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Development of Standard Concentrations of Foliar Nutrients for Saskatoon

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ABSTRACT

Soil and foliar samples were collected from saskatoon orchards in Saskatchewan, Manitoba, and Alberta, Canada from 1997 to 1999 and analyzed for macro- and micronutrient content. Foliar samples were collected twice a month from the end of May until September in 1997 to examine the pattern of change in foliar nutrient concentrations throughout the season and to determine the most stable time period for foliar sampling. This period was determined to be from the last week in July until mid-August. Nutrient concentrations of foliar samples collected during this period from 1997 to 1999 were summarized according to the mean, median, minimum, and maximum values. Mean foliar nutrient concentrations were as follows: 2.48% nitrogen (N), 0.18% phosphorus (P), 1.15% potassium (K), 0.15% sulfur (S), 1.52% calcium (Ca), 0.50% magnesium (Mg), 6.9 ppm copper (Cu), 106 ppm iron (Fe), 124 ppm manganese (Mn), 16 ppm zinc (Zn), and 27 ppm boron (B). A number of significant positive correlations were found between soil and foliar levels of a nutrient, with the majority of these correlations occurring for the nutrients Cu, P, and Mn. Another study conducted during 2001–2002 examined differences in the foliar nutrient concentrations of the saskatoon cultivars 'Smoky' and 'Thiessen' sampled from nine orchards in Saskatchewan. Foliar concentrations of N, K, S, Ca, Mg, Cu, Mn, Zn, and B were significantly higher in 'Smoky' than in 'Thiessen,' whereas foliar K content was higher in 'Thiessen' than in 'Smoky'.

Keywords: saskatoon, serviceberry, *Amelanchier alnifolia*, foliar analysis, leaf analysis, foliar nutrient concentration

INTRODUCTION

The saskatoon (*Amelanchier alnifolia* Nutt.) is a new horticultural crop. It is a member of the Rosaceae family and a close relative of the apple and pear. Its

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berry-like fruit have widespread popularity on the Canadian prairies. A small tree or shrub native to this region, it is now increasingly grown in orchards. However, very little is known about the nutrient requirements of saskatoons.

Proper fruit-tree nutrition is required to maximize fruit yield, improve fruit quality, and maximize production efficiency (Singha et al., 1982). Inadequate knowledge of the tree's nutrient status can frequently result in excessive fertilizer applications and nutrient imbalances as well as undetected deficiencies or excesses within the tree. Foliar analysis is widely used to determine the nutrition of perennial fruit crops. It is considered to be a better indicator of the nutrient status of fruit trees than soil analysis (Cline, 1990; Singha et al., 1982). Soil samples that are representative of the entire rooting zone of the tree are difficult to obtain. As well, tree performance has often been poorly correlated with soil test values (Cline, 1990). However, reference standards of foliar nutrient concentrations are required in order to interpret foliar analysis results. No such standards exist for saskatoons.

The survey method is commonly used to establish nutrient standards for fruit trees. It is considered to be a quicker and more economical method for establishing foliar nutrient ranges of fruit trees than field trials (Webster, 1991). This method should ideally involve sampling a large number of orchards in a particular area for at least three years (Stringari et al., 1997).

The objective of this study was to determine the ideal time for foliar sampling and to develop foliar nutrient standards for saskatoons.

MATERIALS AND METHODS

Soil and foliar tissue samples were analyzed for nutrient content from a number of saskatoon orchards on the prairies. Three growers from the Fruit Grower's Society of Alberta, five growers from the Saskatchewan Fruit Grower's Association, and six growers from Manitoba and the University of Saskatchewan supplied soil and foliar tissue samples for this project.

Standard foliar sampling protocol used for apple (*Malus domestica*) orchards was followed (Anonymous, 1994). In 1997, five plants were selected using an *X*-shaped sampling pattern from one or more orchard blocks. From these selected plants, leaves were sampled from the mid-portion of the current season's shoot growth from 10 shoots per plant. Foliar tissue was collected up to twice per month throughout the summer. Growers collected and determined the number of samples that were submitted, as they were covering the cost of the foliar analysis. Samples from growers' orchards included a variety of cultivars and both seedling and clonal material. Foliar samples were collected twice a month from three vegetatively propagated cultivars ('Honeywood,' 'Pembina,' and 'Smoky') within the University of Saskatchewan orchard in Saskatoon and from another cultivar ('Thiessen' seedling) at a grower-managed orchard at Moonlake, 15 km southwest of the city of Saskatoon. Soil was sampled from

under the selected trees at two depths (0–23 cm and 23–46 cm) in the spring and in the fall. Both soil and foliar samples were sent to Enviro-Test Laboratories (Saskatoon, SK) for analysis of macro- and micronutrients on a dry-weight basis. At Enviro-Test, soil samples were dried in a forced-air oven at 30°C–38°C and then ground to <2 mm particles using a flail grinder. Soil was then analyzed according to the following methods: NO_3-N by $CaCl_2$ extraction (Maynard and Kalra, 1993); phosphorus (P) and potassium (K) by a modified Kelowna extraction (Qian et al., 1994); SO_4-S by $CaCl_2$ extraction (Combs et al., 1998); copper (Cu), iron (Fe), zinc (Zn), and manganese (Mn) by DTPA extraction (Liang and Karamanos, 1993); and boron (B) by hot-water extraction (Keren, 1996). Foliar samples were dried at 60°C in a forced-air oven and then ground to <0.5 mm particles using a high-speed cyclone mill. Tissue analyses were conducted at Enviro-Test using the following methodology: total nitrogen (N) by combustion according to AOAC Method 990.03 (AOAC, 1995), and all other nutrients by nitric acid and hydrogen peroxide digestion (Huang and Schulte, 1985).

Frequent foliar sampling was necessary during the first season to determine when foliar nutrient levels were most stable for a standard sampling protocol. This period was determined to be from the end of July until the middle of August. Thus, in 1998 and 1999, growers were requested to submit only one foliar and soil sample during this time. Foliar samples continued to be collected at the University sites twice per month. In 1998 and 1999, foliar and soil samples were also collected by the University from an orchard in Prince Albert, SK (cv. 'Smoky,' clonal). The soil was sampled at each site after the completion of harvest. Due to heavy disease levels of *Entomosporium* leaf and berry spot in 1999, foliar samples were not collected in September of that year.

Foliar nutrient concentrations of all foliar samples submitted by the growers from their orchards and those collected by the University in 1997 were summarized according to five time periods. Data collected by the University were graphed over the season for each year separately.

Data from all foliar samples submitted during the last week of July until mid-August from 1997–1999 were combined. The results from the Prince Albert site were not included in the 1998 means, as these plants were foliar fertigated on a regular basis and had abnormally high foliar nutrient levels. These plants were not fertigated in the following year, and the data from this site were included in the results for 1999. Outliers within this group of data were determined according to stem and leaf plots and discarded, after which extreme high and low values were removed. The remaining data were summarized according to the mean, median, minimum, and maximum values.

A separate study comparing two cultivars was conducted during 2001–2002. This research examined the differences in the foliar nutrient levels of the cultivars 'Smoky' and 'Thiessen.' Nine orchards in Saskatchewan that contained both 'Smoky' and 'Thiessen' clones were selected. Foliar and soil (0–30 cm depth) samples were collected from these cultivars by the University of Saskatchewan, in the manner previously described, between July 21 to

August 15 in 2001 and 2002, then sent to Enviro-Test Laboratories for macro- and micronutrient analysis. Nutrient levels between the cultivars were compared using paired t-tests. Data were summarized according to the mean, median, minimum, and maximum values.

The relationship between foliar and soil nutrient levels was examined using Pearson correlation analysis. A logarithmic transformation of the data was conducted when necessary prior to analysis to create linearity. All statistics were calculated using SYSTAT version 8.0 (SPSS, Chicago, IL).

RESULTS AND DISCUSSION

The foliar nutrient concentrations of foliar samples collected in 1997 from grower orchards and the University of Saskatchewan were summarized according to time period (data not shown). However, not all sites or the same sites were represented in each period and some of the differences in the nutrient concentrations over the season in this data were also associated with the variability among the sites and different cultivars represented. A more accurate representation of the change in foliar nutrient concentration throughout the season is presented in Figures 1 and 2. These graphs show the change in the macro- (Figure 1) and micronutrient (Figure 2) concentrations of the foliar samples collected by the University twice per month from May to September of 1997 to 1999. Foliar nutrient concentrations of N, P, K, and sulfur (S) all decreased throughout the season and that of calcium (Ca) and magnesium (Mg) increased. The largest change in N and P occurred early in the growing season. The foliar micronutrient concentrations were in general more variable than those of the macronutrients. Levels of Cu and B were higher very early in the season but were relatively constant thereafter, with some fluctuations. Iron levels showed large variations but no specific trends. Foliar Mn concentrations increased over the season, while those of Zn showed a slight decrease, with some fluctuations. Similar seasonal trends in foliar nutrient concentrations have been observed in the past in both pear (*Pyrus pyrifolica* cv. Patharnakh and *P. communis* cv. LeConte) (Kamboj et al., 1995) and apple (*Malus domestica*) (Diamond et al., 1998; Graley, 1982; Tagliavini et al., 1992).

Standards for foliar analysis of perennial fruit trees are usually developed during the period of time of minimal nutrient fluctuation within the growing season, which usually occurs after the cessation of shoot growth (Diamond et al., 1998). For saskatoons, it was determined that the period in which the majority of the foliar nutrients showed the least change throughout the season was from the last week in July until mid-August. This period was chosen as most suitable for developing foliar nutrient standards for saskatoons. Stringari et al. (1997) defined foliar analysis standards as the range in which 80% of the plantings without nutritional disorders falls. Before any statistical data processing, Stringari et al. (1997) discarded any abnormally high nutrient values, which

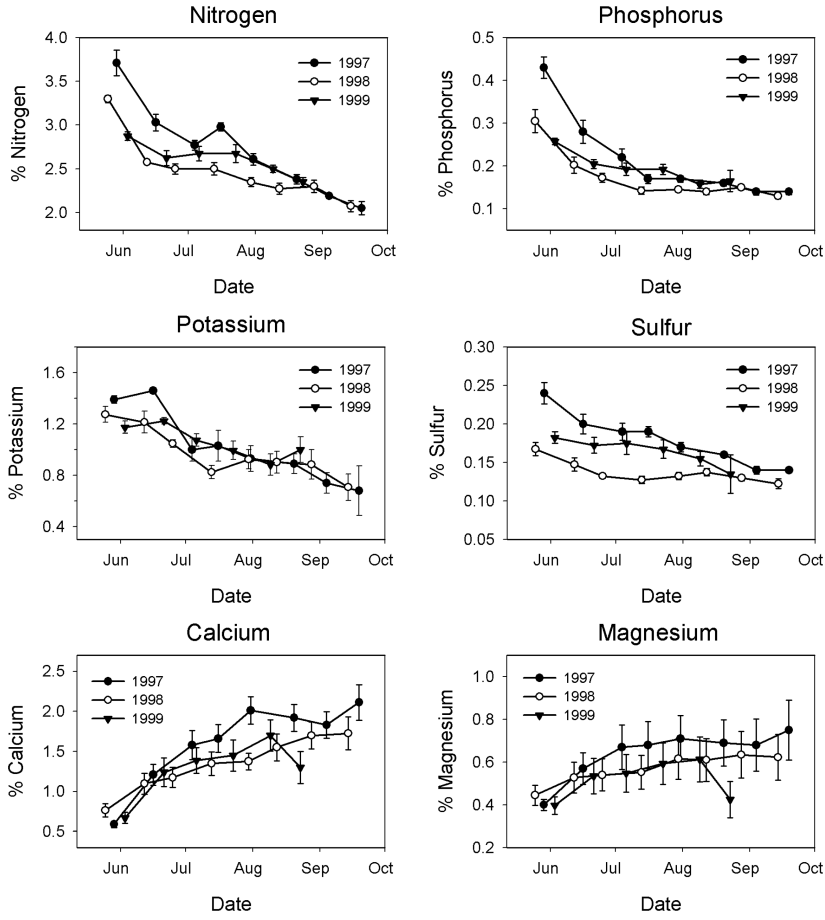

Figure 1. Macronutrient content (dry-weight basis) of saskatoon (*Amelanchier alnifolia*) leaves sampled by the University of Saskatchewan throughout the growing seasons of 1997–1999. Means are derived from four samples one each from the cultivars 'Honeywood,' 'Smoky,' 'Pembina' (sampled from the University research orchard) and 'Thiessen' (sampled from Moonlake). Means from the last sampling date in 1999 are from only the cultivars 'Pembina' and 'Honeywood.'

were attributed to contamination. In this study, values outlying the normal distribution as determined by stem and leaf plots were removed. Only abnormally high values were removed in this process. The three lowest and three highest values (approximately 18%–20%) were then removed from the normal distribution to obtain a normal range of foliar nutrient concentrations. The resulting data are summarized in Table 1.

Mean foliar nutrient values of N, P, K, Ca, Mg, Cu, Fe, Mn, and B obtained within the selected time period for saskatoons in this study generally fell within

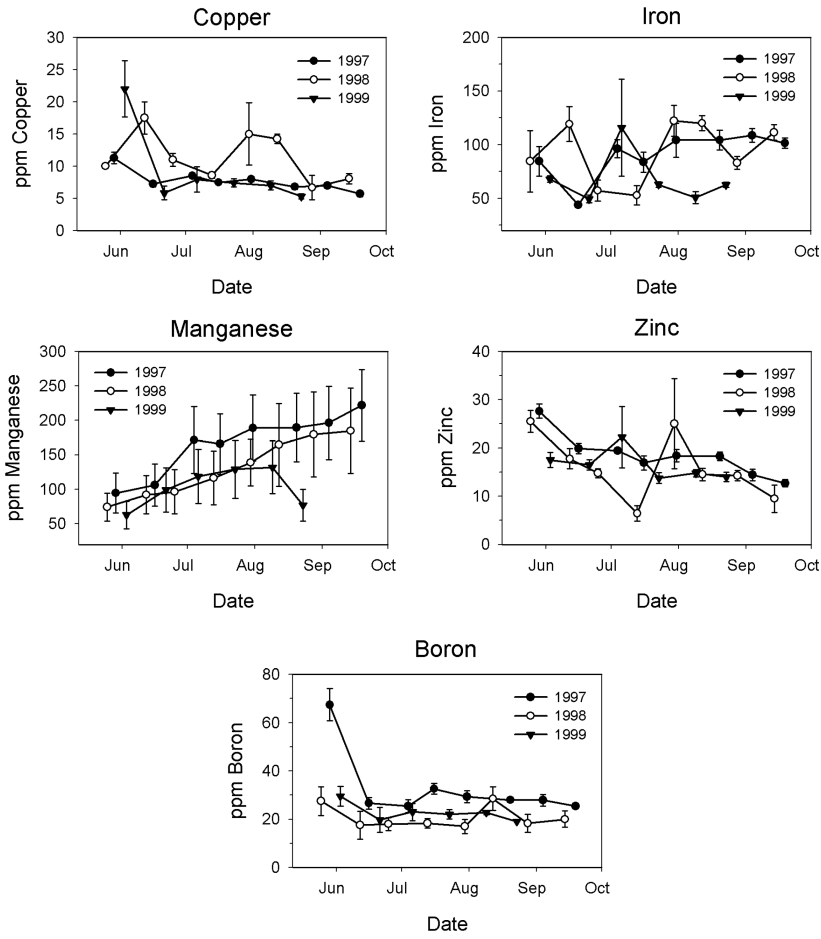

Figure 2. Micronutrient content (dry-weight basis) of saskatoon (*Amelanchier alnifolia*) leaves sampled by the University of Saskatchewan throughout the growing seasons of 1997–99. Means are derived from four samples, one each from the cultivars 'Honeywood,' 'Smoky,' 'Pembina' (sampled from the University research orchard) and 'Thiessen' (sampled from Moonlake). Means from the last sampling date in 1999 are only from the cultivars 'Pembina' and 'Honeywood.'

the normal range for that of apple and pear, but values for S and Zn were lower than what is reported as normal for these fruits (Table 1) (Shear and Faust, 1980; Jones et al., 1991). Within the nutrient ranges found for saskatoon, the minimum values of K, S, Cu, Zn, B, and sometimes Fe fell into the low-to-deficient categories for apple and pear, whereas the maximum values of Mg, Mn, and sometimes N for saskatoon were higher than what is considered normal for apple and pear (Shear and Faust, 1980; Jones et al., 1991). Many of the differences in foliar nutrient concentrations between saskatoon in this

Table 1
Foliar nutrient concentrations of saskatoon sampled between July 21 and August 15 of 1997 to 1999 from orchards in Alberta, Manitoba, and Saskatchewan

	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
Mean	2.48	0.18	1.15	0.15	1.52	0.50	6.9	106	124	16	27
Median	2.45	0.18	1.20	0.15	1.50	0.48	6.3	101	120	16	28
Min	2.16	0.14	0.84	0.13	1.10	0.35	4.9	57	65	11	19
Max	2.80	0.25	1.50	0.18	2.02	0.79	11	164	230	26	38
S.E.[Z]	0.035	0.005	0.035	0.003	0.045	0.025	0.293	5.66	8.01	0.735	0.980

[Z]Standard error of the mean.
Outliers and extreme values were removed. Data are based on 27 to 30 samples.

study and those reported for apple or pear can be attributed largely to genetic differences. However, other factors may also have been involved. Low values of K were often associated with a heavy fruit load, which competes with the leaves for K (Erf and Proctor, 1989). All sites sampled had high soil K levels. Low values of foliar Cu, Zn, and B were sometimes but not always associated with low soil levels of these nutrients. In addition, some sites that had low soil values had normal foliar concentrations of these nutrients. In spite of low foliar levels of Cu, Zn, and B, no typical symptoms of deficiency of these micronutrients were observed. Low Cu and Zn levels in some years may have been associated with water stress on lighter-textured soils. Chandel and Chauhan (1990) reported a reduced uptake of Zn and Cu by apple trees that were water stressed. Even though no visual deficiency of these nutrients was apparent, levels still may have been deficient. Previous studies have shown that changes in fertilization practices can improve tree performance when foliar nutrients are below the deficiency level even though no visual symptoms of deficiency exist (Singha et al., 1982). Even the higher levels of foliar S concentrations in saskatoons were often low relative to apple and pear in spite of adequate soil levels of S. The lower foliar levels of Fe generally occurred in 1999, which had higher-than-average precipitation. Iron chlorosis on lower leaves of saskatoon is common during wet years in heavy soils or soils with poor drainage. Saskatoons may be more adapted to lower Fe levels in their leaves than apples and pears because the natural habitat of saskatoons is often on high pH soils where Fe is less available. The maximum value of foliar Mg levels found in saskatoons was consistently higher than the normal maximums for apple and pear. A number of sites sampled had very high (>1000 ppm) levels of Mn in their leaves (data not shown). It is not known if these excessive levels of Mn were due to contamination. Levels of Mn greater than 300 ppm in foliar tissue are considered to be toxic for apple (Hanson, 1993; Ebel et al., 2000); however, no signs of Mn toxicity were observed in saskatoons. The range of foliar N in Table 1 is higher than what

is considered normal for apples and pears. These N levels are probably on the high side as these values were obtained from two "on" (higher yielding) years and one "off" (lower yielding) year, and foliar N is generally higher in the "on" years (Sadowski et al., 1995). The saskatoon tends to exhibit some degree of alternate bearing, with certain cultivars (i.e., 'Smoky') expressing this trait more than others (unpublished data).

Results of the two-cultivar study are shown in Table 2. Significant differences in foliar nutrient content between the cultivars 'Smoky' and 'Thiessen' were found for nine of the 11 nutrients. Foliar N, K, S, Ca, Mg, Cu, Mn, Zn, and B levels all were higher in 'Smoky' than in 'Thiessen,' whereas foliar K concentration was lower in 'Smoky' than in 'Thiessen.' 'Smoky' is a higher-yielding cultivar than 'Thiessen.' The heavier fruit load of 'Smoky' may have accounted for its lower foliar concentrations of K, which is translocated from the leaves to the fruit. Foliar P and Fe levels were not significantly different between the two cultivars; however, a larger sample size may have revealed significance. The largest percentage differences between the two cultivars occurred for foliar K, Ca, Mg, Cu, Mn, and Zn. Differences in optimal foliar nutrient concentrations are common among cultivars (Jentsch and Eaton, 1982/83; Sadowski et al., 1995; Singha et al., 1982; Tagliavini et al., 1992). Foliar nutrient values obtained from this two-cultivar study were comparable to those in Table 1.

A number of significant correlations were found between the soil and foliar concentrations of a nutrient for the saskatoons sampled in 1997 throughout the season (Table 3) and from 1997–1999 during the last week in July until mid-August (Table 4). The majority of the correlations occurred for the nutrients Cu, P, and Mn. In addition, significant correlations between the soil and foliar nutrient concentrations of the two-cultivar study were found only for P ($r = 0.50$, $P = 0.015$) and Cu ($r = 0.64$, $P = <0.001$). Typically, few or weak correlations have been found between the foliar and soil levels of a nutrient in woody perennial fruit crops (Frink, 1965; Hanson, 1987; Singha et al., 1982). Some correlations, often weak but significant, have been found previously for soil and foliar nutrients. Ruiz and Navia (1980) found a relationship in apple between soil and foliar levels of Zn but not Mn and Fe. Foliar micronutrients were directly correlated with those in the soil in apple (*Malus spp.*) and stone fruits (*Prunus spp.*) in Czechoslovakia (Hudska, 1990). Weak but significant correlations were found between foliar and soil P, K, Ca, and Mg in blueberry (*Vaccinium corymbosum*) (Hanson, 1987). Of the macronutrients, only foliar N and Mg of apple were weakly but significantly correlated with that in the soil (Frink, 1965). Morgan and Hennerty (1976) attributed the poor relationship between soil and foliar nutrients in apple trees to a number of factors: (a) nutrient reserves within the tree may be unaccounted for; (b) soil samples usually do not reflect the entire depth of the root system from which nutrients are obtained; (c) conventional soil tests do not measure the buffering capacity of the soil solution against changes in the labile nutrient fraction; and (d) many other factors also influence the uptake and translocation of nutrients

Table 2
Foliar nutrient concentrations of the saskatoon cultivars 'Smoky' and 'Thiessen' sampled from nine orchards in Saskatchewan between July 21 and Aug. 15 in 2001 and 2002

	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
'Smoky'											
Mean	2.55	0.20	1.04	0.16	1.65	0.59	6.3	127	160	18.4	26.3
Min	2.30	0.13	0.66	0.14	1.11	0.33	3.9	70	49	8.9	18.0
Max	3.06	0.30	1.44	0.20	2.11	0.83	12.9	200	490	38.0	39.8
'Thiessen'											
Mean	2.34	0.19	1.35	0.15	1.27	0.44	5.2	142	123	14.7	24.1
Min	2.00	0.12	1.02	0.13	0.59	0.29	3.0	67	49	6.9	19.0
Max	2.64	0.40	2.05	0.18	1.74	0.60	7.0	275	219	30.0	30.0
Difference											
Mean	0.210	0.017	−0.318	0.013	0.371	0.144	1.04	−14.2	36.5	3.71	2.15
S.D.[Z]	0.109	0.036	0.144	0.011	0.137	0.072	1.81	33.9	74.0	2.78	3.77
Probability	<0.001	0.066	<0.001	<0.001	<0.001	<0.001	0.026	0.093	0.044	<0.001	0.027

[Z] Standard deviation of the difference.
The difference is obtained from paired t-tests performed between the cultivars for each site.

Table 3
Correlations between nutrient concentrations of soil and foliar samples of saskatoons collected in 1997 at different time periods throughout the growing season from orchards in Alberta, Manitoba, and Saskatchewan

Period	Foliar nutrient	Soil (0–23 cm) nutrient	Soil (23–46 cm) nutrient	Soil (0–46 cm) nutrient	Correlation coefficient (r)	Probability	Number of samples
1	N		N		0.508	0.026	19
	Cu	Log Cu			0.646	0.003	19
	Cu		Log Cu		0.641	0.003	19
	Cu			Log Cu	0.646	0.003	19
	Log Mn	Log Mn			0.732	<0.001	19
	Log Mn		Log Mn		0.471	0.042	19
	Log Mn			Mn	0.718	0.001	19
	B	B			0.580	0.009	19
	B			B	0.650	0.005	17
2	Log K	Log K			0.722	0.008	12
	Log K			Log K	0.642	0.033	11
	Cu	Log Cu			0.700	0.011	12
	Cu		Log Cu		0.733	0.010	11
	Cu			Log Cu	0.717	0.013	11
	Mn	Mn			0.809	0.001	12
	B		B		0.715	0.013	11
	B			B	0.706	0.015	11
3	Log N	Log N			0.461	0.041	20
	Log N		Log N		0.503	0.033	18
	Log P	Log P			0.593	0.006	20
	Log P			Log P	0.593	0.010	18
	S	S			0.462	0.040	20
	Cu	Log Cu			0.727	<0.001	19
	Cu		Log Cu		0.735	0.001	18
	Cu			Log Cu	0.730	0.001	18
	Log Mn	Mn			0.779	<0.001	19
	Log Mn		Log Mn		0.476	0.046	18
	Log Mn			Mn	0.704	0.001	18
4	Log P	Log P			0.710	0.048	8
	Log P		Log P		0.792	0.034	7
	Log P			P	0.781	0.038	7
	K		K		0.778	0.040	7
	Mn	Mn			0.849	0.008	8
5	P	Log P			0.992	0.001	5
	P		P		0.979	0.004	5
	Log P			Log P	0.991	0.001	5
	Zn	Log Zn			0.992	0.001	5
	Zn		Log Zn		0.986	0.002	5
	Zn			Log Zn	0.996	<0.001	5

Period 1 = end of May to mid-June; period 2 = mid-June to end of June; period 3 = July; period 4 = August; period 5 = beginning of Sept. to mid-Sept. A log transformation ensured linearity prior to correlation analyses when necessary.

Table 4
Correlations between soil and foliar nutrient concentrations of saskatoons sampled between July 21 and Aug. 15 in 1997–1999 from orchards in Alberta, Manitoba, and Saskatchewan

Foliar nutrient	Soil (0–23 cm) nutrient	Soil (23–46 cm) nutrient	Soil (0–46 cm) nutrient	Correlation coefficient (r)	Probability	Number of samples
N	Log N			0.570	0.001	32
Log N		Log N		0.395	0.031	30
Log N			Log N	0.458	0.011	30
Log P	Log P			0.658	<0.001	32
Log P		Log P		0.530	0.003	30
Log P			Log P	0.633	<0.001	30
S	S			0.412	0.019	32
Log Mn	Log Mn			0.490	0.004	32
Log Mn			Log Mn	0.366	0.047	30

by trees, including soil temperature, pH, and tree growth rate. Soil management, groundcover, soil type, precipitation, growing system, fruit load, and cultivar all can affect foliar nutrient concentrations (Cline, 1990; Hudska, 1990; Jentsch and Eaton, 1982/83) and weaken the relationship between foliar and soil nutrient levels. The uptake of many nutrients such as K (Cline, 1990), Fe, Mn, Zn, and Cu (Chandel and Chauhan, 1990) is affected by soil moisture levels. In light of the many factors that influence a tree's nutrient status, it is not surprising that Singha et al. (1982) found that variations in foliar nutrient concentrations were more closely related to differences in orchard management practices than to differences between soils.

CONCLUSIONS

This study has determined typical foliar nutrient ranges for saskatoons and the most suitable time period for foliar sampling within the growing season. This information was not previously available, and will provide saskatoon growers with a means to interpret the nutrient status of their orchards. However, the results of this study are preliminary. More extensive sampling needs to be done to improve the accuracy of the data and to refine the foliar nutrient values into normal, low, and high ranges. Differences in foliar nutrient concentrations among cultivars should also be studied more extensively in the future. Nevertheless, these data provide a basis of reference standards for foliar analysis of saskatoons upon which future research can expand. This information is essential for developing and monitoring fertilization practices for saskatoons.

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