Economic Analysis of Nitrogen Rate on Vine Production and Fruit Yield of Pruned Cranberry Beds

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SUMMARY. Four nitrogen rates (0, 50, 100, and 150 lb/acre) and four spring pruning severities (none, low, medium, and high) were applied annually in all combinations at two commercial 'Stevens' cranberry (*Vaccinium macrocarpon*) farms in southeastern Massachusetts for 4 years (consecutive). Because runners generated from pruning vines are used to establish new plantings, determining the vine weight generated from each treatment combination was an important criterion for the economic analysis; these data were collected each spring. Mean pruning weight across nitrogen treatments at both locations, collected from the low, medium, and high severity pruning treatments, was 0.17, 0.35, and 0.54 ton/acre, respectively. Economic analysis of the data indicated that nitrogen rate largely determined net income revenues; pruning severity did not significantly affect net income. Nitrogen rates of 100 and 150 lb/acre led to declines in fruit yield and ultimately, in net income. Annual removal of 0.5 ton of vines per acre while applying 50 lb/acre nitrogen did not negatively impact net income values over the 4-year study period. When deciding on horticultural management options for vine propagation, growers should consider the impact of their fertilizer program on fruit yield.

Cranberry beds typically are planted by using unrooted vines that are pressed directly into the soil using a disc with multiple rotating heads. Once planted, beds are maintained in production for at least 20 years. The development of new cultivars and the increased need for economic efficiency has encouraged the development of alternative business plan models for Massachusetts cranberry growers, including the establishment of new beds and more frequent replanting of existing beds. However, both activities as currently practiced have extended payback periods. Using vines produced on-farm can shorten the payback period for the cranberry grower. Therefore, many growers are evaluating the costs and benefits of pruning existing beds

on their own farms to provide the vines (runners) that can be used to establish or replant cranberry beds.

Several variables combine to complicate the issues surrounding choosing planting stock and determining crop performance when planting new cranberry vines. Many cultivars of cranberry are available (Caruso, 2008), but cranberry vines cannot be purchased from certified nurseries as identifiable genetic stock as is the case with many other small fruit (Buonassisi et al., 1989; California Department of Food and Agriculture, 2008). Vines are moved within and between states without inspection and verification of pest status (especially weed seeds) or cultivar. These factors combine to

increase the potential of genetic diversity for vines that may physically appear to be the same cultivar but may not actually be the cultivar that is named in the purchase. Researchers have characterized cranberry cultivars by genetic fingerprint technology (Novy et al., 1996; Vorsa and Novy, 1995) and have confirmed that established beds may comprise several genetic variants, primarily due to volunteer seedlings becoming established over the life of a cranberry bed. Anecdotal evidence indicates that volunteer seedlings often possess less desirable characters such as reduced productivity and fruit rot susceptibility. Growers who purchase vines from external sources must consider these potential problems and strive to ensure that they receive a reliable product.

Cranberries are pruned for many reasons (Sandler and DeMoranville, 2008), including removing excess vegetative growth to facilitate the use of dry harvesting equipment, to improve aeration in the canopy to minimize the growth of fruit rot fungi (Caruso and Ramsdell, 1995) and to increase light penetration to promote development of fruit color (Suhayda, 2008). Early experiments in New Jersey showed improvements in yield in the first or second year following pruning (Chambers, 1918); subsequent studies reported that severe pruning decreased upright density and flower bud production (Doehlert, 1955). Although research has documented various aspects of pruning cranberry vines, none have assessed the economic risks and benefits of pruning vines in combination with fertilizer regimes for the purpose of using the vines for replanting within an individual's farm.

The decision to dedicate portions of an active cranberry farm to vine propagation can be motivated by

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
0.0929	ft ²	m ²	10.7639
2.54	inch(es)	cm	0.3937
6.4516	inch ²	cm ²	0.1550
0.4536	lb	kg	2.2046
1.1209	lb/acre	kg·ha ⁻¹	0.8922
4.8824	lb/ft ²	kg·m ⁻²	0.2048
28.3495	oz	g	0.0353
0.9072	ton(s)	Mg	1.1023
2.2417	ton/acre	Mg·ha ⁻¹	0.4461
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

several reasons. First, external sources of vines can be costly, therefore growers may want to renovate and replant with their own vines to save money. Second, some growers have reduced management inputs to a portion of their properties to remain economically solvent. These beds may not be profitable for fruit production, but growers may be able to generate additional income through selling vines. In such instances, growers may find the commercial resale of vines to other growers more profitable than managing the farms for fruit production. Third, new cultivars are being released that contain desirable characteristics such as high yield, improved color, and/or enhanced health-related components (Integrity Propagation, 2008a, 2008b, 2008c; Kresty et al., 2008; McCown and Zeldin, 2003). Growers may opt to plant these new cultivars into nursery beds and maximize vine propagation. Last, as mentioned above, the lack of certified propagators for most cranberry cultivars may further motivate growers to use a known source of planting stock.

The objectives of this research were to evaluate the interaction of nitrogen rate and pruning severity on vine propagation and yield components of cranberry, to evaluate economic costs and benefits of these practices, and to develop recommendations for growers who wish to use nursery beds for vine propagation and/or fruit production.

Materials and methods

Two commercial cranberry farms in southeastern Massachusetts were used in this study and are identified by their location: South Carver

[SC (lat. 41°50'25.58"N, long. 70°43'56.45"W)] and Rochester [RCH (lat. 41°45'54.10"N, long. 70°50'52.13"W)]. Both sites were planted to the cultivar Stevens. SC and RCH were planted in 2000 and 1998, respectively. Soils at both sites are described as Tihonet mixed, mesic Typic Psammaquent (U.S. Department of Agriculture, 2008). At each site, the study was randomized complete block design with treatments arranged in a split-plot with three replicates. Pruning severity (none, low, medium, and high) was the main effect and nitrogen (N) rate (0, 50, 100, and 150 lb/acre) was the subplot. RCH plots were 2.5 × 10 m and plots at SC were 2 × 14 m. Each site was managed as a commercial bed with respect to pest control, irrigation, and frost protection, however, fertilization was applied according to predetermined research treatments. No pruning was performed on any other portion of the bed in which the plots were established. In cranberry production, application of a thin layer of sand is a common horticultural practice that buries runners and encourages upright production (DeMoranville et al., 1996). RCH received a 0.5-inch layer of sand during Winter 2004; SC did not receive any sand applications during the course of the experiment.

PRUNING TREATMENTS. Pruning was accomplished with a rotating head pruner with multiple slats with about 10 to 12 equally spaced knives per slat. Two different pruning machines were used, each owned and modified by the individual grower. Thus, two approaches were needed to create the various pruning severities. At SC, the pruner head on the

machine owned by the grower was stationary. Thus, pruning severity was accomplished by pruning the plots once, twice, or three times. The pruning machine owned by the grower at RCH had an adjustable head that permitted pruning at different depths into the canopy. Each plot was pruned once, but the head was set at three equally spaced settings to prune the vine canopy at three different severities. Pruners preferentially remove runners, rather than uprights. After each annual pruning event (Table 1), vine clippings from each plot were raked, placed into black plastic bags, and weighed in the field using a hanging digital scale (model 71S-018215; Cabela's, Sydney, NE).

NITROGEN TREATMENTS. Granular formulations of fertilizer for all treatments were applied at both sites in four equal portions (equal four-way split) in all years. The objective was to vary the amount of N applied to the vines while holding phosphorus (P) and potassium (K) applications equal among treatments. Plots designated as 0 N received applications of 0N–10.8P–20.8K (0–25–25) for a total rate of 21.6 lb/acre P and 41.6 lb/acre K per year, applied in an equal four-way split. These rates are within the recommended ranges for bearing cranberry vines (DeMoranville, 2008). N was applied to the low, medium, and high N plots four times at the rates of 12.5, 25, and 37.5 lb/acre, respectively. Fertilizer was applied to these N plots using combinations of 20N–4.3P–8.3K (20–10–10), 21N–0P–0K (21–0–0), and 0N–10.8P–20.8K in adjusted proportions so that each plot received the targeted N rate and a total seasonal P and K rate of 21.6 and 41.6

Table 1. Field study information related to dates of pruning treatments, fertilizer applications, upright sample collections, and harvest from two commercial cranberry farms in southeastern Massachusetts, Rochester (RCH) and South Carver (SC).

Site	Year	Pruning treatment ^a	Fertilizer (growth stage)				Vine samples ^x	Fruit harvest
			Roughneck ^y	Bloom	Fruit set	Bud set		
RCH	2003	15 Apr.	6 June	2 July	28 July	21 Aug.	12 Aug.	17 Sept.
	2004	30 Apr.	2 June	23 June	12 July	3 Aug.	11 Aug.	13 Sept.
	2005	18 Apr.	31 May	20 June	13 July	5 Aug.	24 Aug.	29 Sept.
	2006	20 Apr.	30 May	26 June	20 July	16 Aug.	24 Aug.	5 Oct.
SC	2003	29 Apr.	6 June	2 July	22 July	13 Aug.	7 Aug.	28 Aug.
	2004	4 May	2 June	23 June	20 July	10 Aug.	10 Aug.	14 Sept.
	2005	29 Apr.	2 June	20 June	12 July	17 Aug.	17 Aug.	17 Oct.
	2006	17 Apr.	23 May	27 June	17 July	23 Aug.	23 Aug.	19 Sept.

^aDate of pruning event and determination of vine weight in the field.

^yGrowth stage describing about 0.5 to 1 inches (1.27–2.54 cm) of new growth.

^xSamples collected to assess number and weight of reproductive and vegetative uprights.

lb/acre, respectively, matching that in the 0 N plots. Ammonium nitrogen was the sole source of N in the 21N-0P-0K formulation; the 20N-4.3P-8.3K formulation was 19% monoammonium phosphate, 39% urea, and 16% potassium chloride. Triple superphosphate and potassium sulfate were the nutrient sources in the 0N-10.8P-20.8K formulation. Application dates (Table 1) were chosen based on crop phenology (Sandler and DeMoranville, 2008). Fertilizer was spread uniformly by hand across each nitrogen plot. Irrigation or rainfall typically followed application within 72 h.

UPRIGHT EVALUATION. To assess the effect of pruning and N rate on vegetative growth and upright number, vine samples were collected annually in the late summer at each site (Table 1). One vine sample was collected from every treatment plot by excising all vegetative material at the bog surface within a 28-inch² area. Sampling templates were made by cutting 6-inch-diameter PVC pipe into 1-inch-wide bands. The sampling ring was randomly placed into a plot and positioned as close to the bog surface as possible. Using hand clippers, cuts were made around the entire inner perimeter to permit collection of runners that were passing through the area of the ring. The uprights were then held together and clipped as close as possible to the bog surface. The samples were placed into small resealable plastic bags and transferred to the freezer for storage at -20 °C until evaluations were performed.

Vine samples were evaluated for various yield components, including number and weight of reproductive and vegetative (nonflowering) uprights, as well as runner and total plant dry weight. Uprights and runners were dried for at least 48 h at 60 °C before dry weights were recorded. Total weight was calculated as the sum of vegetative and reproductive upright weight combined with runner weight. Percentage of reproductive uprights was calculated by dividing the number of reproductive uprights by the number of total uprights.

FRUIT YIELD. Each fall, a 1-ft² area was selected randomly for each replicate and all berries within this area were collected (Table 1). Fruit

were stored and evaluated according to previously published protocols (Sandler, 1995). Fruit infected by fruit rot fungi, damaged by insects or physiological causes, or bruised by mechanical means were deemed unusable. Marketable yield was calculated from the weight of all healthy berries collected from the sample area. Potential yield was determined by multiplying the total number of fruit (healthy and unusable) by the average berry weight of the healthy fruit.

ECONOMIC ANALYSIS. Numbers generated for the economic analysis assumed payment for fruit based on yearly price per barrel (1 barrel = 100 lb) reports (National Agricultural Statistics Service, 2006, 2008) and a purchase price for 'Stevens' vines of \$2500 per ton (Cape Cod Cranberry Growers' Association, unpublished data). Pruning costs were estimated based on values provided by commercial growers for machine, operator, and labor costs (Suhayda, 2008). Fruit income was calculated from the price per barrel for the years 2003 to 2006 multiplied by fruit yield (barrels/acre) from each respective year. Income from the generated vines (i.e., money saved from using on-farm vines) was calculated by multiplying the weight of the pruned vines by \$2500 per ton. Net income was calculated as the revenues generated from the sum of fruit income plus the vine income minus the sum of the cost of fertilizer and the cost of pruning.

STATISTICAL ANALYSIS. Data were analyzed with SAS (version 9.1; SAS Institute, Cary, NC). Model assumptions were tested through residual analysis (Shapiro-Wilk statistic) and no transformations were needed. Because the same measurements were collected annually over a 4-year period, data were analyzed as a repeated measures experiment in Proc Mixed with an unstructured model (Littell et al., 1998). Although pruning severity is referred to in the text with the labels of low, medium, and high, pruning treatments were analyzed as continuous variables to reflect the continuity of treatment application (as sequential number of passes or incremental depths into the vine canopy) with which the vines were pruned. Significant levels that could be legitimately tested for best fit were

determined by using partitioning of the sum of squares via Slice option in Proc Mixed. Responses to nitrogen rate and/or pruning severity were determined by evaluating linear and quadratic trends from single df analysis. Whenever trends were significant, regression equations were calculated. Means were separated using Fisher's protected least significant difference (LSD) at $P \leq 0.05$.

Results and discussion

Site $\times$ treatment interactions were not significant ($P > 0.05$) for all measured parameters, therefore site data were pooled for subsequent analyses. This is of particular interest because two individually modified machines were used for pruning and suggests that the treatments effects described below would apply to various machines and pruning methods.

SPRING PRUNING WEIGHT PRODUCTION. Mean pruning weight ($\pm$ SE) collected from the annual spring pruning treatments are presented in Table 2. When pooled across nitrogen treatments at both locations (to gauge the performance of the pruning severities as a continuous treatment), mean pruning weight $\pm$ SE (4-year average) collected from the pruning treatments previously designated as low, medium, and high severity was 0.17 ± 0.02 , 0.35 ± 0.03 , and 0.54 ± 0.03 ton/acre, respectively. These data indicated that the selection of pruning techniques (number of passes or head depth) were adequate to achieve three equally spaced levels of pruning severity. An effect of N rate was not seen in year 1 as the fertilizer treatments had not yet been applied at the time of pruning. Response in cranberry growth to changes in fertilizer regime may not be expressed until the following year (Davenport and Vorsa, 1999) and the response to N rate can be seen in subsequent years (Table 2). Vine weight collected during annual medium and high pruning treatments from areas that received no N inputs decreased during the 4-year study; vine weight generated from the 0 N/low pruning treatment was relatively consistent. With repeated annual applications of 100 or 150 lb/acre N, vine weight increased for all pruned treatments by year 4.

Data analysis indicated that the effect of nitrogen rate on pruning weight varied by pruning treatment

Table 2. Mean cranberry vine weights collected from an annual spring pruning treatment at two commercial cranberry farms that also received various rates of nitrogen in 2003 to 2006 (N = 6). Pruning treatments were achieved by adjusting the pruner head to three different positions in the vine canopy or by using a stationary head and making one, two, or three passes. Site data are pooled.

Pruning treatment	Applied nitrogen (lb/acre) ^z	Vine wt [mean ± SE (ton/acre)] ^z			
		Year 1	Year 2	Year 3	Year 4
None	0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	50	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	100	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	150	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Low	0	0.09 ± 0.02	0.09 ± 0.04	0.09 ± 0.04	0.08 ± 0.03
	50	0.14 ± 0.04	0.13 ± 0.05	0.18 ± 0.05	0.18 ± 0.06
	100	0.09 ± 0.01	0.13 ± 0.04	0.20 ± 0.06	0.38 ± 0.14
	150	0.10 ± 0.01	0.14 ± 0.04	0.28 ± 0.06	0.38 ± 0.12
Medium	0	0.25 ± 0.06	0.17 ± 0.04	0.17 ± 0.06	0.06 ± 0.02
	50	0.23 ± 0.06	0.20 ± 0.06	0.28 ± 0.06	0.43 ± 0.16
	100	0.25 ± 0.03	0.26 ± 0.09	0.53 ± 0.12	0.68 ± 0.24
	150	0.37 ± 0.10	0.33 ± 0.09	0.64 ± 0.11	0.79 ± 0.20
High	0	0.54 ± 0.10	0.59 ± 0.11	0.33 ± 0.08	0.20 ± 0.03
	50	0.54 ± 0.12	0.51 ± 0.08	0.47 ± 0.10	0.42 ± 0.06
	100	0.37 ± 0.12	0.58 ± 0.10	0.64 ± 0.06	0.87 ± 0.12
	150	0.31 ± 0.08	0.63 ± 0.09	0.68 ± 0.08	0.88 ± 0.15

^z1 lb/acre = 1.1209 kg·ha⁻¹, 1 ton/acre = 2.2417 Mg·ha⁻¹.

($P < 0.001$). An examination of the data from those plots where pruning treatments removed vines showed that for all three pruning severities, vine weight increased linearly ($P \leq 0.008$) as N rate increased. The trends for this interaction in the final year of the study are presented in Fig. 1. Because pruning in year 1 was conducted before the application of nitrogen treatments and response of cranberry growth to fertilizer treatment may lag for a season (Davenport and Vorsa, 1999), presentation of the spring pruning data as a 4-year mean were deemed inappropriate to describe the observed treatment effects. Although N rate was highly significant in all years, the proportion of the variation explained by N rate for the first 2 years was very low ($r^2 < 0.10$). However, in years 3 and 4, the proportion of the variation explained by N increased overall (r^2 values between 0.20 and 0.54) and increased with pruning severity (Fig. 1). The low r^2 values were associated with the low severity pruning treatment; thus, factors other than N account for the variation in pruning weight. Pairwise slope comparisons ($P = 0.05$) indicated that the response in the fourth year of N rate on pruning weight generated by pruning at the high severity was greater than pruning at the low severity, whereas the medium severity was intermediate.

YIELD COMPONENT EVALUATION.

The number and weight of vegetative uprights per unit area, and total weight per unit area increased in a quadratic fashion and runner weight increased linearly as the rate of nitrogen applied increased ($P < 0.001$; data not shown). Excessive nitrogen is known to cause overgrowth of

vegetative plant parts (Davenport and Vorsa, 1999; Eck, 1976) in the form of lengthy runner growth and/or very long uprights (Chandler, 1961). Concomitant to the stimulation of vegetative growth, the number and percentage of reproductive uprights decreased linearly ($P \leq 0.018$; Fig. 2); the weight of

Fig. 1. Interaction of nitrogen rate and pruning severity on cranberry vine weight collected from a spring pruning event at two cranberry farms (site data pooled) in the fourth year following repeated annual treatments for 4 years, N = 6. Pruning severity was achieved by adjusting the pruner head to three different positions in the vine canopy or by using a stationary head and making one, two, or three passes. Values are mean ± SE. Regression equations are as follows: $y = (2.21 \times 10^{-3})x + 0.089$, $r^2 = 0.20$ (low severity); $y = (4.92 \times 10^{-3})x + 0.119$, $r^2 = 0.30$ (medium severity); $y = (5.01 \times 10^{-3})x + 0.216$, $r^2 = 0.54$ (high severity). Lines with similar letters have slopes that are not significantly different according to Student-Newman-Keuls' test ($P = 0.05$); 1 ton/acre = 2.2417 Mg·ha⁻¹, 1 lb/acre = 1.1209 kg·ha⁻¹.

Fig. 2. Effect of nitrogen rate on percentage of reproductive uprights (4-year average) from cranberry vines pruned annually over a 4-year period ($N = 96$); 1 lb/acre = 1.1209 kg·ha⁻¹.

reproductive uprights decreased in a quadratic fashion with increasing nitrogen rate (data not shown). Because the percentage of reproductive uprights has been shown to be an important yield determinant (Baumann and Eaton, 1986; Eaton and Kyte, 1978), the decrease in reproductive uprights (along with the increase in runners and vegetative uprights) with increasing nitrogen rates can help to explain the yield decrease associated with increased nitrogen rates noted below. Total plant weight per unit area collected during the summer sampling (post-pruning) decreased linearly with increasing pruning severity ($P = 0.022$) yielding the following mean ($N = 96$) values for the 4-year period: none = 0.93 ± 0.039 kg·m⁻², low = 0.86 ± 0.034 kg·m⁻², medium = 0.88 ± 0.037 kg·m⁻², and heavy = 0.80 ± 0.032 kg·m⁻². Pruning did not affect the total number or weight of uprights, therefore, the decrease in weight can be associated with the removal of runners. The lack of pruning effect on number of uprights corroborates previous (Strik and Poole, 1991, 1992) and more recent research (Suhayda, 2008).

FRUIT YIELD. Pruning treatment had no effect on yield or weight per berry (data not shown). This differed with previous findings by Strik and Poole (Strik and Poole, 1991, 1992) who reported unpruned and lightly pruned vines had higher berry yield and greater number of berries compared with more heavily pruned treatments. However, the amount of vine weight removed from our high pruning treatment was less than that in their light pruning treatment (0.54 vs. 0.80 ton/acre, respectively) and this may account for the lack of adverse pruning effects on yield reported in our study. In addition, because our treatments primarily achieved vine reduction through the removal of runners rather than upright removal, this could also account for the lack of yield effects from the pruning treatment. Suhayda (2008) also reported that light pruning increased yield. Although the vine weight removed in our light pruning treatment was equivalent to that from the Suhayda study, our work differed due to the inclusion of nitrogen rate as a subplot treatment. It is possible that the substantial effect of nitrogen on yield contributed to muting any potential

pruning effects on yield (Davenport, 1996; Davenport and Vorsa, 1999; Eaton, 1971).

Because cranberries may be biennial bearing (Eaton, 1978; Roper and Klueh, 1994), it was not unexpected to see yearly fluctuations across a particular treatment in marketable and potential yield (Table 3). Weather can also influence the amplitude of the yearly fluctuations (DeMoranville and Caruso, 2008). The effect of nitrogen rate (averaged across all pruning treatments) on marketable yield, potential yield, and weight per healthy berry varied by year ($P < 0.001$; Table 3). The decrease was best described as linear ($P < 0.009$) in years 1, 3, and 4 for marketable and potential yield and as quadratic ($P < 0.001$) in Year 2. The decrease in berry weight was best described as quadratic in years 2 and 3 ($P < 0.022$). Mean separation tests indicated that applications of more than 50 lb/acre nitrogen reduced marketable and potential yield. High rates of nitrogen decreased berry size in most years, but the results were variable. Excessive nitrogen application (accompanied by excessive vegetative growth) is often inversely related to yield (Davenport, 1996; DeMoranville, 1992; Hart et al., 1990, 1994).

Of the nitrogen rates used in this study, only the 50 N treatment falls within current recommendations for 'Stevens' in Massachusetts (DeMoranville, 2008). For comparison purposes, the 3-year average yield for a typical management program at SC (50 lb/acre N and no pruning) before the start of the study was 145 barrels/acre. At the end of the study, the average yield from the unpruned 50 N treatment was 136 ± 19.4 barrels/acre. These data were not available for RCH.

Table 3. Marketable yield, potential yield, and weight per berry of cranberry vines that were pruned annually and treated with various nitrogen rates for a 4-year period (2003–06) at two sites (site data pooled), and averaged across pruning treatments ($N = 24$).

Applied nitrogen (lb/acre) ^a	Marketable yield (100-lb barrels/acre) ^a				Potential yield (100-lb barrels/acre) ^a				Fruit wt (g/berry) ^a			
	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4
0	90.5 a ^y	200.0 a	105.5 a	122.6 a	235.6 a	231.8 b	123.4 a	150.4 a	1.55 a	1.51 ab	1.48 a	1.57 a
50	95.6 a	216.7 a	72.8 b	108.3 a	254.4 a	286.0 a	109.9 a	143.5 a	1.57 a	1.65 a	1.75 a	1.74 a
100	64.4 b	105.9 b	7.4 c	22.8 b	220.4 a	160.2 c	17.8 b	37.2 b	1.66 a	1.63 a	0.65 b	1.43 a
150	43.7 b	24.3 c	1.2 c	9.7 b	170.6 b	50.5 d	4.3 b	17.9 b	1.39 b	1.39 b	0.37 b	1.66 a

^a 1 lb/acre = 1.1209 kg·ha⁻¹, 1 100-lb (45.4 kg) barrel per acre = 112.0851 kg·ha⁻¹, 1 g = 0.0353 oz.

^y Mean separation within columns using Fisher's protected least significant difference test ($P < 0.05$).

Table 4. Economic analysis derived from fruit and vine income from cranberry vines that were pruned annually and received repeated annual applications of nitrogen at two commercial cranberry farms (site data pooled), and averaged across pruning treatments (N = 24). General production costs are presumed equivalent across treatments.

Applied nitrogen (lb/acre) ^z	Fruit income ^v (\$/acre) ^y				Vine income (\$/acre)				Net income ^x (\$/acre)				Mean net income (\$/acre)
	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	
0	3,079 a ^v	6,403 a	3,787 a	4,746 a	555 a	537 b	370 d	209 c	3,366 a	6,672 a	3,888 a	4,686 a	4,653 a
50	3,250 a	6,939 a	2,615 b	4,192 a	569 a	525 b	578 c	637 b	3,523 a	7,169 a	2,898 b	4,534 a	4,531 a
100	2,191 b	3,392 b	266 c	884 b	443 a	603 ab	856 b	1,208 a	2,311 b	3,673 b	799 c	1,769 b	2,138 b
150	1,486 b	779 c	43 c	376 b	487 a	682 a	1,006 a	1,288 a	1,623 b	1,112 c	700 c	1,315 b	1,188 c

^z1 lb/acre = 1.1209 kg/ha, \$1.00/acre = \$2.4711/ha.

^yAssuming year 1, 2, 3, and 4 payments of \$34.10, \$32.10, \$36.00, and \$38.80 per 100-lb (45.4 kg) barrel (\$1.00/barrel = \$22.0462/Mg), respectively (National Agricultural Statistics Service, 2006, 2008), and a purchase cost of \$2500 per ton (\$2755.78/Mg) for 'Stevens' vine.

^xNet income = (revenue from fruit yield + savings from using own vines) - (fertilizer costs + pruning costs). Pruning costs: low severity = \$179/acre; medium severity = \$358/acre; and high severity = \$537/acre (Suhayda, 2008). Nitrogen costs = \$0, \$27, \$54, and \$81/acre for respective nitrogen treatments.

^vMean separation within columns using Fisher's protected least significant difference test, $P < 0.05$.

ECONOMIC ANALYSIS. Because net income was affected only by nitrogen treatment, a 4-year economic analysis using data averaged across pruning treatments is presented in Table 4; fruit income was also affected by N rate only. Although vine income was affected by the interaction of pruning and nitrogen treatments when analyzed separately (data not shown), Table 4 presents fruit and vine income data (the components that were used to generate net income) in terms of N treatment only to allow the reader to correlate the effect of N on net income from the component parts. The biennial bearing of cranberry yield was reflected in the yearly fluctuations in fruit income for each treatment. Income from fruit declined linearly ($P < 0.001$) as nitrogen rate increased. Similar to the yield response, the decrease was best described as linear ($P < 0.001$) in years 1, 3, and 4 for fruit and net income and as quadratic ($P < 0.012$) in year 2. The increase in vine income was best described as linear in years 2, 3, and 4 ($P < 0.001$).

The highest net incomes were generated from the 0 and 50 N treatments in each year and for the 4-year period overall (Table 4). Although the 0 N treatment produced high yields and generated comparable income to the 50 N treatment during the 4 years of this study, previous research indicates that this practice would not be sustainable and is not recommended (Davenport, 1996; DeMoranville, 1992). In addition, vine weight (Table 2) and vine income (Table 4) generated in the plots that received 0 N declined in each successive year of the study. For general fruit production purposes for most cranberry cultivars, the ideal rate N rate would likely fall in between 0 and 50 lb/acre.

The use of high rates of nitrogen (100–150 lb/acre) increased the income generated by pruning vines; income was increased 2- to 6-fold compared with the 0 and 50 N treatments (Table 4). The greatest amount of vines was collected in the fourth year of the study from plots receiving 100 and 150 lb/acre N (0.68–0.88 ton/acre) (Table 2). However, the increased vine production came at the expense of lowered fruit production (Table 3) and substantial net income losses (about

\$3000/acre). Successive negative net incomes certainly could not be tolerated in a commercial farming operation.

Overall, net income and mean net income were the highest with applications of 0 and 50 lb/acre nitrogen. Compared with the 50 N treatment, the 100 and 150 N treatments produced 52% and 74% less income, respectively, after 4 years. Based on this study, growers who choose to prune at a rate that removes ≈ 0.5 ton/acre of vines should not expect to sacrifice net income revenues as long as vines are used or sold. While exact returns cannot be predicted, moderate fertility combined with pruning that does not sacrifice upright shoots (and therefore, yield) has the potential for good financial returns.

The price per ton of cranberry vines is variable at present due to increased interest in renovation, which may make supplies short. If growers pruned 0.75 ton/acre of cranberry vines, they would need to receive about \$9000 per ton to receive more monies than if they used the vines on-farms and produced 175 barrels/acre of fruit (at the prices used in this study, about \$32 to \$39 per barrel) (National Agricultural Statistics Service, 2006, 2008). The break-even point for pruning compared with fruit production is likely to be very fluid (e.g., prices per barrel for the 2008 and 2009 crop are expected to be in the high \$40's and about \$60, respectively, which would push the needed price for a ton of vines even higher) and vary by individual circumstance. However, the values presented in this discussion should give a reasonable gauge of when vine sales (as the sole source of monetary income) might be more financially beneficial than fruit sales alone or some combination of fruit and vine sales.

Conclusions

Nitrogen rate is the main factor influencing net income potential for growers using nursery beds for vine propagation within their farm business. The decision to prune vines on one's own farm for planting within the farm system is certainly an individual management choice and cannot be solely driven by economics. Several advantages to using one's own vines include knowing the status of potential weed or pest infestation as

well as productivity history for the vines. Additionally, the grower can time pruning to coincide with planting; if storage is needed, the grower can also control the storage conditions, minimizing additional risk.

Other models for vine propagation may have potential for incorporation into some business plans. One idea is to mow the bed for vines periodically without the expectation of producing fruit. Data from two small studies suggested that mowed beds may better preserve the genetics of the original vines (K. Patten, unpublished data). As the bed ages, runners may more likely arise from off-type vines (less genetically similar to the original planted material) that arise from seeds deposited on the bog floor. These data also indicated that genetic impurity increased with each successive bed planted from prunings. The genetic shift of mowed and/or pruned beds should be further studied to substantiate these trends.

Currently, cranberry growers plant at a rate of 1 to 2 ton/acre, depending on cultivar, weed management choices, fertilizer rate, and available plant material (Sandler, 2004; Sandler et al., 2004). Depending on pruning severity, 2 to 8 acres would be needed to provide enough vines to plant 1 acre of new bog. From data generated in this study, a grower could generate 0.5 ton/acre vines, apply 50 lb/acre nitrogen, and still earn a positive net income on a per annum basis.

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