Efficacy Testing of Organic Nutritional Products for Ontario Canada Vineyards

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ABSTRACT. A study was conducted to determine the efficacy of three foliar applied organic fertilizers and their impact on yield, fruit composition, and plant nutrition in mature own-rooted 'Baco noir' grapevines in Niagara-on-the-Lake, Ontario, Canada. Three foliar fertilizer products (liquid fish fertilizer, seaweed extract, "Monty's Evergreen") were applied biweekly as individual treatments as well as in the form of a complete (combination) application at dealer recommended rates from bloom to 2 weeks post-veraison. A control treatment consisted of 150 kg/ha ammonium nitrate (51 kg N/ha) added one week before bloom. Despite using less than 10% of the total N applied in the control, the complete foliar application equalled or surpassed the control in almost all yield, fruit composition, and vine nutrition variables. Despite severely reduced yield due to berry moth patterns experienced in the region in 2005, the complete foliar treatment increased yield by 15%, and this was considered sufficient to justify the increased material costs. The results of this study suggest that the use of foliar fertilizers is effective in replacing soil-applied ammonium nitrate for nutrient supplementation to 'Baco noir' grapevines. The implications of

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this study may cause grape growers in the Niagara Peninsula to reevaluate their nutrient management practices.

KEYWORDS. Fish fertilizer, foliar fertilizer, N, plant nutrition, seaweed-based fertilizer, *Vitis*

INTRODUCTION

Many of the vineyards in the Niagara Peninsula in Ontario, Canada, are grown on heavy clay soils. Although these soils are rich in nutrients, their high cation exchange capacity (CEC) causes them to bind up many elements, quickly rendering them unavailable for the plant. This is especially true with phosphorus (P) and potassium (K). As a result, growers in the Niagara region often apply excess P and K in hopes that more will be available to the vine. In the case of K, this excessive addition can often lead to the inability of the vine to take up other nutrients such as calcium (Ca) and magnesium (Mg) (Morris et al., 1980; Wolf et al., 1983). Correlations have been shown between high soil K levels and reduced Mg intake in both 'Concord' (Morris et al., 1980) and 'Seyval' grapevines (Wolf et al., 1983). After several years of excessive K additions, this problem can escalate into Ca and Mg deficiencies in the vine despite adequate amounts of these elements in the soil, due to K's antagonistic relationship with Mg and Ca (Morris et al., 1980). In addition to potential negative environmental impacts, adding excess granular fertilizers to the soil is also a major expense to growers, who are essentially paying for much more fertilizer than the plant needs.

A potential solution to this problem is the use of foliar-applied fertilizers, which can be sprayed at regular intervals throughout the season rather than in a single large application. Numerous studies have examined the benefits of foliar fertilizer applications as opposed to traditional ground-applied methods (Abbasi et al., 2003; Johnson et al., 2001; Reeve et al., 2005; Wolf et al., 1983). Reickenberg and Pritts (1996) found that raspberry plants were capable of absorbing both nitrogen (N) and K through the leaves rather quickly and efficiently with up to half of the N available from urea being translocated to throughout the plant within 2 days, while approximately one-third of the K was translocated in the same amount of time. Urea uptake efficiency in peach trees could be as high as 69% from foliar applications, with N translocation to the various components of the trees comparable to soil applications (Johnson et al., 2001). Foliar fertilizers, with their rapid absorption rates, allow for multiple targeted applications (Johnson et al., 2001; Reickenberg and Pritts, 1996). Many of these fertilizers can be applied with the regular pesticide sprays, resulting in fewer passes through the field than a soil-applied fertilizer program would require.

The most common form of N application is ammonium nitrate, which is applied on an annual basis by many growers. In regions with coarse-textured soils located near water courses, the use of granular N fertilizers may result in N leaching, causing pollution of groundwater (El-Tarabily et al., 2003; Johnson et al., 2001). For this reason, Johnson et al. (2001) explored the possibility of using foliar-applied urea as the only supplemental N source in peaches grown in California. This leaching problem is also one of the reasons fish-based fertilizers are used in the United Arab Emirates (UAE; El-Tarabily et al., 2003).

For soil-applied fertilizers timing is critical, because in order to optimize nutrient uptake, single-application soil-applied fertilizers should coincide with root development (Conradie, 1980). In South Africa, the best times for N fertilization to the soil are in spring between budburst and postbloom or after harvest (Conradie, 1980). Similar results were found for P, K, Ca, and Mg, all of which had optimal absorption from budburst until the start of veraison (Conradie, 1981). The uptake of nutrients was greatest when the fertilizer applications were split between spring and fall applications (Conradie, 1980, 1981, 1986; Conradie and Saayman, 1989). The spring applications allowed adequate N uptake during the growing season, with the fall application providing N reserves for a quick start in the spring (Conradie, 1980). The warm postharvest temperatures in South Africa make fall fertilizer applications beneficial; however, this practice is not generally carried out in cool, temperate regions because very little if any root growth occurs postharvest. Foliar fertilizers give the grower more freedom to apply fertilizers throughout the growing season without being limited by specific time slots.

The organic movement has been gaining popularity in all facets of agriculture (Malusá et al., 2004; Reeve et al., 2005) and was another reason for initializing this trial. Two studies (Malusá et al., 2004; Reeve et al., 2005) indicated that organic viticulture increased to 29,200 ha in Italy as of 2002 and 15,000 ha of biodynamic vineyards in France as of 1998. Both studies stated the importance of improving soil health and increasing soil biological activity. They also emphasized that by minimizing direct N additions, the quality of the grapes was increased in terms of anthocyanin and phenol concentrations. Nutrient management in organic and biodynamic viticulture has primarily involved using animal manures and cover crop management to supply nutrients to the soil and increase soil organic matter. Biodynamic viticulture also involves the use of various compost sprays, which, like seaweed extracts, contain plant growth regulators such as cytokinins (Reeve et al., 2005). The use of these sprays is commonly dismissed due to their low concentrations of nutrients, which in theory could not possibly affect plant growth or nutrition (Reeve et al., 2005). The counterargument, however, is that the effectiveness of these sprays comes mostly from the activity of plant growth regulators, which are not needed in high concentrations, rather than from the actual nutrients, as in the case of seaweed extracts (Reeve et al., 2005; Turan and Köse, 2004). These growth regulators reputedly increase nutrient uptake and produce healthier plants in general (Reeve et al., 2005; Turan and Köse, 2004).

Fish by-products are currently used as fertilizers in many parts of the world and provide a viable organic alternative to standard mineral fertilizers (Aung and Flick, 1980; Blatt and McRae, 1998; El-Tarabily et al., 2003; Emino, 1981). In the UAE, fish emulsions, fish meal powders, and seaweed extracts are used as soil-applied alternatives to inorganic chemical fertilizers, which frequently leach into waterways and groundwater (El-Tarabily et al., 2003). The use of fish emulsions (5.3–4–0.9 N-P-K) as a soil-applied fertilizer resulted in equal or better performance than a commercial inorganic 27–5.5–9 fertilizer in radish production (El-Tarabily et al., 2003). Fish-based fertilizers matched commercial inorganic fertilizers in terms of yield and plant growth of greenhouse-grown tomatoes and several other plants despite having much lower N-P-K values (Aung and Flick, 1980; Emino, 1981). Fish by-products also matched standard fertilizers in the production of cabbage, beans, and carrots (Blatt and McRae, 1998). The ability for fish emulsions to produce plants of equal or greater growth and yields as those grown with conventional fertilizers, despite significantly lower N-P-K values, is likely due to its complex composition. Fish emulsions contain, along with N-P-K, many essential amino acids, proteins, lipids, and various vitamins (El-Tarabily et al., 2003). The fish emulsions also contained a combination of bacteria, actinomycetes, and plant growth regulators, all of which might have explained the positive effects of fish emulsions in radish production (El-Tarabily et al., 2003). The high concentrations of plant growth regulators were suggested as a major reason why the radishes had equal growth to those with the inorganic fertilizer despite lower plant nutrient concentrations (El-Tarabily et al., 2003). Fish emulsion is also far less likely to leach out of the ground following rain compared to a standard inorganic fertilizer (El-Tarabily et al., 2003). Negative aspects of the fish fertilizers, along with their odor, include the possibility of later flowering and delayed fruit ripening (shown with tomatoes; Aung and Flick, 1980). This could be a detrimental side effect in cool climate regions where fruit maturity of some late maturing grape varieties can not be delayed.

Foliar applications of fish emulsions on peppers and tomatoes have had antibacterial effects, whereby bacterial spot (*Xanthamonas campestris*) was controlled by fish emulsion equal to or better than chemical pesticides (Abassi et al., 2003). Authors speculated that the fish emulsion improved the plants' natural defences against bacterial infection or that it produced a more balanced microflora that inhibited the population of detrimental bacterial or fungi (Abassi et al., 2003). However, these hypotheses were not substantiated.

Seaweed extracts are another alternative group of fertilizers that are being used on numerous crops around the world (El-Tarabily et al., 2003). A major use for seaweed extracts has been in the turf industry (Zhang et al., 2003). Although they do not contain significant amounts of N-P-K (Table 1), seaweed extracts contain compounds such as cytokinins, auxins, and polyamines (Turan and Köse, 2004; Zhang et al., 2003). Little is known about how the seaweed extract enhances plant growth, but it is assumed that the hormones aid in the production of superoxide dismutase, which helps combat the production of oxides under stress conditions (Zhang et al., 2003). Turf grass grown with seaweed extract had a tendency to have greater drought and salinity tolerance (Zhang et al., 2003). Seaweed extracts also slightly increased the photochemical activity of the turf as well as overall turf quality (Zhang et al., 2003). Testing on grapevines and greenhouse vegetables has also shown positive results with seaweed-based fertilizers in terms of improved nutrient uptake and root growth. Foliar-applied seaweed products enhanced the root growth of cucumber plants and effectively increased the total plant dry mass (Nelson and Van Staden, 1984). Although yield did not increase, the plants grown with the weekly foliar application of seaweed extracts were able to withstand more drought and nutrient stress. Use of seaweed products on greenhouse-grown tomatoes also increased root growth, which can result in the increased uptake of nutrients (Vavrina et al., 2004). It was suggested that cytokinins in the seaweed product caused this accelerated root growth. However, testing was not done to verify whether cytokinins alone would have had the same results or what concentrations of cytokinins would be needed to achieve these results. On grapevines, the

TABLE 1. Elemental analysis of three liquid fertilizers and the actual macroelement and microelement amounts added in five fertilizer treatments, 'Baco noir' grapes, Niagara-on-the-Lake, Ont

Elemental composition of liquid fertilizers						
Treatment		% of Dry weight				
		N	P	K	Ca	Mg
Fish fertilizer		2.20	2.70	0.30	0.60	0.03
Monty's Evergreen		8.56	17.00	8.90	0.03	<0.01
Seaweed fertilizer		0.20	0.80	0.30	<0.01	0.09
Treatment		mg/kg dry weight				
		Mn	Zn	Fe	Cu	B
Fish fertilizer		11.84	74.68	228.67	<1.0	4.64
Monty's Evergreen		338.93	635.27	1405.4	<1.0	226.08
Seaweed fertilizer		6.25	1173.78	154.81	<1.0	510.22
Quantities of all fertilizers added in treatments						
Treatment	Amount added	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (kg/ha)	Mg (kg/ha)
Control (34–0–0)	150 kg/ha	51	0	0	0	0
Fish fertilizer	170 L/ha	3.74	4.59	0.51	0.00097	n/a
Monty's Evergreen	3.24 L/ha	0.28	0.55	0.29	1.02	0.051
Seaweed fertilizer	5.22 L/ha	0.01	0.04	0.02	n/a	0.0047
Complete	n/a	4.69	5.99	0.91	1.02	0.056
Treatment	Amount added	Mn (g/ha)	Zn (g/ha)	Fe (g/ha)	Cu (g/ha)	B (g/ha)
Control (34–0–0)	150 kg/ha	0	0	0	0	0
Fish fertilizer	170 L/ha	2.01	12.70	38.87	n/a	0.79
Monty's Evergreen	3.24 L/ha	1.10	2.06	4.55	n/a	0.73
Seaweed fertilizer	5.22 L/ha	0.03	6.13	0.81	n/a	2.66
Complete	n/a	3.14	20.89	44.24	n/a	4.18

use of foliar-applied seaweed extracts increased the uptake of both macroelements and microelements to optimal levels (Turan and Köse, 2004). The use of seaweed extracts in vineyards was recommended on soils with low or adequate nutrient levels; the organic and biodegradable nature of seaweed extracts also makes them a valuable product to sustainable agriculture (Turan and Köse, 2004).

This experiment tested the efficacy of three different foliar-applied organic fertilizers. These fertilizers were a fish emulsion, seaweed extract, and a general-purpose 8–16–8 organic fertilizer ("Monty's Evergreen").

Comparison of foliar organic fertilizers to standard soil-applied fertilizers is important not only to address the problems associated with soil-applied fertilizers but also to verify their efficacy, since an increasing number of local growers have begun using these products in conjunction with their regular fertilization practices. Testing of these products in a commercial vineyard setting was therefore important to validate the usefulness of these and similar materials.

MATERIALS AND METHODS

Experimental Design and Plant Material

A 3 ha block of mature own-rooted Baco noir grapevines was for this experiment. The vineyard was located in Niagara-on-the-Lake, Ont., and the soil series consisted of Jeddo 4 and 6 (humic luvic gleysol) with a mixture of Chinguacousy 14 (gleyed brunisolic grey-brown luvisol) (Kingston and Presant, 1989). These soils are heavy clay loams that are characterized by poor drainage. This vineyard had been tiled every other row to try and compensate for the poor natural drainage. The vine spacing of this vineyard was 2.4 m × 1.2 m (row × vine) and training system was four-arm Kniffin. The pesticide spray program was based on the recommendations of the Ontario Ministry of Agriculture, Food and Rural Affairs (2004).

Treatments

Five treatments were applied in a randomized complete block design replicated three times. Each treatment replicate consisted of four row sections with the two outer rows acting as buffer zones. One of the two center rows in each four-row treatment replicate was designated for data collection, and 10 vines were identified equidistantly along each row for this purpose. The treatments were as follows: control (150 kg N/ha of ammonium nitrate soil-applied one week pre-bloom [4 June 2005]); complete, consisting of fish emulsion (30 L/ha) + seaweed extract (0.87 L/ha) + Monty's Evergreen (0.54 L/ha); fish emulsion only (30 L/ha); Monty's Evergreen only (0.54 L/ha); seaweed only (0.87 L/ha). The soil application was done with a Vicon 1-ton capacity fertilizer spreader. The calibration was done in adjacent vineyards to ensure that the 150 kg/ha of ammonium nitrate could be verified. Spray applications were done biweekly starting one week pre-bloom (4 June) and continuing to after veraison (11 and 25 June; 9 and 23 July; 5 and 20 Aug.) using a 1500L orchard mist air blast sprayer. Calibration was done by spraying a full tank of water and determining the number of rows covered in a specific gear and rpm combination; this was used to perform all spray fertilizer applications.

Plant Tissue and Organic Fertilizer Analysis

Petiole samples were taken from basal leaves adjacent to clusters on 27 Aug. 2005. About 60 petioles were sampled per treatment and were analyzed at Agri-Food Laboratories, Guelph, Ont., for elemental analysis. Petiole samples were dry-ashed at 550°C and extracted with concentrated hydrochloric and nitric acids (Carter, 1993). Samples were then analyzed for total N, P, K, Ca, Mg, Mn, Fe, Cu, Zn, and B using a Perkin-Elmer Optima 3000 inductively coupled plasma emission spectroscopy (ICP). Elemental analysis of the three organic fertilizers was also performed using ICP following extraction (Carter, 1993).

Yield Components

Prior to commercial harvest (6 Sept. 2005), 100-berry samples were collected from each predesignated data vine and were stored at –25°C for later analysis. Yield and cluster number were recorded for each of these vines as well. Berry weights were determined from the 100-berry samples; cluster weight was based on yield per vine and cluster per vine data. Berries per cluster were calculated from cluster weight and berry weight data.

Berry Composition

The berry samples were placed in 250-mL beakers, heated in an 80°C water bath for 1 h, and juiced using an Omega 500 juicer. The juice was then strained to separate the clear juice from the pulp. The juice was tested for soluble solids (Brix) using an Abbé refractometer (AO Corp., Buffalo, N.Y.) with temperature compensation. An Accumet pH meter (Fisher Scientific, Mississauga, Ont.) was used to measure pH, and titratable acidity (TA) was measured using a PC Titrate Automatic titration system (Mann-Tech, Guelph, Ont.). The titration was done using standardized 0.1 N NaOH. The remainder of each sample was then centrifuged for 15 min at 5000 rpm to clarify the juice. Using a tenfold dilution, sample absorbances were read at 420 and 520 nm in 10-mm cuvettes against a blank (3.5 pH buffer) using a Biotech Ultraspec

1000E UV/Vis spectrophotometer (Pharmacia, Peapack, N.J.). Color intensity (A_{520} + A_{420}) and hue (A_{420}/A_{520}) were thereafter calculated (Mazza et al., 1999). Values were multiplied by 10 to convert the data to undiluted equivalents. The total anthocyanins were measured by the pH shift method (Metivier et al., 1980). Two buffer solutions were prepared using the following reagents: pH 4.5 buffer was made using 1.0 M sodium acetate and 1.0 M HCl, while pH 1.0 buffer was made using 0.2 M KCl and 0.2 M HCL. Two 1.0-mL aliquots of each sample were then diluted with either 9.0 mL of pH 1.0 or pH 4.5 buffers and placed in the dark at room temperature for 1 h. Absorbance of these mixtures was then measured at 520 nm against pH 1.0 and 4.5 blanks. Total anthocyanins were calculated as follows:

$$\text{Total anthocyanins (mg/L)} = \text{pH 1 } A_{520} - \text{pH 4.5 } A_{520}) \times 255.75$$

Phenol measurements were done using the Folin-Ciocalteu reagent (Zoecklein et al., 1995). A phenol stock solution (5000 mg/L gallic acid [GA]) was created, from which 0, 50, 100, 150, 250, and 500 mg/L GA calibration standards were prepared. These standards were then diluted tenfold and a 1.0-mL aliquot was then placed in separate 100-mL volumetric flasks along with approximately 60 mL of distilled water; 5.0 mL of Folin-Ciocalteu reagent was then added and mixed, followed by 15.0-mL 20% sodium carbonate. The mixture was then mixed thoroughly and allowed to sit for 2 h in the dark at room temperature before absorbance was measured spectrophotometrically at 765 nm in 10-mm cuvettes. These absorbance values were used to make the calibration curve. The berry extract samples (1.0 mL) were then prepared the same way and the calibration curve was used to convert the absorbance values to phenol concentrations in GA equivalents.

Yeast-assimilable N (YAN) can be categorized as N due to free primary amino acids + N due to ammonia. In order to measure N concentration from free primary amino acids the NOPA assay (Dukes and Butzke, 1998) was used. This method involved the preparation of isoleucine standards at concentrations of 0, 28, 56, 84, 112, and 140 mg N/L. Two sets of test tubes were marked for each of the standards and samples. One set received 3.0 mL of NOPA B (non-reactive blank) and one set received 3.0 mL of reactive NOPA A. To each of these tubes 50 μL of standard (or sample) was added and mixed thoroughly. The reaction was then allowed to stand for 10 min. The samples were then placed in 10-mm UV-grade cuvettes and the absorbance was measured spectrophotometrically at 335 nm. The standards were used to make a standard curve from which the N concentration of the samples could be calculated.

The ammonia concentration of the berries was determined spectrophotometrically following a reaction involving phenol nitroprusside and alkaline hypochlorite. A set of standard solutions were prepared using ammonium sulfate at concentrations of 0, 28, 56, and 112 mg N/L. The reaction mixture (in labeled test tubes) consisted of 5.0 mL of distilled water, 0.5 mL of 20 mM phosphate buffer, and 50 μL of standard (or sample), followed by thorough mixing. Exactly 1.0 mL of phenol nitroprusside was then added followed by 1.0 mL alkaline hypochlorite and thorough mixing. The reaction was allowed to stand for 30 min, after which samples were placed in 10-mm cuvettes and the absorbance read at 570 nm. A blank was also made, consisting of 7.0 mL distilled water, 0.5 mL 20 mM phosphate buffer, and 50 μL sample. The blank was then mixed and the absorbance was read at 570 nm. The blank absorbance was subtracted from the corresponding reaction tube absorbance to give the corrected absorbance value, which was used in conjunction with the standard curve to determine the mg N/L attributed to ammonia.

Statistical Analysis

All data collected were analyzed using SAS statistical software version 9.1 (SAS Institute, Cary, N.C.) by means of the general linear models procedure. Dunnett's *t*-test was used to determine the existence of differences between the control and the other treatments. Duncan's multiple range test was used for mean separation of treatments.

RESULTS AND DISCUSSION

Tissue Analysis

There were no treatment differences for N, P or K (Table 2). The N concentrations (1.39% to 1.57%) were in the range reported by Hilbert et al. (2003), in which moderate N application resulted in petiole N values of 0.91%, whereas high N applications resulted in concentrations of 2.69% N. Visual observations suggested that the leaves of the seaweed treatment were slightly more yellow than the other treatments; this was thought to be a potential N deficiency. However, the petiole N concentrations in all the treatments were well above the deficient concentration of

TABLE 2. Elemental composition of 'Baco noir' grapevine petioles as impacted by various foliar organic fertilizer amendments, Niagara-on-the-Lake, Ont., 2005

Treatment	% of Dry weight					mg/kg dry weight				
	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu	B
Control[z]	1.50	0.35	1.92	2.76a[x]	1.73	70.33b	95.55	60.95ab	17.21	48.95a
Complete foliar	1.57	0.32	2.11	**2.33b**[w]	1.93	141.26a	115.60	83.15a	31.56	45.87b
Fish fertilizer	1.43	0.28	2.04	**2.43b**	1.80	137.30a	98.32	66.45ab	26.37	**45.17bc**
Monty's Evergreen	1.51	0.28	1.97	**2.40b**	1.65	99.88ab	88.55	59.35ab	16.10	**43.18c**
Seaweed fertilizer	1.39	0.24	2.00	**2.32b**	1.75	108.66ab	95.99	52.33b	14.46	**44.70bc**
Significance[y]	ns	ns	ns	**	ns	*	ns	*	ns	**

[z]The control consisted of a ground-applied 34–0–0 granular fertilizer at a rate of 50 kg N/ha.
[y]*, **, ns: Significant at $P \leq 0.05$, 0.01, or not significant, respectively.
[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[w]Boldfaced means are significantly different from the control, Dunnett's *t*-test, $P \leq 0.05$.

0.5% suggested by Conradie (1980). The overall lack of treatment difference in the N concentration is relevant since a soil-applied N fertilizer was used as a control to compare with the foliar-applied organic fertilizers. The apparent lack of response in the foliar treatments in terms of N concentration is contrary to some literature, since many studies have shown that seaweed aids the uptake of elements such as N (Turan and Köse, 2004). However, this result was only found with the addition of supplemental N. It might be argued, therefore, that the foliar fertilizers were able to equal the results of the ammonium nitrate in terms of providing N to the vines. This is significant, since the N added by the foliar materials was substantially lower than that of the soil-applied N. This supports suggestions that despite reduced N content, fish fertilizers can match commercial fertilizers in plant performance (Aung and Flick, 1980; El-Tarabily et al., 2003; Emino, 1981).

Petiole P concentrations (0.24% to 0.35%) did not differ among treatments despite additions in the foliar treatments. The K concentrations (1.92% to 2.11%) were also not different among treatments. This suggests that soil K was sufficient to supply the vines adequately. This was somewhat surprising, since the heavy clay-based soil was expected to bind the much of the K (Reickenberg and Pritts, 1996). The complete treatment had the highest K concentration numerically, suggesting that K from the foliar sprays was absorbed through the plant tissue; however, the difference was not significant.

Petiole Ca concentrations differed between treatments. However, the control treatment had the highest concentrations. The elevated Ca concentrations in the control treatment (2.76%, compared to 2.32% to 2.43% for other treatments) are not readily explainable. No supplemental Ca was added to the control treatment and therefore any Ca uptake would have been from the soil. The fish fertilizer contained very little Ca; however, Monty's Evergreen and the complete foliar treatments added an additional 1.02 kg Ca/ha through the season that was not reflected in the petiole concentrations (Table 1).

Petiole manganese (Mn), iron (Fe), and boron (B) concentrations were different between treatments. The differences in Mn and Fe concentrations between treatments could be explained by the fertilizers added, although < 4 g/ha Mn and < 50 g/ha Fe were added in the foliar treatments. However, since all of the foliar fertilizers contained both of these elements it is likely that the applications had an effect on the petiole analysis (Table 1). The complete treatment was the only one with higher Fe concentration (83 mg/kg, compared to 52 to 66 mg/kg in other treatments), which could be attributed to the Fe in all three fertilizers combined, whereas the individual applications did not provide enough to make a difference. For Mn, the complete treatment also had the highest concentration (141 mg/kg) and the control had the lowest (70 mg/kg). The fish treatment was equal to the complete treatment (137 mg/kg). This might be attributed to the greater amount of total Mn applied in the fish fertilizer and complete treatments (3.1 and 2.0 g/ha, respectively). Seaweed extracts can result in increased microelement uptake by grapevines (Turan and Köse, 2004). This was shown with Mn specifically since the highest uptake of Mn occurred at moderate Mn concentrations with the highest concentration of seaweed extract (Turan and Köse, 2004). The higher B concentrations in the control (49 mg/kg, compared to 43 to 45 mg/kg in other treatments) are difficult to explain. The foliar applications contained small amounts of B (all < 5 g/ha) and it was expected that these treatments might have increased petiole B. Petiole Zn (range 96 to 116 mg/kg) and Cu (range 14 to 32 mg/kg) were not affected by the treatments.

The tissue analysis showed that none of the treatments had nutrient deficiencies, when compared to optimal nutrient concentrations (Ontario Ministry of Agriculture, Food and Rural Affairs, 2004). This suggests that all the vines were relatively healthy and that it is likely that the soil already contained many of the nutrients needed for grape production.

Yield Components

The complete foliar treatment had higher yield than Monty's Evergreen but did not differ from the three other treatments (Table 3). The complete foliar and control treatments had highest cluster weight and berries per cluster, but the complete treatment had lowest berry weight. These data suggest that the organic fertilizers, when used in conjunction, might enhance certain yield components. However, these yield data must be regarded with some caution, since berry moth pressure throughout the season reduced typical yields (ca. 10 t/ha) to levels < 2 t/ha. Vine size was equal among the control and three of four foliar treatments (range 0.44 to 0.55 kg per vine) but was inexplicably lower in the seaweed treatment (0.27 kg per vine; Table 3). Further testing of these foliar products will be necessary to determine their long-term efficacy.

Berry Composition

All of the treatments showed Brix to be relatively high (range 24.3–26.1). The control and the seaweed treatments had the highest Brix, while the

TABLE 3. Yield components of ‘Baco noir’ grapes as impacted by various foliar organic fertilizer amendments, Niagara-on-the-Lake, Ont., 2005

Treatment	Vine size (kg/vine)	Yield (t/ha)	Clusters/vine	Cluster wt. (g)	Berries/cluster	Berry wt. (g)
Control[z]	0.55a[x]	1.51ab	44	17.8ab	19ab	0.93ab
Complete foliar	0.44a	1.74a	48	19.6a	22a	0.89b
Fish fertilizer	0.43a	1.68ab	50	15.9b	17b	0.95a
Monty’s Evergreen	0.50a	1.28b	39	15.6b	17b	0.90ab
Seaweed fertilizer	0.27b	1.48ab	45	16.2b	18b	0.92ab
Significance[y]	*	*	ns	*	**	*

[z]The control consisted of a ground-applied 34–0–0 granular fertilizer at a rate of 50 kg N/ha.

[y]*, **, ns: Significant at $P \leq 0.05$, 0.01, or not significant, respectively.

[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan’s multiple range test.

complete foliar treatment had the lowest Brix (Table 4). The fish fertilizer treatment was also lower than the control and seaweed but it was higher than the complete treatment. These differences in Brix support previous findings in which the fish fertilizers had a tendency to delay the bloom date and fruit maturity of tomatoes (Aung and Flick, 1980). Other treatments were similar in terms of Brix. This suppression of Brix accumulation by fish fertilizer may be of concern in cool climate regions for late-season cultivars such as Cabernet Sauvignon and Merlot.

The complete foliar treatment had both the highest pH and the highest TA, while the control was among the lowest for both variables (Table 4). The high TA (13.9 to 14.9 g/L) and relatively high pH (3.49 to 3.64) are typical of cultivars such as Baco noir and Marechal Foch. The seaweed and control treatments were at the low end of the spectrum, while the fish and the Monty's Evergreen treatments were in the middle. The TA values in this experiment are typical of those observed elsewhere (Beelman and Gallander, 1970). The variation in TA and pH among the treatments is not readily explainable. Excessive K addition can increase pH (Conradie and Saayman, 1989; Delgado et al., 2004; Dundon et al., 1984; Morris et al., 1980). Some have shown TA to decrease, while others have seen it rise as a result of excessive K addition (Conradie and Saayman, 1989; Delgado et al., 2004; Dundon et al., 1984; Morris et al., 1980). However, it is unlikely that K differences among treatments could be implicated, since petiole K did not differ among treatments, and < 1 kg/ha was added in the complete foliar treatment.

There were treatment differences in all color-related variables except hue. Fish fertilizer had lowest A420, A520, and color intensity. Monty's Evergreen and seaweed had highest A420, A520, and color intensity, although these did not differ significantly from the control. The seaweed treatment also had highest anthocyanin and phenol concentrations. The control was lowest in anthocyanins and phenols. Keller et al. (1999) showed that increased N concentrations reduced the anthocyanin and the phenol concentrations in the must in various *Vitis vinifera* cultivars. However, it is unlikely that these differences are attributable to N concentrations. The color-inhibiting effects of high N are not seen until additions are well above 100 kg N/ha; in this study the additions did not exceed 51 kg N/ha for any treatment. Moreover, there was no difference in petiole N concentrations among treatments, and the actual concentrations are lower than those found to adversely affect color and anthocyanins (Conradie and Saayman, 1989; Hilbert et al., 2003).

TABLE 4. Berry composition of 'Baco noir' grapes as impacted by various foliar organic fertilizer amendments, Niagara-on-the-Lake, Ont., 2005

Treatment	°Brix	Titratable acidity (g/L)	pH	A420	A520	Hue	Intensity	Total anthocyanins (mg/L)	Total phenols (mg/L)
Control[z]	26.1a[x]	13.9b	3.52ab	11.56ab	21.63b	0.54	33.18ab	1414.0d	3075.9b
Complete foliar	**24.3c**[w]	14.9a	3.64a	11.21bc	21.02bc	0.54	32.22bc	**1707.5c**	3270.4ab
Fish fertilizer	**25.2b**	14.6ab	3.54ab	**10.73c**	20.08c	0.54	**30.81c**	**1755.1bc**	3237.6ab
Monty's Evergreen	25.6ab	14.1ab	3.56ab	12.00a	23.03a	0.52	35.03a	**1941.6ab**	3195.7b
Seaweed fertilizer	25.9a	14.4ab	3.49b	12.02a	22.92a	0.53	34.94a	**1987.0a**	**3457.7a**
Significance[y]	****	*	*	***	****	ns	****	****	**

[z]The control consisted of a ground-applied 34–0–0 granular fertilizer at a rate of 50 kg N/ha.

[y] *, **, ***, ****, ns: Significant at $P \leq 0.05$, 0.01, 0.001, 0.0001, or not significant, respectively.

[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's Multiple Range Test.

[w]Boldfaced means are significantly different from the control, Dunnett's *t*-test, $P \leq 0.05$.

Berry Nitrogen Composition

Monty's Evergreen and the complete foliar treatments had the highest N (amino acid and total N concentrations). All foliar treatments exceeded the control in total amino N (Table 5). The seaweed and control had lowest total berry N, which may be indicative of the low N values in the seaweed product (Table 1); the fish had moderate total berry N concentrations. The foliar treatments when used together equaled or exceeded the control for most variables. They provided higher must amino acid concentrations, which can improve fermentation rates and wine complexity (Ough and Bell, 1980; Ough and Lee, 1981; Wade et al., 2004). These berry N concentrations also indicate that N was in fact absorbed successfully through the leaves of the grapevines. This supports the experiments showing that plants are capable of efficient absorption of nutrients through their leaves (Reickenberg and Pritts, 1996). That the seaweed extract treatment had similar N concentrations to the control despite negligible amounts of actual N added to the vines would seem to support the findings of Reeve et al. (2005), since even in the small concentrations that the product is sprayed on at it can still have positive effects due to growth regulators in the product. This is also supported by other studies in which the seaweed extract was believed to have aided in the uptake of nutrients (Nelson and Van Staden, 1984; Turan and Köse, 2004; Vavrina et al., 2004; Zhang et al., 2003). From an enological viewpoint, all of the musts had N concentrations well above the minimum of 140 mg N/L required

TABLE 5. Berry N composition of 'Baco noir' grapes as impacted by various foliar organic fertilizer amendments, Niagara-on-the-Lake, Ont., 2005

Treatment	Amino acids (mg/L)	Total amino N (mg/L)	Total N (mg/L)
Control[z]	300.58bc[x]	32.69b	333.26cd
Complete foliar	323.44ab	**42.31a**	365.76ab
Fish fertilizer	313.36bc	**43.43a**	356.78bc
Monty's Evergreen	**345.17a**[w]	**42.69a**	**387.86a**
Seaweed fertilizer	288.61c	**39.15a**	327.75d
Significance[y]	****	****	****

[z]The control consisted of a ground-applied 34-0-0 granular fertilizer at a rate of 50 kg N/ha.
[y]****: Significant at $P \leq 0.0001$.
[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[w]Boldfaced means are significantly different from the control, Dunnett's *t*-test, $P \leq 0.05$.

for safe fermentation (Margalit, 2004). Although numerically there were differences, these would not likely have had any impact on fermentation kinetics.

Cost Analysis

The cost of using the complete foliar fertilizer treatment against a complete soil-applied program was compared in this cursory analysis. The complete soil application would normally include application of triple superphosphate (0–46–0) and muriate of potash (0–0–60) in addition to ammonium nitrate (34-0-0). P and K fertilizers were not used in the experiment in 2005. For the sake of cost analysis, a moderate application rates of 150 kg/ha was used for each of the soil-applied fertilizers. For the foliar-applied fertilizers the rates used in this experiment and recommended by the distributors were used in the cost analysis. Using these rates, the cost of the foliar-applied organic treatment was $485.70/ha for six applications in a season, while the soil-applied fertilizers cost only $255.60/ha. Based on the statistical analysis, the 15% increase in yield found with the complete foliar treatment over the control was not considered significant. However, in a more typical year there might be a difference. It must also be noted that there are manufacturer claims that the fish product also has antifungal properties and as such has value beyond mere nutrient implications. These properties were not assessed in this experiment but should warrant further experimentation.

CONCLUSIONS AND GROWER BENEFITS

The objective of this study was to determine whether the use of foliar-applied organic fertilizers could be as efficacious as traditional practices using soil-applied fertilizers, particularly in terms of vine nutrition and berry composition. Foliar fertilizers were effective in providing equal or better vine nutrition and fruit composition than the control in which fertilizer was soil applied. Individual applications of fish fertilizer, seaweed extract, and Monty's Evergreen alone, in general, did not perform as well as the complete treatment that comprised all three products. Some foliar treatments resulted in higher concentrations of petiole Mn and Fe, but N, P, K, Ca, Mg, Zn, Cu, and B were not increased by foliar treatments. Some foliar treatments substantially increased A420, A520, intensity, anthocyanins, and phenols over the control. This could have potential positive impact on wine quality. The foliar treatments increased total amino N, and Monty's Evergreen increased amino acids, total amino N, and total N. The cost of the foliar program exceeded that of the soil-applied program by $230/ha. This difference could be compensated for by increases in yield or possibly by improvements in fruit quality. Based on the results obtained in this study, foliar-applied organic fertilizers have potential for replacing standard soil-applied fertilizers in Baco noir grapes with respect to nutrient availability and berry composition, but further testing is needed to further validate this.

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