

Second cropping of wild blueberries — Effects of management practices

Leonard J. Eaton and Vilis O. Nams

Department of Environmental Sciences, Nova Scotia Agricultural College, Box 550, Truro, Nova Scotia, Canada B2N 5E3 (e-mail: eatonres@eastlink.ca). Received 29 June 2005, accepted 7 April 2006.

Eaton, L. J. and Nams, V. O. 2006. **Second cropping of wild blueberries — Effects of management practices.** *Can. J. Plant Sci.* **86**: 1189–1195. Wild blueberries (*Vaccinium angustifolium* Ait.) are normally managed on a biennial basis. Pruning forces the plant into a vegetative year without fruit, followed by the first crop year, which provides the greatest harvest. In subsequent years, harvest levels drop dramatically. Prior to the introduction of selective herbicides, second crop yields were too low to allow the adoption of a double harvest. This study was initiated to compare production and incomes of a single cropping (2-yr management cycle, the present system) versus a double cropping system (3-yr management cycle), using systems that include herbicides. Total yields and net incomes over the 12-yr study were affected by fertilizer applications, but not by management system (2-yr management cycle versus 3-yr management cycle) or pruning (burning versus mowing). Yields in second crop plots were lower than those in first crop plots, even though blossom numbers were higher. Fertilizer affected many aspects of blueberry plant development, including stem length, numbers of buds and blossoms, and fruit yields. Over time, yields and net incomes in the 3-yr management cycle were similar to those for the standard 2-yr management cycle.

Key words: *Vaccinium angustifolium*, 3-yr management, net income, fertilization, pruning

Eaton, L. J. et Nams, V. O. 2006. **Récolte double de bleuets sauvages – Incidence des pratiques de gestion.** *Can. J. Plant Sci.* **86**: 1189–1195. En temps normal, on traite le bleuets sauvages (*Vaccinium angustifolium* Ait.) comme une culture bisannuelle. L'élagage plonge la plante dans un état végétatif pendant une année durant laquelle elle ne donne pas de fruits. L'année suivante se caractérise par la récolte la plus abondante. Ensuite, le nombre de fruits baisse de manière draconienne. Avant l'arrivée des herbicides sélectifs, le rendement de la troisième année était trop faible pour qu'on songe à adopter un système de double récolte. Les auteurs ont entrepris une étude afin de comparer la production et le revenu venant d'un régime à récolte unique (cycle de deux ans, comme c'est le cas présentement) à ceux d'un régime à double récolte (cycle de trois ans) recourant aux herbicides. Le rendement global et le revenu net relevés lors de cette étude de 12 ans ont été affectés par les applications d'engrais, mais pas par le système cultural (cycle de deux ans contre cycle de trois ans) ni par l'élagage (brûlis contre tonte). Le rendement des parcelles de trois ans était plus faible que celui des parcelles de deux ans, malgré une floraison plus abondante. La fertilisation affecte maints aspects du développement de la plante, notamment la longueur des tiges, le nombre de bourgeons et de fleurs, et le rendement fruitier. Avec le temps, le rendement et le revenu net issus du cycle de trois ans se rapprochent de ceux observés pour le cycle de deux ans.

Mots clés: *Vaccinium angustifolium*, culture triennale, revenu net, fertilisation, élagage

The wild blueberry (*Vaccinium angustifolium* Ait.), an important horticultural crop in Eastern Canada and Maine, USA, is a stress-tolerant calcifuge shrub well adapted to acid, nutrient-poor environments (Grime 1979; Chapin 1980). It grows in well-drained orthic humoferric podzols (Canada Soil Survey Committee 1978), which are generally acid (pH 3.9–5.5), infertile, and have well-developed organic horizons (Trevett 1962). The wild blueberry is forced from its natural perennial fruit production into a biennial production system by regular pruning (mowing or burning) that removes most of the above-ground plant material (Hall et al. 1979). The plant grows vegetatively during the first year after pruning, and initiates flower buds for the second (crop) year from August to October, followed by winter dormancy (Hall et al. 1979). During the crop year, flower buds further develop during spring, and flowering occurs in May and June. The flowers are pollinated by insects, and the ovary walls develop quickly after ovules are fertilized (Bell 1950). Fruit remain quiescent during June and July, and then further enlarge and ripen until harvest, which usually occurs in August and early September. Rapid plant growth follow-

ing pruning results in maximum production in the crop year, but blueberry fruit production in subsequent years decreases steadily because fewer new resources are available for fruit production (Jordan and Eaton 1995). Experiments with second cropping (repeating prune-crop-crop cycles) in the 1940s and 1950s (Trevett 1962; Black 1963; Kender et al. 1964) were discontinued because second crop yields were consistently less than 50% of first crop yields, and were thus considered uneconomical (Trevett 1962). During the 1970s and 1980s introduction of selective herbicides for wild blueberry production contributed to dramatic yield increases (Jensen and Kimball 1985; Jensen 1986); these increases appear to have resulted largely from decreased weed pressure following herbicide applications (Yarborough et al. 1986), and appear to reflect greater plant stand density as well as increased numbers of buds and flowers (Eaton 1994).

Increased blueberry fruit yields have prompted renewed interest in second cropping as an alternative to the regular 2-yr prune-crop management practice employed by the industry (Kinsman 1993). One Nova Scotia wild blueberry producer

Table 1. Experimental treatments and cropping cycles

(a) Treatments												
Treatment	Management Cycle		Pruning	Fertilizer								
1	2-yr		Mow	No								
2	3-yr		Mow	No								
3	2-yr		Mow	Yes (prune year)								
4	3-yr		Mow	Yes (prune year)								
5	3-yr		Mow	Yes (prune year and first crop year)								
6	2-yr		Burn	No								
7	3-yr		Burn	No								
8	2-yr		Burn	Yes (prune year)								
9	3-yr		Burn	Yes (prune year)								
10	3-yr		Burn	Yes (prune year and first crop year)								

(b) Time lines of 2-yr and 3-yr management cycles												
Management	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
2-yr	Prune	Crop	Prune	Crop	Prune	Crop	Prune	Crop	Prune	Crop	Prune	Crop
3-yr	Prune	First crop	Second crop	Prune	First crop	Second crop	Prune	First crop	Second crop	Prune	First crop	Second crop

has successfully converted a portion of his blueberry production system to second cropping. His second crop yields, from 1985 through 2004, averaged 71% of first crop yields (David Dickinson, personal communication), and are well above the average second crop yields obtained prior to the introduction of selective herbicides. Other attempts at second cropping have been less successful, at least partially due to problems with plant damage by mechanical harvesters (Gary Brown, personal communication).

The objectives of this study were: (1) to compare and contrast first and second crop management systems over 12 yr; (2) to assess the effects of pruning methods (burning and mowing) and (3) fertilizer applications on wild blueberry growth and production.

MATERIALS AND METHODS

Site Selection

Two studies were established, at the Nova Scotia Wild Blueberry Institute Field Station (Blueberry Institute), Debert, NS (63°27'W, 45°26'N), and at the Tower field, Mt. Thom, NS (62E°9'W, 45°28'N). The Blueberry Institute is a level site near sea level (elevation 45 m), cleared from forest in 1980, and was consistently burn pruned prior to the present study. The soil type is a Truro sandy loam to loamy sand (Webb et al. 1991). Bloom begins in mid to late May and harvest is generally mid August. The Tower field (elevation 230+ m) was developed from gently sloping hillside farmland approximately 45 yr ago, and the soil is a Kirk Hill gravelly sandy loam (Webb et al. 1991). It was also regularly burned pruned prior to the study. Flowering and fruit maturity at Mount Thom are normally approximately 2 wk later than those at the Debert site.

Field Studies

At each location, 10 treatments were applied to 3 × 8 m plots, separated by 1 m walkways, and arranged in a com-

pletely randomized block design with five replications. Treatments, combinations of management cycle (2-yr, 3-yr), pruning method (burning or mowing), and fertilizer rate (0 or 300 kg ha⁻¹ 17-17-17) were applied in May (Table 1). Treatment plots were burned with an oil burner or mowed with a flail mower or a ride-on lawn mower. Fertilizer was applied by hand spreading in prune years of both management cycles and in the first crop year of the 3-yr management cycle. Velpar (3-cyclhexyl-6-(dimethylamino)-methyl-1,3,5-triazine-2,4 (1H,3H)-dione) was applied at rates of 2.2 to 1.45 kg a.i. ha⁻¹ to all plots in May of each pruning year to maintain weed control. A direct comparison of 2-yr management yields with the second crop of the 3-yr management cycle, within the same year, was possible only in the 6th and 12th yr of the study.

During each crop year, growth and flowering characteristics were measured on samples of 50 stems per plot clipped at 20-cm intervals along a 10-m transect laid out within each plot. Yields were determined at harvest time when entire plots were hand raked. Soil and leaf tissue samples were taken from each plot in 1989 and 1990, and in 1994 and 1995. Soil samples were obtained with a standard core sampler to a depth of 15 cm. Ten to fifteen soil cores from each plot were bulked to form a sample. Leaf samples were obtained by taking the top 5–10 leaves from approximately 50 stems in each plot, for analysis of nutrient status. Soil samples were analyzed for soil pH, P₂O₅, K₂O, Ca and Mg, and leaf tissue samples were analyzed for N, P, K Ca, and Mg content, at the Quality Evaluation Laboratory, Nova Scotia Department of Agriculture and Fisheries, Truro, NS.

Production Costs

Yields and net incomes were calculated for the years 1989–2000. Net income is defined as the difference between income and the management and harvest costs for each production cycle. Management costs were developed for each treatment combination, based on the costs listed in McIsaac

Table 2. ANOVA results for comparisons of growth stages among management schemes and crop years

Crop developmental characteristic	Comparison of 2-yr management vs:				Within 3-yr management: crop year 1 vs. year 2	
	First crop of 3-yr		Second crop of 3-yr		<i>t</i> ^y	<i>P</i>
	<i>F</i> ^z	<i>P</i>	<i>F</i> ^z	<i>P</i>		
Yield/crop year	13.5	0.001	24.9	0.001	-1.80	0.08
Stem length	32.6	0.001	427	0.001	21.4	0.001
Buds	1.09	0.30	21.3	0.001	3.57	0.001
Blossoms	11.5	0.001	28.7	0.001	2.67	0.01
Buds/stem length	12.7	0.001	145	0.001	-11.8	<0.001
Blossoms/buds	25.3	0.001	0.29	0.59	-5.28	<0.001
Yield/blossoms	55.6	0.001	21.4	0.001	2.00	0.05

^zDegrees of freedom = 1, 96.^yDegrees of freedom = 59.*P*, probability level.

and Reid (2000), including pruning, herbicide applications, other pesticides, fertilizer applications, and harvest costs. Income was determined by multiplying the fruit yield (kg ha⁻¹) by the average fruit price for each year of the study.

Statistical Analyses

Data were analyzed using Systat software (Wilkinson et al. 1999). Treatment effects were detected with a backward step-wise ANOVA, with treatment factors of fertilizer, location, management cycle and all combinations of interactions. Because of errors in the pruning treatments at the Mt Thom location, pruning analyses were done for the Debert location data only. Residuals from general linear models were normally distributed and there were no obvious trends in the variances of residuals versus estimates. Thus, the data did not have to be transformed. Statistical significance was assessed at the 0.05 level and all error bars were determined for 95% confidence intervals.

Various aspects of the growth cycle during the crop year were analyzed: initial stem length, numbers of buds and blossoms, and final yield. We also considered the success level of transition from one growth stage to the next, by calculating ratios – for example, the ratio (number of blossoms)/(number of buds) gave us a measure of developmental performance from buds to blossoms. The ratios required normalization by a log-transformation before analysis, and the means and confidence intervals were transformed back for display.

The crop years complicated the analysis of the growth stage variables because comparisons between crop years 1 and 2 were within sampling units, but comparisons between management types were among sampling units (Table 2). For management effects, we compared values from the crop year of 2-yr management to the first crop year of 3-yr management, and then within 3-yr management, we compared first crop to the second crop. To test for interaction between fertilization and crop year, we could only use 3-yr management data. We first tested for the interaction between fertilization and crop year by determining if the differences between crop years 1 and 2 were between fertilizer levels. If this was nonsignificant then we continued the analysis with values averaged for the two crop years. We then compared values between fertilization levels (0 and 300 kg ha⁻¹ of 17-17-17), for 3-yr management. If this was nonsignificant we

combined fertilization levels, and finally conducted a 2-way ANOVA (including 2-yr management) with fertilization as present/absent, versus type of management.

RESULTS

Mean Yields and Net Incomes

Total yields throughout the 12 yr of the study were affected by fertilizer applications ($F = 32.8$, $df = 1$, 97 , $P < 0.001$), but there were no effects of management ($F = 3.0$, $df = 1$, 97 , $P = 0.088$) or location ($F = 0.12$, $df = 1$, 97 , $P = 0.73$) (Fig. 1a). There was, as well, no effect of pruning at the Debert site ($F = 0.08$, $df = 1$, 96 , $P = 0.78$). No interactions detected among the treatment factors.

Effects on net income over the 12 yr were similar to those on yield (Fig. 1b). There was a fertilizer effect ($F = 31.5$, $df = 1$, 97 , $P < 0.001$), but no effect of management ($F = 2.46$, $df = 1$, 97 , $P = 0.12$) or location ($F = 1.30$, $df = 1$, 97 , $P = 0.26$), and no interactions among treatment factors. There was also no effect of pruning at the Debert site on net income ($F = 0.84$, $df = 1$, 96 , $P = 0.37$). Mean net yearly income (averaged over the 12 yr of the study) was \$1902 (± 160) ha⁻¹ for 2-yr management and \$2066 (± 135) ha⁻¹ for 3-yr management. Net yearly income was \$1690 (± 160) ha⁻¹ with no fertilizer and \$2278 (± 135) ha⁻¹ with fertilizer.

The analyses for both total yields and net incomes were repeated for those years when both 2- and 3-yr management crops were harvested simultaneously (1990, 1994, 1996, 2000). This was done to determine whether unusually high yields in some years, such as 5300 kg ha⁻¹ in 1991 (the second crop year of the 3-yr management but not a crop year for the 2-yr management), might confound the analyses. The results were similar to that for the totals, with the same factors found to have effects on both yield and net income (data not shown). Thus, the variation among years did not affect our results.

Plant Growth and Development

Three-year management resulted in total yields similar to those of 2-yr management, even though there were two more harvests with 3-yr management over the 12 yr of the study. In order to investigate the source of these effects, we analyzed developmental differences at various phases of the

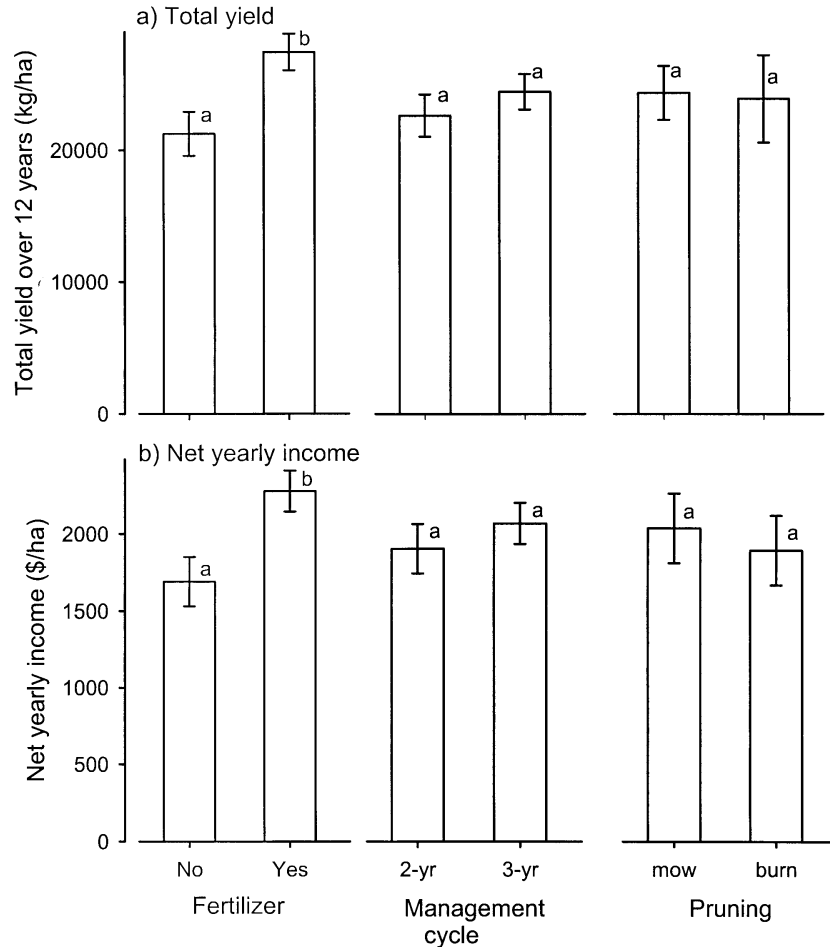


Fig. 1. Total yield and net income in response to fertilization, management cycle and pruning method. Different letters above the bars within a treatment factor indicate significant differences. Error bars indicate 95% confidence intervals.

growth cycle. We considered initial stem length, numbers of buds and blossoms, final yield, and the ratios of buds to stem length, numbers of blossoms to numbers of buds, and yields to numbers of blossoms.

Most developmental variables were different between management cycles (Table 2). Overall, yields were lower under the 3-yr management cycle than under the 2-yr management cycle throughout the study (Fig. 2). Stems were longer and more branched in the second crop year of the 3-yr management cycle than in the first crop year for either management cycle. Numbers of fruit buds per stem were similar in each management cycle in the first crop year, but were higher in the second crop plants of the 3-yr management cycle. There were, on average, more blossoms in the first crop year of the 3-yr management cycle than in the first crop year of the 2-yr management cycle, and more still in the second crop year of 3-yr management cycle. These differences, however, did not result in greater yields. In fact, yields were lower in both the first crop and second crop years of the 3-yr than in the 2-yr management cycle. The ratio of yield to blossoms was almost half as high for the 3-

yr than the 2-yr management cycle (Fig. 3). Thus, the key reason for the lower yield with 3-yr management was lower production of fruit from blossoms.

We tested whether fertilization increased any of the crop development parameters in the second crop year. Fertilization had some effects on stem length (Table 3). There was no interaction between fertilization and management cycle, but fertilization did not result in differences among stem lengths in the first crop year for either management cycle (Tables 3 and 4). Stems were longer in the second crop year in response to fertilization, but response to fertilization in both the prune and first crop years was not significant.

For all other variables, there were no interactions between fertilization and crop year, and no difference between fertilizing for 1 or 2 yr (Table 4). Fertilization affected bud and blossom numbers (Fig. 2) and the ratios of buds to stem length and yield to blossom number (Fig. 3), but did not affect the ratio of blossoms to buds (Table 4).

Levels of soil P and K were higher in plots fertilized than those not fertilized in the years samples were taken (1989, 1990, 1994 and 1995) except for soil P at Debert in 1990

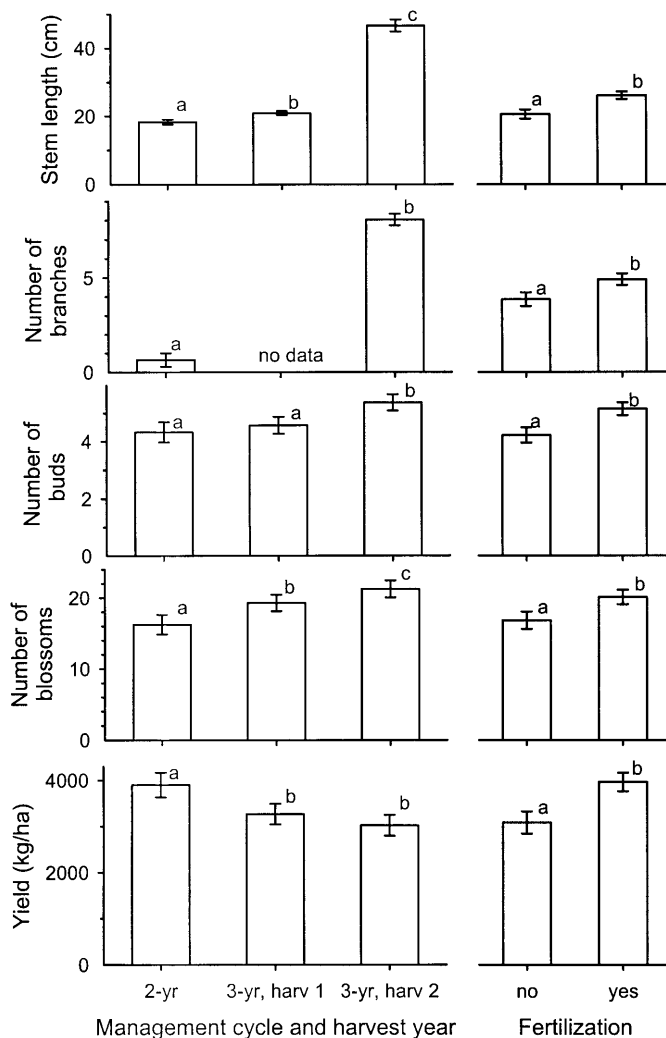


Fig. 2. Yield and plant developmental characteristics in response to fertilization and crop years within management cycles. Different letters above the bars for fertilization treatments or for crop years within management cycle treatments indicate significant differences. Error bars indicate 95% confidence intervals.

Table 3. Stem length (mean ± 95% C.I.) in response to management, fertilization and crop years

Management	Fertilizer application years	Crop year	
		First	Second
2-yr	None	18.71 ± 1.75a	
	Prune	22.27 ± 1.87a	
3-yr	None	18.73 ± 2.16a	39.24 ± 3.89b
	Prune	23.76 ± 2.32a	46.11 ± 4.09bc
	Prune and first crop	22.47 ± 2.20a	49.15 ± 4.87c

a-c Means ± 95% C.I. followed by different letters are significantly different from each other at P = 0.05.

(data not shown). Levels of leaf tissue P and K in fertilized plots were higher than those in unfertilized plots only in the Tower field in 1989 and 1995, and in the Blueberry Institute field in 1995 (data not shown).

DISCUSSION

Prior to the introduction of selective herbicides for wild blueberry management in the 1970s (Yarborough et al. 1986; Jensen and Yarborough 2004), second cropping of wild blueberries was not a viable alternative to the 2-yr management cycle, because the second crop yields were so much lower than first crop yields (Trevett 1962; Black 1963; Kender et al. 1964). The results of this study, on the other hand, clearly demonstrate that a 3-yr management cycle results in total yields (over 12 yr) similar to that obtained from the 2-yr management cycle, even though second crop yields were lower than first crop yields. This is because over 12 yr there were eight crops in the 3-yr management cycle compared to six crops in the 2-yr management cycle. It is likely that selective herbicides contributed to the increased second crop yield by improving plant growth and stem numbers (Eaton 1994). Jordan and Eaton (1995) reported similar results from a study of a commercial blueberry opera-

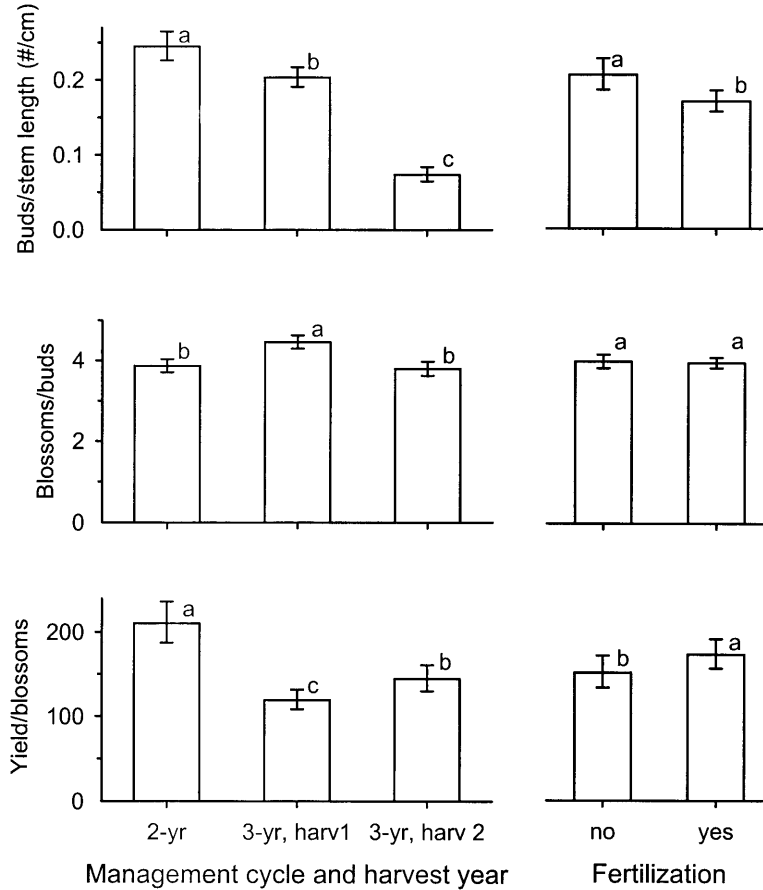


Fig. 3. Yield component ratios in response to fertilization and management schemes. Different letters above the bars within a treatment factor indicate significant differences. Error bars are 95% confidence intervals.

Table 4. ANOVA results for effects of management treatments on blueberry developmental characteristics

Variables	Difference in crop years (2-1) among fertilizer levels ^z		Fertilizer, applied at crop year 1 vs. at crop years 1 and 2 ^z		Fertilizer ^y × management		Fertilizer ^y	
	F (df = 2, 57)	P	F (df = 1, 57)	P	F (df = 1, 96)	P	F (df = 1, 96)	P
Stem length	4.41	0.02	0.01	0.93	1.93 ^x	0.17	30.8	<0.001
Buds	1.35	0.27	0.03	0.86	1.04	0.24	9.60	0.003
Blossoms	0.49	0.62	0.03	0.87	0.10	0.75	5.03	0.03
Yield	0.49	0.62	2.69	0.11	0.29	0.59	12.5	0.001
Buds/stem length	0.13	0.88	1.21	0.28	0.62	0.43	5.50	0.021
Blossoms/buds	2.17	0.12	0.01	0.93	1.62	0.21	0.01	0.97
Yield/blossoms	1.10	0.34	2.28	0.14	0.02	0.89	5.88	0.02

^zFor 3-yr management only.

^yData for both fertilizer treatments were combined, thus this just considers presence vs. absence of fertilizer.

^xThis comparison only used fertilizer level of 1 (df 1, 76).

df, degrees of freedom.

P, probability level.

tion that obtained second-crop yields averaging 70% of first crop yields. In addition, average second crop yields in 54 harvest sets since 1985 were 71.58% of first crop yields in a commercial 3-yr management program (David Dickinson, personal communication).

In this study, fertilizer applications resulted in increased crop yields under both management cycles, and also

increased soil levels of P and K. Penney and McRae (2000) also reported yield increases from fertilizer applications. These results are in contrast to the results of a number of fertilizer studies on wild blueberries within the region (Eaton 1988, 1994; Eaton et al. 1997; Sanderson and Eaton 2004). It is possible that the effects in this study were evident as an accumulated effect (i.e., over the 12-yr study), whereas in

the other studies assessments were made only within specific crop years. It appears that the stimulative effects of fertilizer applications on vegetative growth also enhanced yields.

Yields were lower under the 3-yr management cycle than the 2-yr management cycle, including the first crop years, even though there were more blossoms per stem in the 3-yr management plots. It is possible that some differences reflect effects of weather conditions, since the crop years of the two management systems were in phase only in 1990 and in 1996. Yields have been found to vary widely from year to year (Eaton 1994), indicating that growth and production of the wild blueberry are highly weather dependent.

It appears that the key difference between management types was in the production of fruit from blossoms. Less fruit was produced under 3-yr management than under 2-yr management, even though blossom numbers were higher in the former. Similarly, Jordan and Eaton (1995) found reduced growth and production in second crop blueberries and suggested it was the result of decreased nutrient levels within the plants. This deficiency may have been alleviated in this study by fertilization, since fertilization increased soil and plant P and K (although not consistently in leaf tissue), and somewhat increased the ratio of yield to blossoms.

The results of this study suggest that fertilization is worthwhile for increasing the numbers of buds and blossoms per stem, fruit yield relative to blossom number, and second crop yield. It appears that fertilizer applications provided nutrients needed for yield development in the second crop year. These effects have been revealed in long-term studies such as this and others (i.e., Eaton 1994; Penny and McRae 2000) where effects were considered over a number of production cycles.

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