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Effect of Organic Amendments on Half-Highbush Blueberry Production and Soil Fertility

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ABSTRACT

Five treatments were compared using two half-highbush blueberry cultivars (cv Chippewa and Polaris) transplanted and grown for their first three growing seasons at a site in Boutiliers Point, N.S., a Gibraltar brown sandy loam (Ferro-Humic Podzol). The five treatments were as follows: Alfalfa meal + rock P + wood ash; NPK fertilizer; Municipal Solid Waste (MSWC) compost; Ruminant compost; food waste, manure and yardwaste compost (FMYC). All amendments were weighed and applied in an amount equivalent to the total N of the recommended NPK fertilizer for blueberries, assuming 25% N availability from each of the organic amendments. Soil extractable nutrients, leaf nutrients and fruit yields were measured and compared. The fertility treatments produced few effects on extractable levels of nutrients in the soil and leaf. 'Chippewa' responded more than 'Polaris' to the fertility treatments. The K fertilizing ability of the Ruminant compost was evident in all three growing seasons. 'Chippewa' showed consistent soil and leaf P response to Ruminant compost throughout the growing season; however, it failed to produce a comparative increase in the fruit yield. The NPK fertilizer treatment reduced the soil pH compared to other soil amendments while the MSW treatment increased the soil pH each year. The yield results showed that there were no statistical differences between the treatments for either cultivar (one year of data). Thus, the composts provided equivalent amounts of plant essential nutrients without increasing the trace element concentration in soil and tissue.

Key Words: Blueberry, Extractable soil nutrients, Leaf nutrients, Yield

INTRODUCTION

The Province of Nova Scotia has become a world leader at diverting valuable 'wastes' from disposal. Since the release of the Province's Solid Waste-Resource Management Strategy in 1996, Nova Scotia has achieved the target of recycling 50% of its solid waste, mostly by composting. Thus, it was inevitable that researchers would evaluate the application of organic amendments and composts made from solid wastes to grow various food crops. Furthermore, research and development of organic blueberry production is necessary due to growing agribusiness interests in the substantially higher market value of certified organic blueberries (Sciarappa et al., 2003).

Highbush blueberries have been considered a marginal crop for Nova Scotia due to their sensitivity to winter injury. Despite this, production has increased since 1930 when the first commercial acreage was planted, and currently blueberries are produced annually on over 54 hectares (John, 2000). Half-high blueberries are a cross between highbush *(Vaccinium corymbosum L.*) and lowbush blueberries (*V. angustifolium Ait.*) and were developed at the University of Minnesota (Finn et al. 1990). Half-high blueberry plants are short in stature and cold-hardier than highbush blueberries and could be favoured in the colder regions of Nova Scotia (John, 2000).

Only a few comparison studies between organic and conventional fertilizers have addressed the issue of soil and plant nutrients in small fruit production (Warman, 1987; Woese et al., 1997; Miller et.al., 2006; Hargreaves et al., 2008b). In addition, few studies have evaluated the use of municipal solid waste composts for agricultural production (He et al., 1992; Murphy et al., 2000; Warman et al. 2004; Hargreaves et al., 2008a). A comparative study is vital to evaluate the feasibility of using various organic amendments in place of chemical fertilizers. To this end, the first three years of a long-term study were initiated with the following objective: to evaluate plant nutrition, soil fertility, and yields from the application of four organic amendments and a chemical fertilizer treatment to half-high blueberries.

MATERIALS and METHODS

Two half-high blueberry cultivars (*Vaccinium corymbosum L. / V.angustifolium Ait.*) were chosen for the study. The cultivar descriptions are as follows (John, 2000): ‘Polaris’ [‘Bluetta’ x B15 (G65 X ‘Ashworth’)] - early, very hardy, upright and spreading up to 1 meter, moderate size fruit, light blue, very firm, excellent fruit quality. ‘Chippewa’ [(B18A (G65 X ‘Ashworth’) X U53 (‘Dixi’ X Michigan lowbush No 1)] - mid season, very hardy, large light blue berries, sweet, good flavor, upright and spreading bush (80 cm tall).

Field experiments were initiated in May 2002 at Boutiliers Point (near Halifax), Nova Scotia, Canada in a Gibraltar brown sandy loam (Ferro-Humic Podsol). The soil chemical properties (Mehlich-3 extractant) prior to the treatment applications were as follows: 4.61 pH; 315.5 mg Ca kg^{-1}; 44.5 mg Mg kg^{-1}; 9.5 mg P kg^{-1}; 58.5 mg K kg^{-1}; 21.5 mg Na kg^{-1}; 85.5 mg S kg^{-1}; 91.5 mg Fe kg^{-1}; 0.6 mg Cu kg^{-1}; 10.2 mg Mn kg^{-1}; 2.3 mg Zn kg^{-1}; 0.3 mg B kg^{-1}.

The study consisted of a randomized complete block design using five treatments (Alfalfa meal +rock P +wood ash; NPK fertilizer; Municipal Solid Waste (MSW) compost; ruminant compost; food waste, manure and yardwaste compost (FMYC). Each treatment was blocked five times giving 25 test plots for each variety, totaling 50 plots for the two varieties. Each block consisted of both the varieties ‘Polaris’ and ‘Chippewa’, each of them treated with all five treatments (10 plots per block). On May 24, 2002, single bushes were planted at the center of each of the plots (lm X lm). Rows were 2 m apart and plants were spaced at 1.5 m within rows.

All the amendments were weighed and applied in an amount equivalent to the total N of the recommended NPK fertilizers for blueberries, with an assumption of 25% N availability from each of the organic amendments. The P and K fertilizer calculations (NPK treatment, rock P and wood ash) were based on the pre-amendment initial Mehlich- 3 soil test values of extractable P and K using the N.S. Soil Test Recommendations (Soils and Crops Branch, 1985).

Amendments were hand broadcast onto each plot and raked into the soil in early June during the planting year and in mid May for the subsequent fruiting years. Inorganic fertilizer was a blend of urea N (45-0-0), super phosphate for P_2O_5 (0-20-0) and potash for K_2O (0-0-60). The rock phosphate used was 'North Carolina' rock phosphate; the total P analysis of the rock P was 100 g kg^{-1}, with ammonium citrate extractable P of 12 g kg^{-1}. The wood ash used in one treatment was obtained from a household wood furnace and was 50 g kg^{-1} total K. The alfalfa meal was purchased locally and had a mean N content of 28 g kg^{-1}. The analysis of the three composts is provided in Table 1.

Table 1: Analysis of the applied organic amendments averaged over the three study years

Parameter	**MSW Compost**	**Ruminant Compost**	**FMY Compost**
Moisture (%)	26.7	44.8	50.7
C:N Ratio	10:1	12.4:1	10.9:1
N (g kg^{-1})	21.2	18.7	11.4
P (g kg^{-1})	11.3	8.3	6.1
K (g kg^{-1})	6.0	15.4	7.1
Ca (g kg^{-1})	96.8	25.6	23.5
Mg (g kg^{-1})	6.0	5.8	4.3
S (g kg^{-1})	12.1	10.2	7.5
Fe (g kg^{-1})	10.4	7.4	9.8
Cu (mg kg^{-1})	176.9	26.0	23.3
Mn (mg kg^{-1})	1279	606	614
Zn (mg kg^{-1})	431	334	254
B (mg kg^{-1})	31.7	21.6	14.4
Cd (mg kg^{-1})	1.4	0.3	0.5
Cr (mg kg^{-1})	22.2	9.2	10.6
Ni (mg kg^{-1})	9.5	6.9	7.2
Pb (mg kg^{-1})	64.6	18.9	24.3

The treatment applications were based on the highbush blueberry N recommendation of 50 kg N ha^{-1} for 2002 and 2003 (planting year and first fruiting year) and 135 kg ha^{-1} for 2004 (second fruiting year). Table 2 shows the amounts of amendments applied for the three years of the study. The plots were hand weeded and rototilled throughout the growing seasons.

Initial soil samples were taken in early May 2002. After the harvest or at leaf sampling, four core samples from each plot, taken to a depth of 15 cm, were mixed and a composite taken. Leaf samples (50-60) were taken from the plots October 2002 and in mid-August of 2003 and 2004. Crows damaged immature fruit in 2003; thus, harvest data was not taken. Netting was used in the second fruiting season.

Mature fruit was harvested at weekly intervals from early August until mid-September in 2004 and the total fruit weight was recorded.

Table 2: Amount of amendments applied to the half-high blueberries from 2002 to 2004

Treatment		Rate (kg ha^{-1})		
		2002	**2003**	**2004**
1	Alf meal[a]	2400	6080	18000
	Rock P	5500	3400	2343
	Wood ash	400	30	0
2	N (45-0-0)	109	109	293
	P_2O_5 (0-20-0)	874	700	625
	K_2O (0-0-60)	120	50	183
3	MSW[b]	18500	17000	42400
4	Ruminant Compost[c]	20100	34000	61100
5	FMYC[d]	32050	30900	116000

[a] The meal averaged 3.8 %, 3.1 % and 2.8 % dry weight in 2002, 2003 and 2004, respectively.
[b] The compost averaged 79 %, 75 % and 66 % dry weight in 2002, 2003 and 2004, respectively.
[c] The compost averaged 66 %, 53 % and 46 % dry weight in 2002, 2003 and 2004, respectively.
[d] The compost averaged 54 %, 45 % and 49 % dry weight in 2002, 2003 and 2004, respectively.

Soil was mixed at a ratio of 2:1 (water:soil), left for 1 hour, and the pH was measured using an Accumet pH meter. Soil mineral elements (Ca, Mg, K, S, Fe, Cu, Mn, Zn, P, Cd, Cr, Ni, Pb, and B) were extracted using the Mehlich-3 extractant and determined using Inductively Coupled Argon Plasma Emission Spectroscopy (ICAP) (Thermo Jarrell Ash ICAP 1100, Thermo Jarrell Corp., Waltham, MA, U.S.A.).

All plant tissue was rinsed with distilled water and dried at 65˚C for 48 hours. The dried leaves were ground and digested with nitric acid according to Zheljazkov and Warman (2002). The digests were analyzed for Ca, Mg, K, S, Fe, Cu, Mn, Zn, P, Cd, Cr, Ni, Pb, and B using ICAP.

As indicated, the experiment began in 2002; the data/results presented in this paper only include 2004 in order to reduce the volume of the manuscript. Reference, however, will sometimes be made to the results of work evaluated in 2002 and 2003. Please note this paper represents the earliest stages of a long-term study that will continue until at least 2010.

Statistical analysis was completed using SAS software version 8.0 (SAS, 2000). After verifying the assumptions, the GLM with randomized complete block design was used for the analysis. If the model was significant at the 0.05 level, treatment means were compared using Tukey's means comparison test. SAS was also used to evaluate the significance of difference between the two-way interaction of cultivar and treatment, and the main effect of cultivar.

RESULTS and DISCUSSION

Extractable Soil Nutrients:

No significant treatment differences were noted in the extractable P content for either blueberry cultivar (Table 3) although soil P increased for each treatment since 2002. In the ‘Chippewa’ plots, the Ruminant compost-treated plots showed higher extractable soil K levels than the other fertility treatments. Also in the ‘Chippewa’ plots, MSW compost produced 80% higher soil extractable Ca levels when compared to the other treatments, and all compost treatments produced higher soil Mg levels (Table 3). Soil extractable S levels were significantly higher (double) in the NPK treatments plots for the ‘Chippewa’ cultivar. No significant treatment differences were noted for ‘Polaris’; however, significant interactions between the cultivars and treatments were recorded in soil extractable Mg and S levels (Table 3).

Warman (1987) compared the response of soil nutrients to various manures and NPK fertilizers applied to lowbush blueberries and noted highest soil NH_4OAc extractable K levels in soils amended with Dairy Manure, which had comparable characteristics with the Ruminant compost used in this study. In a similar study, Warman et al. (2004) showed higher soil Mehlich 3 extractable K levels in lowbush blueberry soils amended with MSW compost when compared with K levels of NPK fertilized soils. Townsend (1973) showed an increase in exchangeable K levels compared to control plots in highbush blueberry soils amended with sawdust and peat mixtures. The higher soil P and K levels in compost treated plots could be due to rates of P and K applied from the composts that were higher than the inorganic fertilizers. This was the result of the relatively low total N content in the composts, that ranged from 11.4 to 21.2 g kg^{-1} (Table 1), which led to the addition of higher than recommended rates of P and K in the composts, in order to apply an equivalent amount of N from each fertility source. Warman et al. (2004) studied the response of similar MSW compost applications to lowbush blueberry soils and attributed the elevated soil extractable P and K levels to the compost nutrient contents. The high extractable Ca levels in MSW compost-treated plots could be attributed to the higher Ca levels in the MSW compost compared to other fertility treatments.

Ruminant and FMYC composts produced the highest levels of soil Zn for both cultivars in 2004 (Table 4). Ruminant compost also produced the highest soil Fe levels in ‘Polaris’ soils, with the alfalfa meal producing the lowest soil Fe. ‘Chippewa’ soils showed higher Mn levels in the NPK treatment compared to all other treatments, but there was no significant effect of treatments on soil Mn in the ‘Polaris’ soils (Table 4). Warman et al. (2004) also showed a similar weak effect on extractable Fe and Mn in lowbush blueberry fields amended with MSW composts. Soil B was lowest in the NPK plots for ‘Chippewa’, but was not influenced by treatments for 'Polaris'. Soil Cu was not affected by treatments for either cultivar.

No significant treatment differences were noted in the soil trace element concentrations of Cd, Cr, Ni and Pb in any of the three growing seasons for either cultivar. Generally, soil Cd, Cr, Ni were in the range of 0.1 to 0.4 mg kg^{-1} while Pb ranged from 2 to 3 mg kg^{-1}.

Table 3: Effect of treatments on the Mehlich 3 soil macronutrient content in 2004 (mg kg^{-1})

Cultivar (Cv)	**Treatment (Trt)**					
		P	**K**	**Ca**	**Mg**	**S**
Chippewa	Alf. Meal	58 a	161 ab	752 bc	60 b	113 b
	NPK	83 a	140 ab	414 c	18 c	248 a
	MSW	46 a	122 b	1255 a	95 a	115 b
	Ruminant	79 a	177 a	620 c	113 a	94 b
	FMYC	74 a	114 b	1012 ab	99 a	125 b
Polaris	Alf. Meal	56 a	123 a	821 a	82 a	121 a
	NPK	56 a	126 a	759 a	81 a	126 a
	MSW	50 a	119 a	653 a	60 a	125 a
	Ruminant	79 a	139 a	752 a	64 a	148 a
	FMYC	96 a	195 a	1071 a	102 a	158 a
Cv	P<	ns	ns	ns	ns	ns
Cv x Trt	P<	ns	ns	ns	0.03	0.03

*Means within columns (for each cultivar) followed by the same letter are not significantly different at $P<0.05$ when interaction or main effects are indicated to be significant.

The treatments produced a significant effect on the soil pH for both cultivars during the three growing seasons (Table 5). The NPK treatment reduced the soil pH and the MSW treatment increased the soil pH compared to the other soil amendments each year, responses that the senior author has noted in other experiments (Warman, 1988; Warman et al., unpublished data).

Leaf Nutrients

The fertility treatments failed to produce a significant effect on most of the macronutrients, especially leaf N, K, Ca and S (Table 6). Ruminant compost and NPK treatments resulted in the highest leaf P levels in ‘Chippewa’ (Table 6). The NPK treatment resulted in lower leaf Mg levels in both cultivars, and ruminant compost produced significantly lower Mg, but only in ‘Polaris’ (Table 6). Ring et al. (2004) wrote that the Mehlich 3 soil extraction method may not reflect the actual leaf P levels in Nova Scotia blueberry soils. Warman et al. (2004) also showed similar soil-plant relationship for P in lowbush blueberry soils amended with MSW compost and NPK fertilizers. Supporting this result, Townsend (1973) showed that leaf P levels did not increase with a corresponding increase in soil P levels due to organic treatments in highbush blueberry fields. In contrast, Black and Zimmerman (2002) showed higher P levels in highbush blueberry leaves in ash-compost treated plots than the control plots.

Table 4: Effect of treatments on the Mehlich 3 soil micronutrient content in 2004 (mg kg^{-1})*

Cultivar (Cv)	**Treatment (Trt)**	**B**	**Fe**	**Cu**	**Mn**	**Zn**
Chippewa	Alf. Meal	0.5 b	99 a	0.9 a	9 b	3.0 b
	NPK	0.3 c	115 a	0.9 a	15 a	3.2 b
	MSW	0.6 a	95 a	1.1 a	11 ab	3.8 b
	Ruminant	0.5 ab	104 a	0.8 a	11 ab	6.2 a
	FMYC	0.6 a	100 a	1.2 a	11 ab	6.2 a
Polaris	Alf. Meal	0.5 a	83 d	0.9 a	7.1 a	3.0 b
	NPK	0.5 a	97 cd	0.8 a	9.2 a	4.0 ab
	MSW	0.5 a	105 bc	0.8 a	9.2 a	3.2 ab
	Ruminant	0.5 a	123 a	1.0 a	17.5 a	7.0 a
	FMYC	0.6 a	114 ab	1.3 a	17.6 a	7.0 a
Cv	P<	ns	ns	ns	ns	ns
Cv x Trt	P<	0.02	ns	ns	ns	ns

* Means within columns (for each cultivar) followed by the same letter are not significantly different at $P<0.05$ when interaction or main effects are indicated to be significant.

The leaf micronutrients Cu, Zn and Fe were unaffected by any of the treatments (Table 7). In 2004, Alfalfa meal and MSW compost produced significantly higher levels of leaf B in ‘Polaris’; however, the FMYC treatment showed higher leaf B in ‘Chippewa’ and the NPK and MSW compost treatments produced the lowest leaf B. The NPK treatment produced significantly higher leaf tissue Mn levels in both the cultivars (Table 7). The NPK treatment produced a strong effect on leaf Mn levels in both the cultivars during two fruiting years (Table 7). However soil analysis did not reveal many treatment differences in Mehlich 3 extractable Mn (Table 4). Manganese availability is directly related to pH and the lower the pH, the higher is the Mn availability (Warman et al., 2004). Haynes and Swift (1985) reported an increase in plant Mn levels as the soil pH was lowered in fertilizer-treated highbush blueberry plots. This explains the higher availability of Mn in NPK plots that were lower in pH compared to the other treatment plots (Table 5). Warman (1998) showed significant increase in Mn levels, both above and below ground, in plots treated with conventional fertilizers when compared to plots treated with organic amendments.

The leaf trace element levels of Cd, Cr, Ni and Pb were unaffected by the fertility treatments. The mean trace element values ranged from 0.1 to 1.8 mg kg^{-1}. Thus, to date, the composts did not increase these elements in the blueberries. Black and Zimmerman (2002) studied the effect of compost treatments on highbush blueberries and also did not find an increase in tissue trace elements due to treatments.

Table 5: Effect of fertility treatments on soil pH in 2002, 2003 and 2004

Cultivar (Cv)	Treatment (Trt)	pH		
		2002	**2003**	**2004**
Chippewa	Alf. Meal	4.70 a	4.85 ab	5.57 a
	NPK	4.23 b	4.36 b	4.41 b
	MSW	4.89 a	5.05 a	5.80 a
	Ruminant	4.78 a	4.93 a	5.67 a
	FMYC	4.86 a	5.01 a	5.76 a
Polaris	Alf. Meal	4.78 a	5.20 b	5.59 ab
	NPK	4.33 b	4.41 c	4.06 b
	MSW	5.09 a	5.54 a	5.95 a
	Ruminant	4.83 a	5.25 b	5.65 a
	FMYC	4.90 a	5.32 b	5.72 a
Cv	P<	0.05	0.00	ns
Cv x Trt	P<	ns	ns	ns

*Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

Fresh Fruit Yields

Harvest data was not taken in the 2003 fruiting season because birds removed immature fruit. There were no statistical differences between the treatments during 2004, which averaged 18 g plant^{-1} for the ‘Chippewa’ and 12 g plant^{-1} for the ‘'Polaris'’ cultivars. Alfalfa meal produced numerically higher yields in ‘Chippewa’ than all of the other treatment means while the MSW treatment produced numerically higher yield in ‘Polaris’ than all of the other treatment means. Townsend (1973), using raw sawdust and peat as soil amendments, found no increase in yields, bush size or vigor during six years of a field study; however, Haynes and Swift (1986) recorded better growth and yield of blueberries when elemental S, peat and pine bark were used.

There is a definite need to determine critical macronutrient and micronutrient levels in half-high blueberries as Ballinger et al. (1958) has determined for highbush blueberries. Given that blueberries have relatively low nutrient requirements, with the exception of Fe, Mn, Cu and S (Korcak, 1988), it would be useful to determine which nutrients are most required to generate the highest yields. For example, Blevins et al. (1996) showed 10% higher yields of highbush blueberries in Missouri from B applications and McArthur (2001) stressed the importance of B in highbush blueberry nutrition.

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Table 6: Effect of treatments on the leaf tissue macronutrient content in 2004 (g kg^{-1})*

Cultivar (Cv)	**Treatment (Trt)**	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Chippewa	Alf. Meal	19 a	0.8 ab	3 a	5 a	1.3 a	2 a
	NPK	19 a	0.9 a	4 a	4 a	0.7 b	2 a
	MSW	18 a	0.7 b	3 a	4 a	1.1 ab	2 a
	Ruminant	18 a	0.9 a	4 a	4 a	1.2 ab	2 a
	FMYC	19 a	0.8 ab	3 a	5 a	1.3 a	3 a
Polaris	Alf. Meal	19 a	1 a	5 a	4 a	1.1 a	2 a
	NPK	17 a	1 a	4 a	4 a	0.6 b	2 a
	MSW	17 a	1 a	4 a	4 a	1.1 a	2 a
	Ruminant	14 a	1 a	3 a	2 a	0.7 ab	2 a
	FMYC	17 a	1 a	4 a	4 a	1.1 a	2 a
Cv	P<	ns	ns	ns	ns	0.01	ns
Cv x Trt	P<	ns	ns	ns	ns	ns	ns

* Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

Table 7: Effect of treatments on the leaf tissue micronutrient content in 2004 (mg kg^{-1})*

Cultivar (Cv)	Treatment (Trt)	B	Fe	Cu	Mn	Zn
Chippewa	Alf. Meal	24 ab	78 a	4 a	269 b	9 a
	NPK	18 b	78 a	3 a	777 a	9 a
	MSW	21 b	120 a	4 a	362 b	10 a
	Ruminant	23 ab	71 a	4 a	270 b	10 a
	FMYC	29 a	79 a	5 a	303 b	12 a
Polaris	Alf. Meal	30 a	85 a	3 a	250 b	9 ab
	NPK	17 b	75 a	2 a	645 a	9 ab
	MSW	31 a	76 a	4 a	381 b	11 a
	Ruminant	20 ab	62 a	2 a	208 b	7 b
	FMYC	27 ab	62 a	3 a	234 b	11 a
Cv	P<	ns	ns	0.00	ns	ns
Cv x Trt	P<	0.04	ns	0.04	ns	ns

*Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

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