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LONG-TERM ECONOMIC EVALUATION OF FIVE CULTIVARS IN TWO ORGANIC APPLE ORCHARD SYSTEMS IN VERMONT, USA, 2006-2013

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ABSTRACT

Apple growers may use several systems to establish orchards intended for organic management, including the planting of new nursery trees and top-grafting existing orchards to convert to selected cultivars. Long-term economic analysis of certified organic orchard systems is critical to evaluate potential profitability of the enterprise. The overall objective of this project was to evaluate long-term economic performance of five apple cultivars ('Ginger Gold', 'Honeycrisp', 'Liberty', 'Macoun', and 'Zestar!') grown in a newly planted orchard and in a top-grafted established orchard. A summary of production costs and income for each cultivar in the two orchard systems from the year of establishment through 2013, as well as long-term financial risk by computing the net present value (NPV) of accumulated cash flow in 20 year projections, are presented. Actual management costs including labor, equipment, and inputs costs were recorded, and commercial grades for fruit and projected net income per hectare for each cultivar for each system were assessed over the study period. There were few differences among cultivars for the percentage of fruit in each grade. Mean separation of fruit grade distribution within each cultivar was variable, and in Orchard 2, three of the cultivars (i.e., 'Ginger Gold', 'Liberty', and 'Macoun') had the highest highest percentage of fruit in the US#1 Count grade, with 'Honeycrisp' fruit distributed equally into US# 1 Count, Utility and Cull and with 'Zestar!' having no difference in % of fruit into US#1 Count and Utility grades. All cultivars in Orchard 1 had negative NPV after 20 years. In Orchard 2, 'Ginger Gold' attained positive NPV in Year 3, 'Liberty' in Year 5, and 'Honeycrisp' in Year 7, and 'Macoun' and 'Zestar!' in Year 8. Income calculations, which incorporate disease and arthropod impacts through fruit grade and horticultural performance through crop yield, and the long-term economic projections provide comprehensive information which apple growers can use to determine which cultivar(s) and orchard system would be best for their organic enterprise.

INTRODUCTION

Long-term evaluation of apple cultivars within different orchard systems is necessary to provide information to aid growers in selecting cultivar(s) and orchard establishment methods that will provide the best economic return under organic management. Economic assessment of conventional, non-organically-managed modern apple production systems in the northeastern United States (U.S.) has been conducted in New York (Robinson et al., 2005, Robinson, 2006, Robinson et al., 2007), but multi-year research on organically-managed orchards in the region is lacking. In addition, no long-term study of economic performance of top-grafted orchards has been performed in the U.S. The overall objective of this project was to comprehensively evaluate cultivar performance of five commercially-important apple cultivars (‘Ginger Gold’, ‘Honeycrisp’, ‘Liberty’, ‘Macoun’, and ‘Zestar!’) grown under organic management and using two orchard establishment systems: (i) a newly planted orchard with, nursery-grown trees, and (ii) a top-grafted older, established orchard. The results presented summarizes eight years (2006-2013) of seasonal data and long-term economic performance of each cultivar within the two orchard systems. These results plus analyses of horticultural performance and pest and disease incidence comparing the five cultivars within each orchard system, which are reported in separate articles (Bradshaw et al., 2015b, Bradshaw et al., 2015a), will provide apple growers with comprehensive information on cultivar performance under organic management in two representative orchard systems and will aid in their decision-making as to which cultivar(s) would fit best into their organic production system.

MATERIALS AND METHODS

Orchard site and experimental design

In 2006, two apple orchards were established at the University of Vermont Horticulture Research and Education Center (HREC) in South Burlington, VT (lat. 44.43162, long. -73.20186, USDA hardiness zone 5a, Köppen-Geiger classification Dfb) as part of the Organic Apple Research and Demonstration (OrganicA) Project (Berkett et al., 2009, Berkett et al., 2006). Orchard 1 was planted in April 2006 with the cultivars ‘Ginger Gold’, ‘Liberty’, ‘Macoun’, and ‘Zestar!’ on Bud. 9 rootstock and ‘Honeycrisp’ on M.26. rootstock at a tree spacing of 1.5 m x 4.6 m and trained to a vertical axis system. Each cultivar was replicated 15 times with three-tree replications in a completely randomized design. Orchard 2 was an existing orchard planted in 1988 with ‘McIntosh’ and ‘Liberty’ trees on M.26 rootstock which was top-grafted in April 2006 to the same five cultivars as were planted in Orchard 1. New cultivars were grafted in a randomized complete block design with two-tree replications. Standard organic management practices were followed in each orchard during the study (Bradshaw, 2015). Weather and weekly orchard scouting data were used in developing an organic pest management program following standard protocols. Organically-approved spray materials including dormant copper, sulfur and/or lime sulfur, kaolin clay, and botanical or biologically-derived products were applied annually to assist in arthropod pest and disease management (Bradshaw, 2015).

Input costs

Labor required for orchard management and harvest activities was recorded for all years. Labor tasks were divided into two groups for unskilled and skilled labor, with per hour values of US$10 and US$25 assigned, respectively. Labor was recorded for the whole orchard since management was consistent across cultivars for all years of the experiment. The only labor activities that were variable by cultivar were hand thinning and fruit harvest, since they were dependent on fruit set and crop yield. Thinning time per tree was multiplied by the unskilled labor rate to determine cost of thinning activity (US$/ha) per cultivar per year. Harvest cost of US$0.06/kg was calculated from piece rate of US$1.20/bushel ($18.1 kg) paid to harvest laborers in commercial orchards in the region. Actual cost of orchard inputs, including trees, trellis materials, irrigation supplies, pest management materials, fertilizers, and applied pollen were recorded each year. In addition, equipment use time was recorded each year for all activities. For equipment cost calculations, the replacement cost of all tools, tractors, and implements was divided by a billable hour expectancy of 500 hours to determine an hourly rate for each. Resulting costs were comparable to published estimates (Lazarus, 2014). Detailed input costs were converted to US$/ha based on tree spacing in each orchard, and presented in a prior publication (Bradshaw, 2015).

Fruit grading

A sample of 10 fruit from each tree in Orchard 1 or 25 fruit per tree in Orchard 2 was assessed for fruit weight, percent red color, and disease and insect pest damage (Bradshaw, 2015), and graded annually within one week of harvest. Fruit grades were assigned based on commercial standards that allow for combination of two adjoining grades, therefore, for this assessment, US Fancy and US#1 were combined and graded as 'US#1' (USDA, 2002). General grade categories for this study included: 1) US#1 Count: fruit over >140 grams in weight, with no punctures, with minor blemishes (under 6 mm in diameter), and with red color 'acceptable for variety' or >50% for 'Macoun', 'Liberty', 'Honeycrisp', 'Zestar!'; 2) US#1 Bag**:** same standards as US#1 Count but fruit weight between 100-140 grams, grade assumes fruit would be sold in tote bags for a lower price than Count fruit; 3) Utility: may have significant cosmetic blemishes but no skin punctures unless corked over, healed 'dry' stings are allowed, this assumes a cider/processing market, where equipment considerations may be in place, so small fruit (under 100g) were rejected ; and 4) Cull: all fruit under 100 g, grossly misshapen fruit, and any fruit with open punctures or feeding wounds, rots, or other gross defects. The percentage of total fruit in each grade category was calculated separately by cultivar. Data values presented are grand means of annual means of the percentage of fruit in each category 2008-2013.

Yield and income

Harvested crop yield (kg/tree) was converted to T/ha based on tree spacing and accumulated from 2008 - 2013 in order to determine cumulative gross income/ha. In this calculation, trees that had died during the experiment were assigned a yield of zero in order to include tree survival in the assessment. This assumed that the proportion of trees that died during the study would be consistent when expanding the data to include a full hectare. Gross income was calculated annually for each cultivar by multiplying harvested yield by the proportion of fruit in each grade category. The resulting kg of fruit in each category was multiplied by the following price levels: US$3.14, US$2.10, US$0.52, and US$0.00 per kg for US#1 Count, US#1 Bag, Utility, and Cull grades, respectively. For this analysis, a retail farm stand market was assumed, which eliminated concerns over packing and storing costs and reflects the smaller-scale, retail-oriented market for most organic orchards in the region. Fruit pricing was determined through a survey of local orchards and from actual pricing in the retail farm stand at the HREC. Prices were static over the course of the study, which was justified by minimal annual variation in observed market prices. Utility fruit price represents actual prices paid by a local processor. These prices are higher than those used in a study conducted in New York which evaluated the cultivar 'Liberty' grown under organic and integrated fruit production systems (Peck et al., 2010), but represent actual prices received for premium retail fruit in Vermont. Net income was calculated by subtracting annual costs from annual gross income for all cultivars in each orchard. Gross and net income was accumulated from 2006-2013 by cultivar within each orchard.

Net Present Value

In order to assess long-term profitability, for each cultivar in each orchard system, net present value analyses were performed. Input, machinery, and labor costs were subtracted from orchard income for each cultivar in each year. All data were converted to US$/ha based on tree spacing and orchard size to standardize data analysis. A discount rate was calculated based on 6% interest rate for moderate-risk investments, which is consistent with another orchard profitability study conducted in New York (Robinson et al., 2007). Annual discount rate was calculated using the formula $(1-i)^t$ where i = interest rate and t = time in years since beginning of orchard establishment. The resulting value declines over time from 1 in year 1 (2006) to 0.309 in year 20 (2025). This net present value (NPV) calculation allows for comparison of alternative potential opportunities for investment of funds with varying lifespans compared to a given return from other investment products. Cash flows for 2014 through 2025 were projected using an average of orchard production and expenses from 2010-2013, during which both orchards were assumed to have reached full production, which is supported by research and extension summaries for training systems from New York (Robinson, 2004, Robinson, 2005, Robinson et al., 2007). Annual net income or loss was multiplied by each year's discount factor to determine annual NPV cash flow, which were then accumulated through Year 20.

Statistical analysis

All data were analyzed separately within each orchard. Cumulative yield and income data and NPV in Year 20 were subjected to analysis of variance (SAS PROC GLM) by cultivar with a significance level of α=0.05. If the overall F-test was significant, pairwise comparisons were performed using Tukey's honestly significant difference (HSD) test. Fruit grade percentages were converted to proportions and transformed using the arcsin square root and the analyses were performed on the transformed data. Analysis of variance by cultivar, year, and cultivar x year interactions using Tukey's HSD for multiple comparisons, was performed on fruit grade category data. Because the percentage of fruit within each category by cultivar was not independent (i.e., all combined percentages = 100); paired t-tests were performed among each category within each cultivar and orchard. Although a significance level for each t-test of α=0.05 was used, adjustments for multiple comparisons were not performed.

RESULTS AND DISCUSSION

Fruit grade

Fruit grade assessments are presented in Table 1. Overall, the combined percentage of fruit in both US#1 grades for each cultivar in each orchard system (range 35-58%) was well below the 90-95% typical of cultivars in commercial non-organic orchards (Tukey and Schotzko, 1988). The percentage of fruit within each commercial grade was only different by cultivar at α=0.05 for the US#1 Bag grade in both orchards, but in Orchard 1, no differences among cultivars were detected after applying Tukey's adjustment for multiple comparisons. In Orchard 2, 'Liberty' and 'Macoun' had a higher percentage of fruit sorted into this grade than 'Honeycrisp'.

Distribution of fruit into commercial grades for each cultivar was important because percentages of fruit in each grade were applied to the total yield for that cultivar, and if high percentages of fruit sorted into lower-valued grades, economic performance would suffer. In Orchard 1, within 'Ginger Gold'. 'Macoun', and 'Zestar!' the fruit were most often graded into the US#1 Count category, although the percentage of fruit in that grade was not always statistically different from other grades. Within 'Ginger Gold', 'Honeycrisp', and 'Liberty', the fruit were also frequently graded into the 'Cull' category. High incidence of fruit rots on 'Honeycrisp' and 'Ginger Gold' (Bradshaw et al., 2015a) potentially explains the incidence of culled fruit for those cultivars. Mean fruit weight of 'Liberty' in Orchard 1 was 121.5 g, and given that the cultivar had among the highest percentage of fruit without disease and pest damage (Bradshaw et al., 2015a), fruit size was likely a primary factor in the Cull grade assigned to nearly 40% of its fruit from 2008-2013. In Orchard 2, within each cultivar, the highest-valued US#1 Count grade had the highest percentage of fruit assigned to it with two exceptions: (i) for 'Zestar!' where the Utility grade had 37.3%, but this was not significantly different than the percentage of fruit assigned the US#1 Count grade (31.6%); and (ii) for 'Honeycrisp', which had a statistically similar percent of fruit graded as Utility and Cull fruit. The percent of fruit graded as US#1 Bag was lowest for all cultivars, which reflects mean fruit weights above the 140 g threshold used for that grade (Bradshaw et al., 2015b).

Yield and income

Cumulative yield and net income are presented in Table 2. Cumulative crop yield per hectare from 2008-2013 differed by cultivar in both orchards. Cumulative net income was calculated by subtracting fixed and variable costs accumulated since orchard establishment (Bradshaw, 2015) from accumulated gross income, and mean separation by cultivar within each orchard was the same as for net income. In Orchard 1, all cultivars had negative values which is not unexpected, because newly planted orchards systems typically do not attain positive accumulated cash flow until ten or more years after establishment (Robinson et al., 2005). In Orchard 2, however, all cultivars had positive net cumulative net income after the eight year from establishment, suggesting that this orchard establishment method may be preferable to planting new trees if a grower has suitable trees to graft. This finding supports previous work from the Czech Republic where top-grafted trees attained positive economic return after Year 8 for some cultivar and rootstock combinations (Blazek et al., 2002). Caution is advised in interpreting these results into commercial application, since tree death may reduce profitability of the top-grafted system. Also, the cumulative net income does not account for the time value of delayed income used in NPV analyses for both orchards which is discussed below.

Net Present Value

Long-term economic performance of the cultivars in each orchard assessed by NPV after 20 years is presented in Figure 1. In Orchard 1, all cultivars had negative NPV by year 20, and an annual NPV trend downward for all years except 2011 and 2013 for most cultivars. NPV at Year 20 ranged from -US$82,952/ha for 'Ginger Gold' to -US$119,260/ha for 'Liberty'. The magnitude of negative NPV after 20 years suggests that small changes in management, pest incidence or fruit grade would not likely bring the cultivars toward profitability. Projections after the 2013 season were based on average costs and income from 2010-2013, and projected income in particular may have been greater if yield and income were increased in later years. However, research results and extension recommendations for vertical axis-trained orchards in New York suggest that full production should be achieved by Year 7, with near-full production attained by Year 5. Given that studies of NPV applied to orchard systems tend to use 15-20-year lifespans for evaluation (Funt et al., 1982, Bechtel et al., 1995, Blazek et al., 2002, Mouron, 2005, Robinson et al., 2007, Bravin et al., 2008), and that the cultivars in this orchard had not even approached positive NPV by Year 20 indicate that Orchard 1 was economically unsuccessful, and significant changes in initial establishment and/or management practices, including use of a more vigorous rootstock or modified training system, would be required to change the economic outlook in the future.

In contrast, all cultivars in Orchard 2 achieved positive NPV by Year 8 or earlier. In Orchard 2, 'Ginger Gold' achieved positive NPV in Year 3, 'Liberty' in Year 5, 'Honeycrisp' in Year 7, and 'Macoun' and 'Zestar!' in Year 8. This is similar to a study in the Czech Republic that modelled economic performance of top-grafted trees at the same tree density which achieved positive NPV after six to ten years (Blazek et al., 2002). Higher incidence of tree death on 'Macoun' and 'Zestar!' likely had the greatest impact on NPV for those cultivars, but they also were among the lowest for harvested cumulative crop yield per tree (Bradshaw et al., 2015b). The degree of difference between the cultivars in this orchard was significant, with NPV for 'Ginger Gold', US$223,313, more than double the next lower cultivar 'Honeycrisp' with US$108,087.

The intent of this research was to evaluate long-term economic performance of five important commercial apple cultivars grown organically in two orchard establishment systems in Vermont. In Orchard 1, low yield and relatively high input and labor costs contributed to negative NPV for all cultivars, and it is not expected that modest improvements in management, yield, or fruit pest incidence would improve the economic performance of the cultivars in this orchard. Crop yield and subsequent economic performance of the cultivars was likely affected by poor tree growth in Orchard 1. Factors that likely contributed to below-optimal tree growth and crop yield include: reduction in net photosynthesis attributable to repeated applications of sulfur and lime sulfur fungicides; high incidence of phytophagous mites; improper rootstock selection for the soil type and planting system; slight to moderate deficiencies of mineral nutrients, and; groundcover competition and potential root damage associated with under-tree cultivation. These factors may be addressed via scion/rootstock selection, soil management and site selection, and groundcover management in future studies. Cultivars with the highest tree survival in Orchard 2 had the highest twenty-year NPV, and 'Ginger Gold' in particular performed well economically in this orchard, which suggests that top-grafting existing trees may be a successful method to transition orchards to new cultivars. Results from this study in combination with the results of assessments of horticultural performance and disease and pest incidence of these cultivars within the two systems will provide information to assist in the selection of cultivars and/or orchard systems for future organic production in Vermont and other New England states.

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Tables and Figures

Table 1. Commercial fruit grade distribution, 2008-2013

	US#1 Count		US#1 Bag		Utility		Cull	
Orchard 1								
Ginger Gold	35.6	A[z]	15.6	B	27.8	A	21.0	A
Honeycrisp	33.3	B	10.5	C	21.0	B	35.2	A
Liberty	19.0	C	28.8	B	12.3	D	39.9	A
Macoun	28.9	A	28.7	A	17.4	B	25.0	B
Zestar!	35.0	A	12.3	C	27.9	B	24.8	B
cultivar (p)	0.6053		0.0436		0.3264		0.3630	
Orchard 2								
Ginger Gold	41.9	A	6.9	C\ab	26.4	B	24.9	B
Honeycrisp	34.1	A	1.1	B\b	29.1	A	35.6	A
Liberty	38.8	A	13.4	C\a	22.2	B	25.6	B
Macoun	36.3	A	15.4	C\a	22.5	B	24.7	B
Zestar!	31.6	A	3.8	C\ab	37.3	A	25.9	B
cultivar (p)	0.6401		0.0021		0.2162		0.6481	

[z]Values represent grand means of annual means of percent of fruit assigned to each grade category for each year 2008-2013. Values followed by the same capital letter within a row do not differ in paired t-tests at α=0.05. No adjustments for multiple comparisons were applied to correlated data within cultivars. Values followed by the same lower-case letter within a column do not differ at α=0.05. Tukey's adjustment for multiple comparisons applied for mean separation by cultivar.
[y]P-value for overall F-test to detect differences among cultivars for each fruit grade.

Table 2. Cumulative yield, gross income, & net income, 2006-2013.

	Cumulative yield (t/ha)		Cumulative gross income, US$/ha		Cumulative net income, US$/ha	
Orchard 1						
Ginger Gold	30.7	ab[z]	$ 44,699	a	$ (77,893)	a
Honeycrisp	35.5	a	$ 42,831	a	$ (80,682)	a
Liberty	25.6	bc	$ 27,280	b	$ (94,300)	b
Macoun	25.1	bc	$ 38,433	ab	$ (83,444)	ab
Zestar!	23.6	c	$ 35,952	ab	$ (85,303)	ab
cultivar (p)[y]	<0.0001		0.0023		0.0037	
Orchard 2						
Ginger Gold	108.4	a	$ 187,689	a	$ 109,717	a
Honeycrisp	72.7	b	$ 93,445	bc	$ 22,195	bc
Liberty	66.2	b	$ 116,816	b	$ 46,374	b
Macoun	38.7	c	$ 66,713	c	$ 90	c
Zestar!	50.3	bc	$ 69,154	c	$ 3,603	c
cultivar (p)	<0.0001	<0.0001	<0.0001			

[z]Values followed by the same lower-case letter within a column do not differ at α=0.05. Tukey's adjustment for multiple comparisons applied for mean separation by cultivar.
[y]P-value for overall F-test to detect differences among cultivars for each fruit grade.

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Figure 1: NPV of accumulated cash flow (US$/ha), Orchard 1, 2006-2025

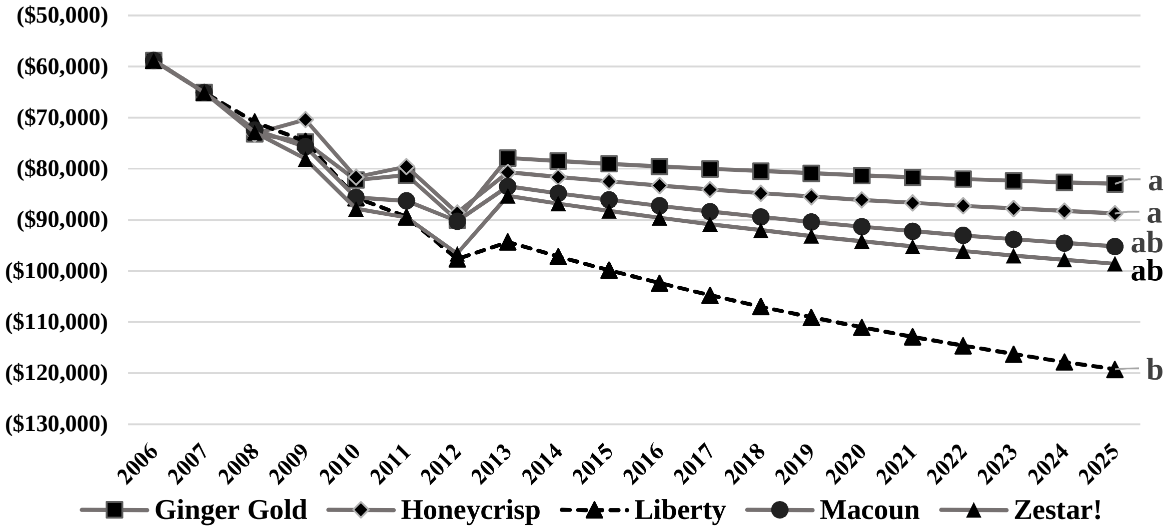
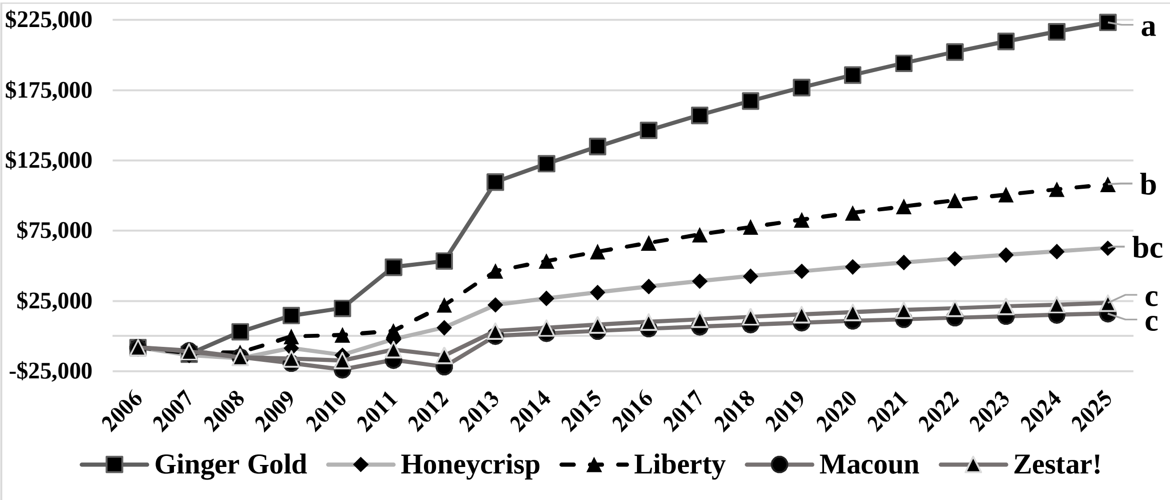


Figure 2: NPV of accumulated cash flow (US$/ha), Orchard 2, 2006-2025



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