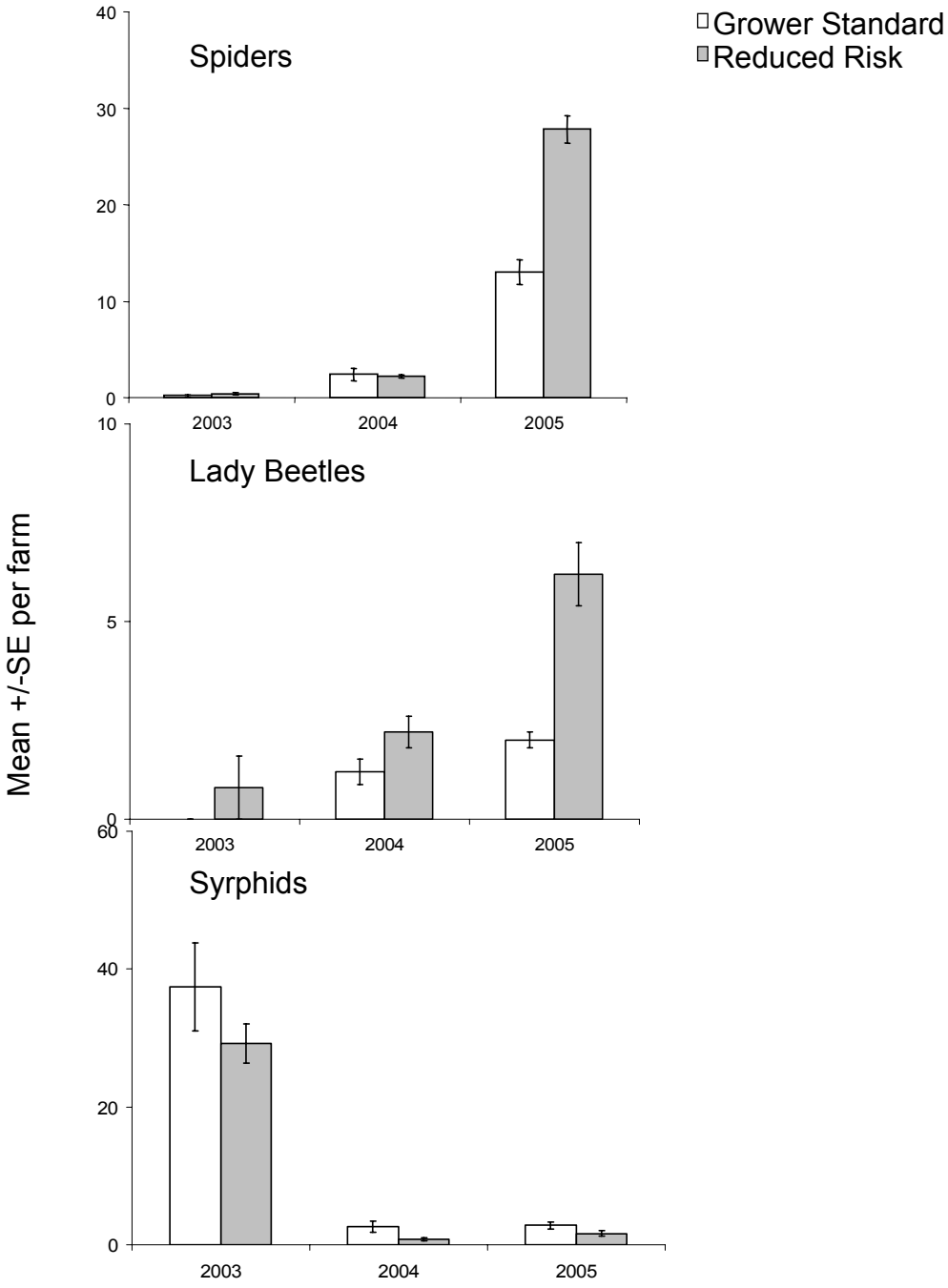

Figure 5. Mean seasonal number of natural enemies in new growth samples.

Recent and Pending Blueberry Cultivar Releases

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Four new blueberry cultivars were released by the USDA-ARS Small Fruit Research Station in 2004 and 2005, with another being requested for release in 2006. These new blueberries were developed from germplasm adapted to the Southern U.S. and include two rabbiteye, two southern highbush, and one evergreen ornamental blueberry cultivar.

'DeSoto' rabbiteye blueberry (*Vaccinium ashei*) resulted from a cross between the rabbiteye blueberry breeding lines, T-110 X T-107, made originally made in Beltsville MD in the early 1970's. 'DeSoto' was selected by A.D. Draper at Poplarville, MS. in 1976 tested as MS 63, and released as a new cultivar in 2004. Plants of 'DeSoto' are semi-dwarf, moderately spreading with good vigor, and have displayed medium to high yield potential as well as durability in droughty mineral soils. Flowering occurs approximately 21 days after 'Climax', providing insurance against late spring frosts. Berries of 'DeSoto' are medium–large, medium to light blue in color, with good picking scars, firmness and flavor and develop on medium to loose clusters. Berry ripening occurs about 14 days after 'Tifblue' and extends over a six week period or longer, thereby extending the fresh market and U-Pick rabbiteye blueberry seasons. The name "DeSoto" was chosen since one of the testing sites for USDA-ARS blueberry germplasm in MS. is adjacent to the DeSoto National Forest in Stone County, MS.

The release of a new rabbiteye blueberry (*V. asheii*) to be named 'Prince' is pending and planned for the fall of 2006. 'Prince' rabbiteye blueberry, resulting from a cross between the two rabbiteye blueberry breeding lines MS 598 and FL 80-11 made at Poplarville, MS, was selected by A.D. Draper in 1996, and was tested as MS 706. Plants of 'Prince' are moderately vigorous, upright, and are productive. Flowering occurs 5 – 7 days before 'Climax', but at about the same time as the southern highbush cultivars 'Star' and 'O'Neal', Thus it's area of adaptation is limited to the Gulf Coast and other regions of the U.S. that historically escape freezing temperatures in early-mid March. Berries of 'Prince' are medium in size and color, have small dry picking scars, and have very good flavor. In southern MS., ripening occurs 7 – 10 days ahead of 'Climax', the most widely grown early-ripening rabbiteye blueberry, and should provide growers the opportunity to capitalize on higher prices associated with early-market windows for blueberries.

'Dixieblue' southern highbush blueberry (*V. corymbosum*) resulted from a cross between G144 X US 75 and was selected by A.D. Draper in 1979 and was subsequently tested as MS 111 and released in 2005. Plants of 'Dixieblue' are moderately vigorous, spreading, and displayed durability and good yield potential in droughty mineral soils. Flowering in 'Dixieblue' occurs approximately 7 days after the rabbiteye blueberry

cultivar ‘Climax’ or 14 days after the southern highbush cultivar ‘Star’, providing a degree of protection from injury by late Spring freezing. ‘Dixieblue’ berries are very attractive, medium to large, flat (disc shaped), light blue, firm, and have good picking scars and flavor. Ripening occurs approximately 10 days after ‘Star’ but 7-10 days ahead of ‘Climax’, providing growers with a new cultivar to utilize in the early ripening ‘continuum’ between southern highbush and the earliest rabbiteye blueberries.

‘Gupton’ southern highbush blueberry (*V. corymbosum*) resulted from a cross between MS 122 X MS 6, was selected by A.D. Draper in 1991, was subsequently tested as MS 548, and was released as a new blueberry cultivar in 2005. Plants of ‘Gupton’ are vigorous, upright, and productive and have demonstrated durability in droughty mineral soil. Flowering in ‘Gupton’ occurs about the same time as that of ‘Dixieblue’. ‘Gupton’ berries are medium - large, light blue, firm, and have good picking scars and flavor. Ripening occurs approximately 10 days before ‘Climax’ which is currently within the early-market threshold.

‘Nativeblue’ ornamental evergreen blueberry (*V. darrowi*) resulted from a cross between FL-4B X US799, and was selected by A.D. Draper in 1994, was subsequently tested as MS 611, and was released as a new cultivar in 2004. ‘Nativeblue’ plants are typical of *V. darrowi* in that they are compact and low growing, finely branched. Foliage of ‘Nativeblue’ is evergreen and glaucous, and leaves change colors as they develop and mature from pink and bluish hues to dark green when mature. Profusive flowering in ‘Nativeblue’ occurs from early March to early April. ‘Nativeblue’ fruit are small, dark, semi-sweet and flavorful and are enjoyed by wildlife. ‘Nativeblue’ is an ornamental adapted to the Southeastern U.S. which may be used to complement azaleas, camellias, crepe myrtles, etc., in landscape settings or which may be grown in pot or basket culture.

These new rabbiteye and southern highbush blueberries provide growers with productive cultivars that produce berries having excellent quality that not only ripen during the early market windows but will also substantially extend the fresh and U-Pick market seasons. The new ornamental cultivar will provide nurserymen and landscapers with an attractive and durable new evergreen to complement the more traditional southern perennials. These blueberry cultivars are readily propagated utilizing both softwood and hardwood cuttings. They are recommended for trial plantings in the Southeastern and Gulf Coast Regions of the U.S. To ensure adequate pollination and good fruit set, these new blueberry cultivars should be interplanted with other rabbiteye or southern highbush blueberry cultivars.

Variety test of Southern Highbush Blueberry for Forcing Culture in Japan

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Summary

One of the major problems in producing high quality blueberry fruit is that the harvesting season of many highbush blueberry cultivars occurs during the rainy season (June and July) in Japan. For this reason, some growers are interested in forcing blueberries into producing mature fruit before the rainy season begins. Using several cultivars of southern highbush growing under heated culture, the flowering and harvesting time, percentage of harvest and yield, and fruit quality parameters were investigated. Potted three and four year old plants were transferred from outdoors into a plastic house on the beginning of February 2004 (experiment 1) and 2005 year (experiment 2). Temperature was maintained between 10C-35C with heating until the beginning or the end of May. Bee pollination, watering, fertilizing were performed using typical methods. In this study, both flowering and harvesting time was advanced 30-40 days under heated culture as compared to the natural environment. A noteworthy finding was that the ripening and harvesting time of almost all cultivars of southern highbush, except 'Ozarkblue', was completed before the rainy season started. However, there needs to be more evaluation of recommended cultivars for plant vigor, plant health and fruit firmness in addition to fruit quality parameters under heat culture.

Introduction

Blueberry culture in Japan has rapidly expanded in recent years. In 2005, the total growing area of four types of blueberries, northern highbush, half-high highbush, southern highbush and rabbiteye blueberry, were estimated to reach about 700ha. Northern highbush is the most popular blueberry, however, the harvesting season of many cultivars occurs during the rainy season (June and July). Therefore, it is very difficult to obtain good taste and good keeping quality of blueberry fruit (Tamada, 1996; Ozeki and Tamada, 2004). For this reason, some blueberry growers are interested in forcing blueberries into producing mature fruit before the rainy season begins.

The quantity of chilling requirement and the early ripening characteristics are very important factors in forcing culture. Trials of southern highbush have been performed under mild winter climatic conditions in some countries (Barrau and Santos et al., 2004; Carter and Clark et al., 2002; Childers and Lyrene, 2006; Ciordia and Garcia et al., 2004; Williamson and Lyrene, 1995). However, reports for forcing culture of southern highbush blueberry are very few (Baptista and Oliveria et al., 2004; Ciordia and Diaz et al., 2001; Ozeki and Tamada 2004).

The purpose of this study was to evaluate several southern highbush cultivars so that recommendations can be made about cultivar adaptation for forcing culture in Japan. The flowering and harvesting time, percentage of harvest and yield, fruit quality parameters were investigated.

Materials and Methods

Two experiments were conducted at the greenhouse of Ozeki blueberry nursery (Ibaraki-ken, Thuchiura-shi, located in the northeast about 75km from Tokyo). In experiment 1 (in 2004), four years old plants of eighteen southern highbush cultivars were grown in 21L vinyl pots with the ratio of mixed volcanic soil 4 : peat moss 6 in volume (Table 2). The northern highbush 'Earliblue' and the rabbiteye 'Climax' were used as the controls.

We used 6 plants for each cultivar, placing one plant in a pot. The transplant was performed in October of the previous year, and the plants were grown under open air condition. The plants were carried into the plastic house on 28th January, and the air heating continued from 4th February to 10th May. The air temperature was managed between 10C-35C. A small size hive of honeybees was carried in house through the flowering period to secure pollination.

Fertilizer was applied two times (first week of March and middle week of April, about 25g per pot at one time) as IB compound fertilizer (N-P-K: 10-10-10). Watering was done as required from an appearance of the surface of pot. Fruits were harvested every five days. Number of fruit and yield were taken on each plant. Fruit were immediately frozen at -20C for juice analysis. In December, frozen fruit were thawed and blended using about 20-30 fruit per harvest day. Sweetness (Soluble solid content, SSC) was measured with a hand refractometer, and citric acid (CA) was measured with a fruit tester (Tokyo Garasu Kiki Co.).

In experiment 2 (in 2005), three-year-old plants of thirteen southern highbush cultivars were grown in 14L vinyl pots (Table 3). The northern highbush 'Earliblue' was used as the control. The plants were carried into the house on 27th January, and the air heating began on 10th February and continued to 18th May. The air temperature was set at 10C-35C from 10th February to 24th May, and was changed to 18C-35C after the 25th March. The mean temperature of the air and pot soil in experiment 2 was higher than that of experiment 1 (Table 1). The kind of potting mix, time of fertilizer application (application rate changed to 18□per pot), watering, bee pollination, harvesting and other methods of investigation were the same as in experiment 1.

Results and Discussion

Flowering Time

Flowering time was investigated every three days. Date of 50 % flowering time varied among cultivars and experiments. Flowering was advanced about 25-50 days (1st-24th March) in experiment 1, and about 45-53 days (26th February-5th March) in experiment 2 under heat culture as compared to the open field culture (usually, at the third week of April) (Table 2 and 3). When comparing cultivars, the date of 50 % flowering time of 'Sharpblue' and 'Sapphire', 'O'Neal' and 'Cape Fear' were earlier than 'Star', 'Reveille', 'Ozarkblue' and 'Pender'. The northern highbush 'Earliblue' was the last to flower in experiment 2.

Comparing the two experiments, the mean 50 % time of flowering in experiment 2 was earlier by about 10 days than that of experiment 1. This difference was considered to be caused by the air temperature in experiment 2 which was higher than that of experiment 1 during the flowering period (Table 1). It has been documented previously that moderately higher air temperature hastens the flowering time of blueberry (Gough 1994; Lyrene 2006).

From the results of these experiments, it was concluded that the chilling requirement of southern highbush cultivars was satisfied by the end of January in most parts of the island of Japan. The monthly mean air temperature for November, December and January in Tokyo was 13.0C, 8.4C and 5.8C, respectively (National Astronomical Observatory 2004).

Ripening Time

Ripening and harvesting time of all southern highbush cultivars were advanced 30-40 days under heat culture as compared to open culture which usually lasts from the first week of June to the end of July (during the rainy season) (Table 2 and 3).
When comparing cultivars, the 50 % ripening time was divided into three ripening seasons in experiment 1;

1 = early season (ripened within 100 day after heating, before 10th May)
'Bladen', 'Cooper', 'Reveille' and 'Sharpblue'.
2 = middle season (ripened between 101-110 day after heating, 11th-20th May)
'Biloxi', 'Blue Ridge', 'Cape Fear', 'Flordablue', 'Georgiagem',
'Misty', 'O'Neal', 'Sapphire' 'Southmoon' and 'Earliblue' (NHB).
3 = late season (ripened over 111 day after heating, after 21st May)
'Magnolia', 'Ozarkblue', 'Pender', 'Star', 'Summit' and 'Climax' (RE).

Therefore, the harvesting time of most of the southern highbush cultivars was finished before the start of the rainy season, except 'Ozarkblue' and the rabbiteye cultivar 'Climax'.

Comparing the two experiments, the time of 50 % ripening was between 92 (5th May)-125 day (7th June) in experiment 1, and was between 85 (5th May)-103 day (23rd May) in experiment 2. From previous reports (Gough 1994; Darnell 2006; Lyrene 2006), the earlier ripening time in experiment 2 was considered to be caused by higher air temperature during the fruit growing period than that of experiment 1 (Table 1). The monthly mean air temperature and rainfall of June and July in Tokyo was 21.8C (rainfall 165mm), 25.4C (rainfall 163mm), respectively (National Astronomical Observatory 2004).

Fruit Growing Period

Fruit growing period (days from 50 % flowering time to 50% ripening time) were different among cultivars and experiments (Table 1 and 2). Across both experiments, the fruit growing period of 'Sharpblue' and the northern highbush 'Earliblue' were shorter than other cultivars, and 'Summit' and the rabbiteye 'Climax' had the longest fruit growing periods. The data indicate that apparently the earliest opening flowers are not consistently the earliest ripening.

When comparing experiments 1 and 2, the fruit growing period of 'Cape Fear', 'Cooper', 'Flordablue', 'Misty', 'O'N'eal' and 'Reveille' in experiment 2, which was at higher air temperature, were longer by about 10 days than that of experiment 1. However, the fruit growing period of 'Summit' and the northern highbush 'Earliblue' in experiment 2 were

shorter than that of experiment 1. These differences were considered to be caused by the fact that the growth rate at the higher ambient temperature was different from cultivar to cultivar. The results of these experiments, showed that there will be more to investigate with regards to the relationship between fruit growing period of the cultivars and the air temperature under heat culture.

Percentage of Fruit Set and Yield

Percentage of fruit set (calculated by dividing the estimate number of floret by total number of harvested fruit per tree) is a very important factor with respect to fruit yield. Comparing cultivars in experiment 1 (Table 2), we found that 'Biloxi', 'Bladen', 'Georgiagem and 'Revelle' had higher percentage of fruit set (over 80 %), and 'Ozarkblue', 'Star' and 'Summit' had lower (under 50%) percentage of fruit set.

Fruit yields were different among cultivars and experiments (Table 2 and 3), however the age of the trees in experiment 1 and 2 was different. As a whole, maximum yield was obtained with 'Magnolia' (1,163.6g) and 'Georgiagem' (1,137.3g) in experiment 1. Meanwhile, the yield of 'Star' in experiment 2 was very low. This result of 'Star' seemed to be caused by something like botrytis disease (estimated from symptoms) during flowering time (Caruso and Ramsdell 1995).

Fruit Quality Parameters

Fruit size, soluble solids content (SSC) and citric acid (CA) content of the fruit juice were different among cultivars and experiments (Table 2 and 3). Overall, fruit size was largest (over 2.0g, at 20%, 50% and 80% harvest time) for 'Southmoon', and smallest for 'Flordablue'. The fruit size of 'Magnolia', 'Misty', 'Reveille' and 'Southmoon' were over 2.0g, in experiment 1. However, the fruits of 'Magnolia', 'Misty' and 'Reveille' were smaller in experiment 2.

The SSC of many cultivars differed in each experiment. The SSC of 'Biloxi' and 'Reveille' were higher than other cultivars in experiments 1 and 2. The CA content of 'Blue Ridge' and 'Southmoon' were higher than other southern highbush cultivars, and 'Cape Fear' was the lowest in experiment 2.

It was considered that the fruit size, SSC and CA content were affected by the age of the trees, number of shoots per tree, number of flowers per shoot and tree, more than fruit yield (Gough, 1994). However, these factors were not adjusted and not investigated in these experiments.

Literature Cited

Baptista, M. C., P. B. Oliveira, L. Lopes-da-Fonseca, C. M. Oliveria. 2004. Early ripening of southern highbush blueberries under mild winter conditions. Programme Book of Abstracts, 8th International Symposium on Vaccinium Culture (3rd-8th May, 2004. Oeiras/Portugal and Seville/Spain). OP15.

Barrau, C., B. de los Santos, D. Calvo, J. J. Medina, J. M. Molina and F. Romero. 2004 Blueberries (*Vaccinium* spp.) in Huelva (Andalsia, Spain): A preliminary study on production data. Programme Book of Abstracts, 8th International Symposium on Vaccinium Culture (3rd-8th May, 2004. Oeiras/Portugal and Seville/Spain). Poster 20.

Carter, P. M. J. R. Clark and R. K. Striegler. 2002. Evaluation of southern highbush cultivars for production in southwestern Arkansas. HortTecnology 12 (2) : 271-274.

Caruso and Ramsdell. 1995. Compendium of blueberry and cranberry diseases. APS Press. St. Paul, MN. p. 23.

Childers, N. F. and P. M. Lyrene. 2006. Blueberries, for growers, gardeners, promoters. Dr. N. F. Childers Horticultural publications. Gainesville, Fl. pp. 266.

Ciordia, M., M. B. Diaz and J. C. Garcia. 2002. Blueberry culture both in pots and under Italian-type tunnels. Acta Hort. 574: 123-127.

Ciordia, M., J. C. Garcia and M. B. Diaz. 2004. Off-season production of southern highbush blueberries in the north of Spain. Programme Book of Abstracts, 8th International Symposium on Vaccinium Culture (3rd-8th May, 2004. Oeiras/Portugal and Seville/Spain). Poster 32.

Darnell, R. L. 2006. Blueberry botany / environmental physiology. In: Childers and Lyrene eds. Blueberries for growers, gardeners, promoters. Dr. N. F. Childers Horticultural publications. Gainesville, Fl. p. 5-13.

Gough, R. E. 1994. The highbush blueberry and its management. Food Products Press. Binghamton, NY. pp. 272.

Lyrene, P. M. 2006. Weather, climate, and blueberry production. In: Childers and Lyrene eds. Blueberries, for growers, gardeners, promoters. Dr. N. F. Childers Horticultural publications. Gainesville, Fl. p. 14-20.

National Astronomical Observatory. 2004. Chronological scientific Table 2005. Maruzen. Tokyo. p. 172-183.

Ozeki, M. and T. Tamada. 2004. The potentials of forcing culture of southern highbush blueberry in Japan. Programme Book of Abstracts, 8th International Symposium on Vaccinium Culture (3rd-8th May, 2004. Oeiras/Portugal and Seville/Spain). P18.

Tamada, T. 1996. Blueberry culture and research in Japan. In: R. E. Gough and R. G. Korcak(eds.), Blueberries: A century of research. Food Products Press, Binghamton, NY. p. 227-241.

Williamson, J. G. and P. M. Lyrene. 1995. Commercial blueberry production in Florida. Univ. of Florida, Cooperative Extension Service. SP. 179:1-43.

Table 1. The change of mean temperature of air and pot soil under heat culture in the plastic greenhouse.

Month	Day	Experiment 1 [1)]		Experiment 2 [2)]	
		Air temp. (C) [3)]	Pot soil temp. (C)	Air temp. (C) [3)]	Pot soil temp. (C)
Feb.	4-10	17.1	10.1	—	—
	11-17	18.7	10.3	19.7	15.0
	18-24	19.9	16.3	21.0	16.5
	25-02	16.8	15.6	22.7	17.8
March	03-09	19.3	14.1	23.1	17.9
	10-16	19.6	15.3	22.7	16.7
	17-23	17.1	14.3	19.8	16.2
	24-30[4)]	20.4	15.4	24.3	18.9
April	31-06	21.4	16.3	26.6	20.9
	07-13	24.0	19.8	24.6	20.7
	14-20	25.2	20.0	26.1	22.1
	21-27	24.0	19.0	26.9	21.9
May	28-04	24.5	19.5	28.6	24.6
	05-11	23.1	19.2	24.8	20.7
	12-18	24.4	21.9	25.9	21.3
	19-25	22.6	19.3	28.9	23.9

1) Heating started from 4th February to 10th May in 2004 year.
2) Heating started from 10th February to 24th May in 2005 year.
3) Plastic house temperature was managed between 10C-35C with automatic heating and ventilation.
4) In experiment 2, minimum heating temperature increased to 18C from 25th March to 24th May.

Table 2. Flowering and harvesting time, fruit growing period, fruit set percentage, yield and fruit quality parameters of the several southern highbush cultivars growing under heat culture in experiment 1 [1)]

Cultivar	50% flowering time[2)]	50% ripening time[2)]	Fruit growing period (day)[3)]	% Fruit set		Yield / tree		Fruit quality parameter	
				Estimate No. of floret /tree [4)]	Percent harvested fruit (%) [5)]	Total No. of fruit	Total No. of fresh weight (□)	Mean fresh fruit weiht (□) [6)]	SSC (%) [7)]
Biloxi	36 fg[z)]	104 fg [z)]	68	476	86.1	410	621.9	1.52 f [z)]	12.3 b[z)]
Bladen	39 ef	100 ijk	61	587	92.0	540	610.9	1.13 h	11.6 b
Blue Ridge	35 gh	106 f	71	954	79.7	760	1,137.3	1.50 fg	9.7 fghi
Cape Fear	31 ij	102 h	71	674	54.0	364	614.0	1.69 de	9.3 hi
Cooper	32 i	92 m	60	437	78.7	344	649.0	1.89 c	10.6 cdefg
Flordablue	41 de	104 fg	63	902	56.4	509	548.4	1.08 h	10.0 efgh
Georgiagem	43 cd	104 fg	61	329	83.3	274	479.0	1.75 cd	10.7 cdefg
Magnolia	47 b	113 e	66	883	59.9	529	1,163.6	2.20 b	9.3 hi
Misty	35 gh	101 ij	66	472	65.7	319	809.5	2.61 a	10.0 efghi
O'Neal	31 ij	104 fg	73	404	75.2	304	517.5	1.70 de	10.4 defgh
Ozarkblue	50 a	125 b	75	237	38.8	92	145.3	1.58 fg	9.8 fghi
Pender	50 a	116 c	66	484	79.5	386	419.1	1.09 h	11.5 bc
Reveille	45 bc	98 kl	53	91	83.5	76	167.9	2.21 b	13.6 a
Sapphire	29 jk	103 gh	74	745	65.4	487	724.5	1.49 g	9.0 i
Sharpblue	27 k	96 l	69	845	73.8	624	989.0	1.59 ef	10.6 cdefg
Southmoon	36 fg	103 gh	67	397	73.6	292	653.1	2.24 b	9.5 ghi
Star	41 d	114 de	73	903	47.0	424	696.4	1.64 de	10.4 defgh
Summit	39 ef	119 c	80	1,010	48.8	493	599.7	1.22 h	10.9 cde
Earliblue *	39 ef	104 fg	65	424	73.1	310	458.8	1.48 g	9.5 ghi
Climax **	43 cd	129 a	86	650	66.3	435	667.5	1.53 fg	13.6 a

1) Heating started from 4th February continued to 10th May. Room temperature were managed between 10C- 35C.
2) Days after 4th February.
3) Days from the 50% flowering time to the 50% ripening time.
4) Calculated to multiply mean No. of floret per flower cluster×total No. flower cluster per tree.
5) Calculated to divide the estimate No. of floret per tree by total No. of harvested fruit per tree.
6) Calculated to divide the total fresh weight by the total No. of harvested fruit per tree.
7) Soluble solid content, the mean of fruits in three time, 20, 50 and 80% of harvested.
* Northern highbush cultivar (NHB), ** Rabbiteye cultivar (RE).
z) Different letters are significant at P=0.05.

Table 3. Flowering and harvesting time, fruit growing period, yield and fruit quality parameters of several southern highbush cultivars growing under heat culture in experiment 2 [1)]

Cultivar	50% flowering time[2)]	50% ripening time[2)]	Fruit growing period (day)[3)]	Yield / tree		Fruit quality parameters		
				Total No. of fruit[4)]	Total fresh weight (g)	Mean fresh fruit weight[4)] (g)	SSC (%) [4)]	CA Content (%) [5)]
Biloxi	20 cd [z)]	97 b [z)]	77	105	154.2	1.49 fg[z)]	13.1 a [z)]	0.99 b [z)]
Blue Ridge	19 cde	97 b	78	170	254.5	1.50 fg	10.1 bc	1.20 a
Cape Fear	20 cd	103 a	83	122	151.4	1.42 g	9.2 cd	0.36 f
Cooper	18 de	97 b	79	90	109.0	1.82 d	8.5 d	0.84 bc
Flordablue	19 cde	97 b	78	360	313.6	0.87 i	9.9 bcd	0.98 b
Georgiagem	21 bc	91 c	70	287	346.2	1.21 h	10.4 bc	0.59 e
Misty	19 cde	97 b	78	56	106.9	1.91 c	13.0 a	0.62 de
Reveille	20 cd	97 b	77	110	138.8	1.25 h	12.4 ab	0.58 e
Sapphire	18 de	85 d	67	163	304.9	1.87 d	10.5 bc	0.65 de
Sharpblue	17 e	91 c	74	224	307.8	1.37 g	12.3 ab	0.68 d
Southmoon	21 bc	91 c	70	116	275.2	2.37 a	13.1 a	0.66 de
Star	23 ab	97 b	74	45	40.4	0.90 i	11.3 bc	1.24 a
Summit	21 bc	97 b	76	125	263.3	2.11 b	11.5 bc	0.75 cd
Earliblue *	24 a	85 d	61	95	152.8	1.61 e	13.5 a	0.70 d

1) Heating started from 4th February continued to 10th May. Room temperatures were managed between 10C-35C.
2) Days after 10th February.
3) Days from the 50% flowering time to the 50% ripening time.
4) Soluble solid content, the mean of fruits over three times - 20, 50 and 80% of harvest.
5) Citric acid, the mean of fruits over three times - 20, 50 and 80% of harvest.
* Northern highbush cultivar (NHb).
z) Different letters are significant at P=0.05.

Evaluating New Pre and Post-Emergence Herbicides for Weed Control in Wild Blueberries

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Introduction

Wild blueberry (*Vaccinium angustifolium*) fields in Maine contain a variety of broadleaf, grassy, and fern weeds, which reduce wild blueberry crop production and hinder harvest. Competition between wild blueberries and weed species for space, water and nutrients will reduce blueberry yields. Because blueberries are pruned every other year and fields may not be tilled or rotated into other crops, the types of weeds and the methods of control are different than cultivated crops (Yarborough, 1996). Hexazinone is a widely used herbicide, which has contributed to increases in the production of wild blueberries in Maine since 1983. Its use has contributed to a four-fold increase in wild blueberry yield over the past 20 years (Yarborough, 2004). Several issues have emerged making it evident that alternatives to hexazinone should be considered. Hexazinone is highly leachable and has been detected in groundwater adjacent to blueberry fields and throughout the state (Yarborough, 1997). Jensen and Yarborough (2004) indicate there is evidence that reliance on hexazinone without herbicide rotation has increased populations of annual grasses and herbaceous weeds such as bunchberry (*Cornus canadensis*). Several alternative herbicides have been evaluated for rotation with hexazinone, but materials have either been ineffective or not registered, as in the case of azafenidin. Therefore alternative herbicides are needed to control these weed populations and to maintain productivity of Maine's wild blueberry production.

Materials and Methods

In 2004 test sites were located at Blueberry Hill Experiment Farm in Jonesboro, Maine. Plot size was 2 x 12 m, with six replications of each treatment arranged in a randomized complete block design with an untreated control (UTC). Hexazinone, at 1 kg/ha and flumioxazin at 0.9 kg/ha or mesotrione at 148, 222, or 444 ml/ha were applied pre-emergence on May 19, 2004 and flumioxazin and mesotrione were applied at the same rates post-emergence on June 9, 2004. Blueberry and weed cover were evaluated on June 23 and August 18, 2004. In 2005, test sites were located in six different fields in eastern Maine in Northport, Union, Penobscot, Lamoine, T-19 and Jonesboro to obtain a diversity of soil types and weed species. A split block design was used in 2005; with treatment plot and UTC plot size of 7.4 x 11 m. Mesotrione was applied at 444 ml/ha and flumioxazin at 0.9 kg/ha pre-emergence from May 11 to June 7, 2005 and post-emergence from June 14 to 22, depending on location. At a right angle to those plots

was an 11 x 37 m plot of hexazinone treatment at 1 kg/ha applied pre-emergence that split both treatments and UTC plots so all treatments were with and without hexazinone. Blueberry and weed cover were evaluated on June 27 and August 26, 2005. Blueberry and weed cover evaluations were made using a Daubenmire cover class scale (Mueller-Dombois and Ellenburg, 1974). Data was transformed to percent cover and analyzed by the General Linear Model of SAS with significant means separated by Duncans multiple range test (SAS Institute, 1995).

Results

In 2004, no significant reductions in cover or phytotoxicity of wild blueberries were noted for any of the treatments. Broadleaf cover averaged less than 20% (Figure 1) and some treatments were less than the hexazinone standard but more than the UTC, however none were statistically different. Grass cover appeared to be released by most treatments (Figure 2), with both the post flumioxazin and mesotrione treatments showing an increase in grass cover. Fern cover also increased with the highest rate of both flumioxazin and mesotrione, but the effect was not significant. In all cases the hexazinone standard and check plot were not significantly different.

In 2005, blueberry cover was significantly reduced by the high phytotoxicity found on the post-emergence treatments (Figure 3). All flumioxazin treatments had high phytotoxicity, but mostly from post-emergence treatments. Grass cover was higher in the UTC than all treatments in June, but not in August. All treatments reduced grass cover in June, but significant additional suppression was obtained with the addition of hexazinone to the flumioxazin and mesotrione treatments, with best suppression obtained with the post-emergence application of flumioxazin (Figure 4). Broadleaf weed cover was initially reduced after pre and post-emergence applications in June, except for the pre-emergence mesotrione application; the cover of post-emergence mesotrione was higher than the control in the August evaluation (Figure 5). Neither flumioxazin nor mesotrione reduced fern cover without hexazinone but with hexazinone fern cover was reduced with the exception of the post-emergence mesotrione treatment in August. The post-emergence flumioxazin had the lowest fern cover.

Discussion and Conclusions

In 2004, broadleaf, grass, and fern cover were lowered with the application of flumioxazin or mesotrione, though not significantly. In 2005 flumioxazin applied pre-emergence delayed the emergence of blueberries and applied post-emergence caused considerable phytotoxicity. Although the blueberry plants recovered their growth was set back considerably compared to the untreated plots. Mesotrione also reduced weed cover more effectively with the addition of hexazinone. In 2005, it appeared that neither flumioxazin nor mesotrione alone were sufficient to suppress weeds, but if applied with hexazinone the weed suppression was significantly increased. The mesotrione has the best potential in combination with hexazinone to reduce weeds not controlled by hexazinone and without injury to wild blueberries.

Literature Cited

Jensen K.I.N. and D.E. Yarborough. 2004. An overview of weed management in the wild lowbush blueberry – past and present. Small Fruits Review. 2 (2/4): 229-225.

Mueller-Dombois, D. and H. Ellenburg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, N.Y.

Yarborough, D.E. 1996. Weed Management in Wild Blueberry Fields, Wild Blueberry Fact Sheet No. 236. The University of Maine Cooperative Extension, Orono, ME. http://www.wildblueberries.maine.edu/PDFs/Weeds/236.pdf

Yarborough, D.E. 1997. Best management practices to reduce hexazinone in groundwater in wild blueberry fields. Brighton Crop Protection Conference – Weeds. 2:1091-1098.

Yarbrough, D.E. 2004. Factors contributing to the increase in productivity in the wild blueberry. Small Fruits Review. 2(1/2): 33-34.

SAS Institute. 1995. SAS Users Guide, Statistics. SAS Institute, Cary, NC.

Figure 1. Broadleaf weed cover after herbicide treatment in 2004. Pre or post indicates pre or post-emergence.

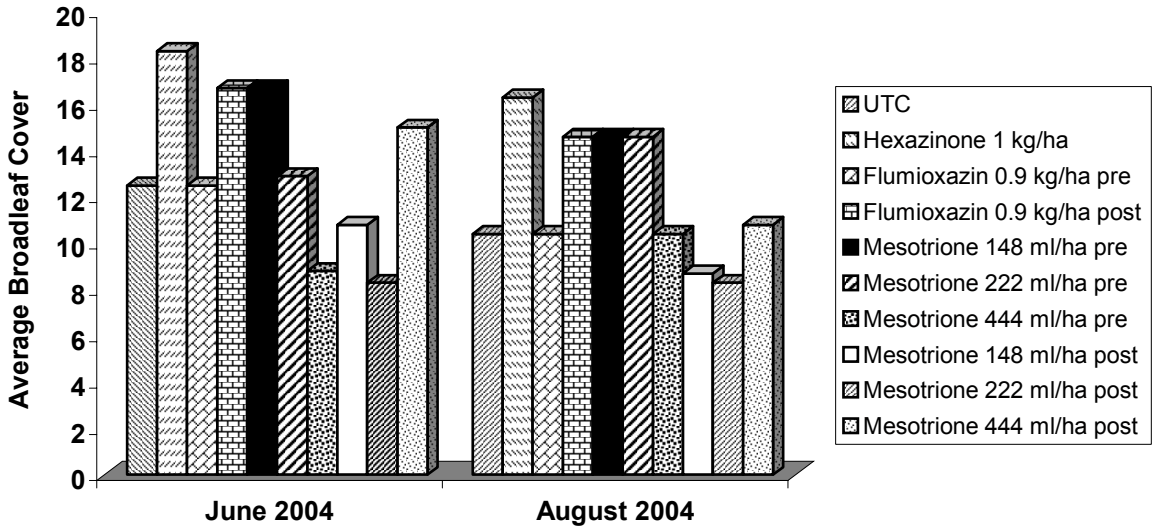


Figure 2. Grass cover following herbicide treatment in 2004. Pre or post indicates pre or post-emergence.

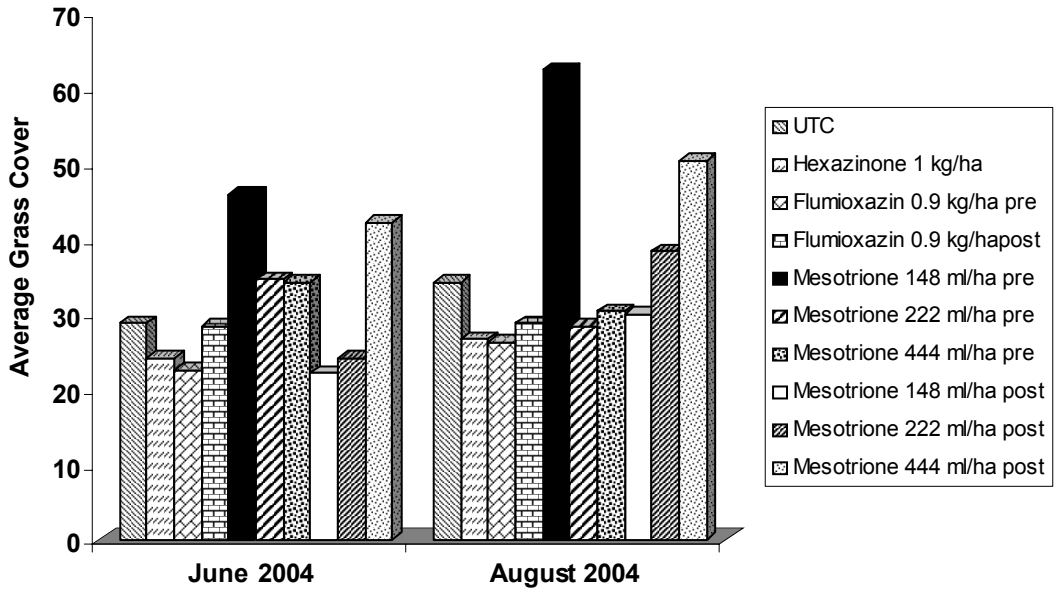


Figure 3. A) Blueberry cover and B) phytotoxicity of blueberry plants following herbicide treatment in 2005.

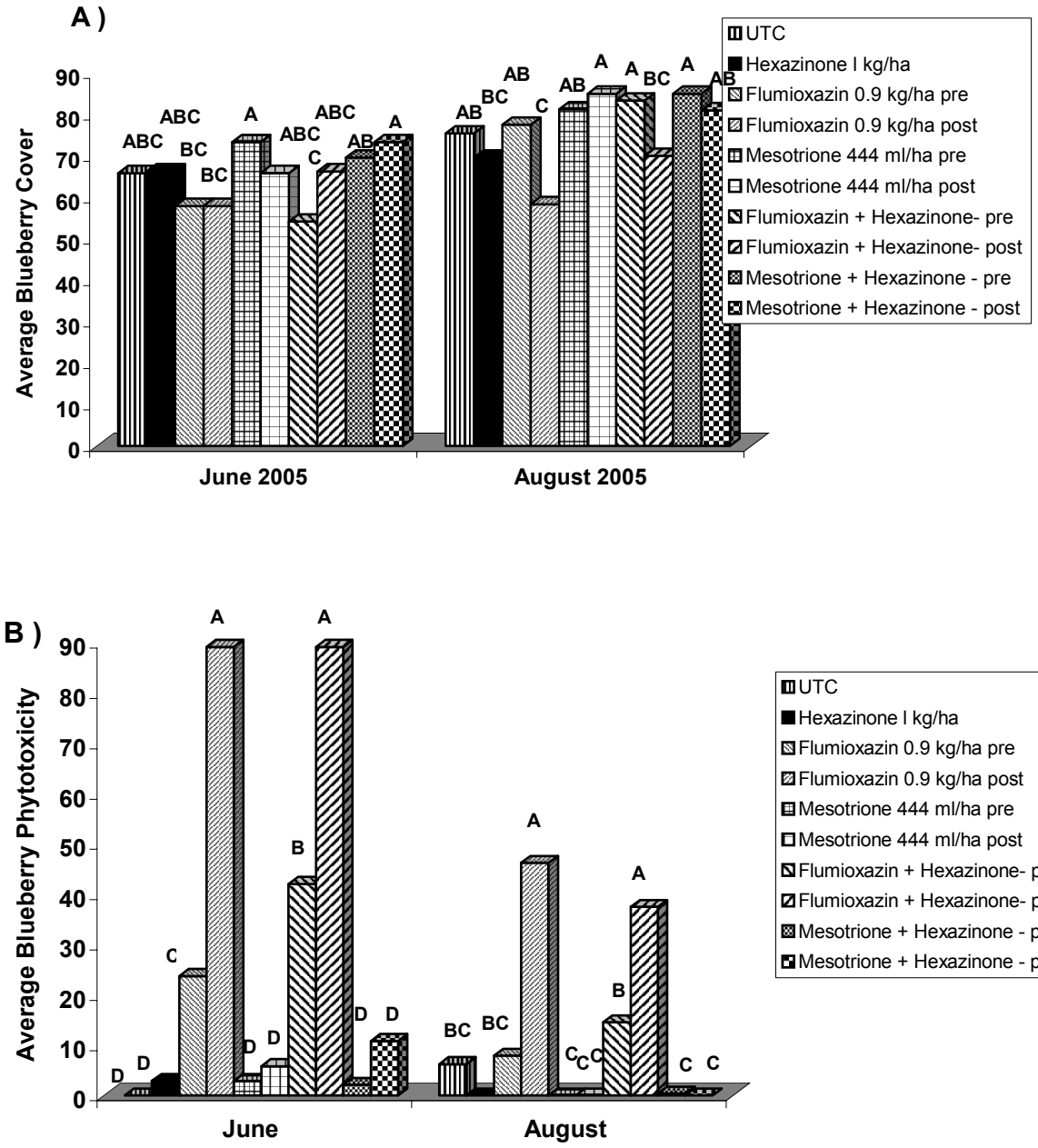


Figure 4. Grass cover following herbicide treatment in 2005.

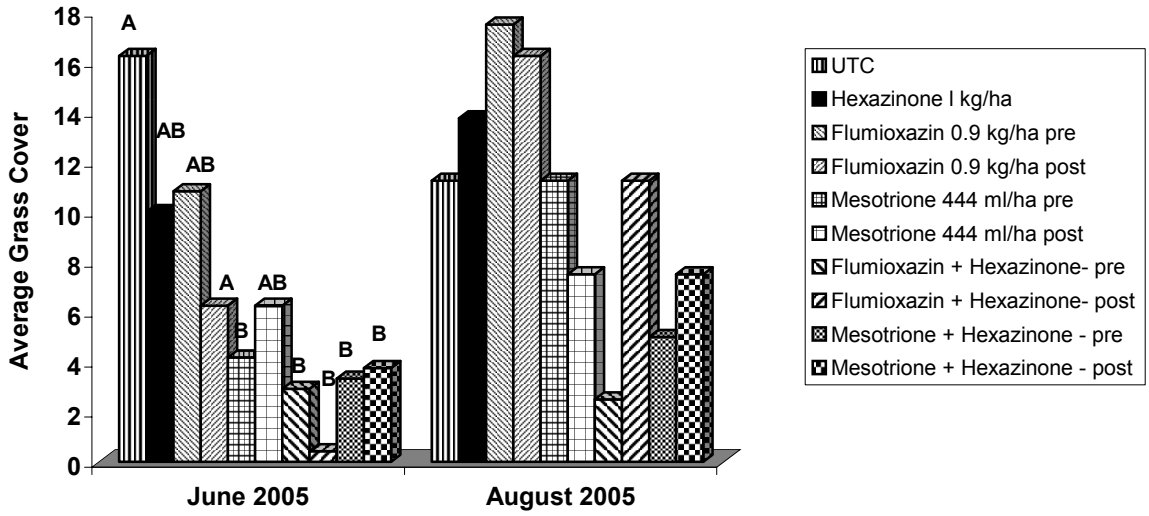
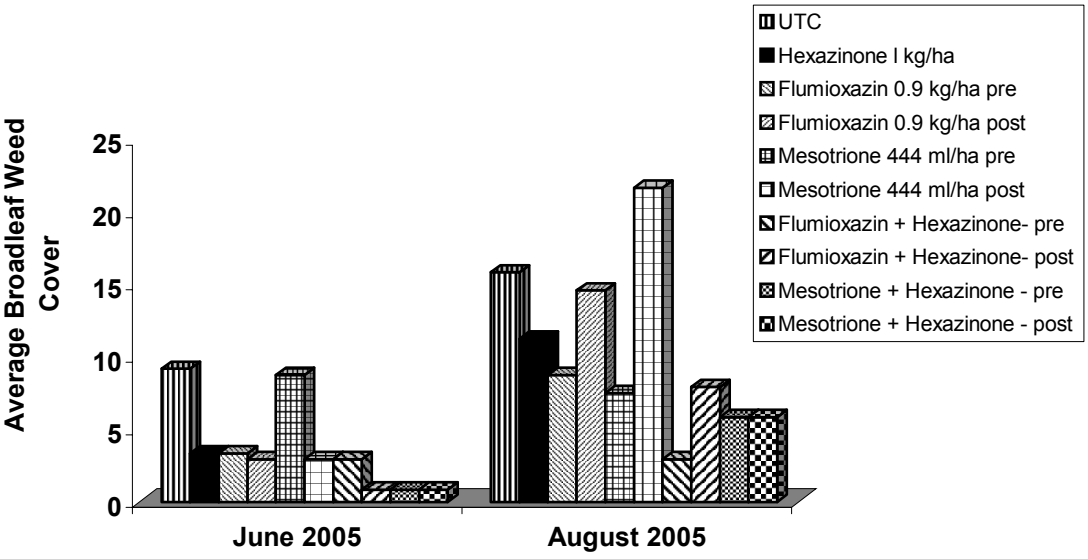


Figure 5. Broadleaf weed cover following herbicide treatment 2005.



New Rabbiteye Blueberry Varieties From The University of Georgia

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Introduction

The University of Georgia Blueberry Breeding Program is aggressively developing new cultivars for use by commercial growers, small pick-your-own operations and home gardeners. The goals are to provide well adapted plants with high quality fruit for the Southeastern U.S. that ripen over an extended period. The program has been in existence for several decades, and this long term effort has led to great improvement of the plant material that is available. Many blueberry varieties on the market today are older selections, however, in the past few years newer varieties with superior performance have been developed. Much of the cultivar development work is with rabbiteye blueberries, which occupy the most acreage in the Southeast. The following is a brief description of new rabbiteye blueberry varieties that have been released by the University of Georgia (UGA) Blueberry Breeding Program since 2001.

Please note the new blueberry releases from UGA are protected varieties. For information on licenses and licensed propagators of UGA blueberry varieties, contact the Georgia Seed Development Commission in Athens (ph. 706-542-5640), or visit their web site at http://www.gsdc.com/.

Alapaha Rabbiteye Blueberry

'Alapaha' (pronounced uh-la-puh-HAH), named for the Alapaha River in south Georgia, was released in 2001 as an early season rabbiteye blueberry (Fig. 1). Plants of 'Alapaha' are fairly vigorous and upright with quite narrow crowns. The variety flowers relatively late (7 to 10 days after the older variety Climax), which helps avoidance of spring freeze damage; yet, fruit of 'Alapaha' ripens quickly beginning about the same time as fruit ripening of 'Climax' (Table 1). 'Alapaha' berries are medium in size and have good firmness, color, flavor and small dry scars which contribute to good shelf life. 'Alapha' yields have been considerably higher than 'Climax' in test plots over a 5-year period. Also, 'Alapaha' yields have been rather consistent from year-to-year. In recent tests, 'Alapaha' was shown to have a very low degree of fruit cracking in response to wetness during ripening (similar to 'Premier'). The new variety produces abundant flower buds and readily breaks leaf buds during or shortly after flowering. 'Alapaha' is recommended for areas where rabbiteye blueberries are grown successfully as an early ripening variety to replace 'Climax'. It is recommended that 'Alapaha' be planted with other rabbiteye blueberry cultivars with a similar time of bloom such as 'Vernon' or 'Brightwell'.

Figure 1. Ripe berries of the early season rabbiteye blueberry variety Alapaha.

Vernon Rabbiteye Blueberry

'Vernon' is also an early season rabbiteye blueberry released in 2004. The new variety has favorable fruit attributes, good yields and excellent plant vigor (Table 1). Similar to 'Alapaha', plants of 'Vernon' also flower relatively late (7 to 10 days after 'Climax' in south Georgia), yet ripen early (same time as 'Climax', but before 'Premier'). Berries of 'Vernon' are flavorful, and have excellent firmness, color, and dry scars which contribute to good shelf life. 'Vernon' berries are large in size (Fig. 2), and yields have been higher than 'Climax' and 'Premier' in test plots over a 5-year period. 'Vernon' would likely benefit from early tipping of vigorous "whips" to induce more branching and shoot growth. The new variety readily breaks numerous leaf buds during or shortly after flowering. 'Vernon' is recommended for trial where rabbiteye blueberries are grown successfully as an early ripening cultivar to replace 'Climax' and/or 'Premier'. It is recommended that 'Vernon' be planted with other rabbiteye blueberry cultivars with a similar time of bloom, such as 'Alapaha' and 'Brightwell' for cross pollination.

Figure 2. Berries of the new rabbiteye blueberry variety Vernon (T-584) compared to the variety Premier.

Ochlockonee Rabbiteye Blueberry

'Ochlockonee' (pronounced ok-LAHK-uh-nee) is a late season rabbiteye blueberry, released in 2002, and named for the Ochlockonee River located in southern Georgia (Fig. 3). Plants of 'Ochlockonee' are vigorous, upright and have moderately narrow crowns. The new variety produces abundant fruiting stems annually with only moderate growth. 'Ochlockonee' is very productive in yield, substantially exceeding 'Tifblue' and 'Brightwell', two widely grown older standard varieties (Table 1). Berries of 'Ochlockonee' ripen about one week after 'Tifblue', and are larger in size. In recent tests, 'Ochlockonee' was shown to have a low degree of fruit cracking in response to wetness during ripening (similar to 'Powderblue'). Other important fruit characters (stem scar, color, firmness, and flavor) of 'Ochlockonee' are similar to those of 'Tifblue'. Plants of 'Ochlockonee' generally flower late enough to escape spring freezes in south and middle Georgia. It is recommended that growers desiring a late ripening rabbiteye blueberry try 'Ochlockonee' in areas where rabbiteye blueberries are successfully grown. It is recommended that 'Ochlockonee' be planted with a rabbiteye cultivar having a similar flowering date ('Powderblue' suggested) for cross pollination.

Figure 3. Ripe berries of the late season rabbiteye blueberry variety Ochlockonee.

Table 1. Ratings of berry and plant attributes of 'Alapaha', 'Climax', 'Premier', 'Vernon', 'Brightwell', 'Ochlockonee', and 'Tifblue' rabbiteye blueberries. Data are averages for a 5 year period from test plots at Alapaha, Ga. Berry size is actual weight of berries (g) at first harvest, yield is total weight (lbs) per plant over the season, and flowering and ripening dates are estimates for 50%. Other ratings are on a scale of 1=poorest to 10=best, with a value of 6-7 generally considered "commercially acceptable". Plants of each blueberry line were at least 6 years old at the beginning of data collection.

Berry/Plant attribute	Variety						
	Alapaha	**Climax**	**Premier**	**Vernon**	**Brightwell**	**Ochlockonee**	**Tifblue**
Yield (lbs/plant)	13.1	6.9	9.9	12.8	12.8	17.0	10.1
Flowering date	March 17	March 7	March 12	March 17	March 21	March 27	March 23
Ripening date	May 30	May 30	June 2	May 31	June 14	June 28	June 22
Berry size (g)	1.24	1.27	1.70	1.85	1.44	1.40	1.02
Berry scar	8.2	8.2	8.0	8.8	8.2	8.0	8.2
Berry color	7.5	8.1	8.0	8.5	7.5	8.2	8.6
Berry firmness	7.9	8.3	7.4	8.5	8.5	8.0	8.0
Berry flavor	8.0	8.0	8.3	7.5	8.0	7.8	7.5
Plant vigor	8.5	8.3	8.8	8.5	8.5	8.5	8.2

Notes

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