Effect of Potassium Fertilization and N-K Interaction on Sugarbeet Quality and Yield

M. Giroux and T. S. Tran
Service de recherche en sols, Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Quebec, 2700 Einstein, Sainte-Foy, Québec, Canada G1P 3W8

ABSTRACT

The objective of this study was to measure the effect of K fertilization and N x K interaction on sugarbeet quality and yield, and to establish the nutritional K balance sheet for sugarbeet cultivated in rich soils. Four rates of N (0, 60, 120 and 180 kg/ha) were factorially applied with four rates of K (0, 80, 160 and 240 kg/ha) in six experimental fields. The K fertilization produced a small root yield increase. When both N and K were applied at high rates, root yield was increased by 3.7 t/ha, but juice purity and sugar extractability decreased. The maximum sugar yield was achieved with 60 kg N/ha and 0 kg K/ha. The apparent utilization coefficient of K fertilizer varied from 40 to 52% among fields. The potassium derived from fertilizer varied from 4.6 to 23.3% according to fertilizer rates and exchangeable K level of soil. The soil K prevailed on fertilizer K for sugarbeet nutrition in rich soils. The top K uptake (leaves + petioles + crowns) returning to the soil compensated for the impoverishment of soil K or for root-K uptake. Petiole analyses indicated that N and K fertilization must be equilibrated to achieve an optimum NO_3-N content in the petiole. The N fertilization should be applied proportionally with K rates. As it is advisable to stop K fertilization in these rich soils, the N rate should be 60 kg N/ha.

Additional Key Words: Plant nutrition, extractable sugar, petiole nitrate

Appropriate N and K fertilization is essential for high root yield of sugarbeets. However, an excess of these nutrients decreases the juice purity and sugar extractability. There is, in fact, a close relationship between N and K fertilization and α-amino-N, K and Na contents in the sugarbeet (Draycott and Cooke, 1966; Tinker, 1965). These compounds are not removed during the juice purification, and consequently increase the molasses-sugar proportion during evaporation.

Sugarbeet roots harvested in Québec often have a K content as high as 9.0 meq K/100 g (0.35%) (RSQ, 1984a). These values exceed the normal concentration, which is about 6.5 meq K/100 g (0.25%) on a fresh basis or 19.7 meq/100 g (0.77%) on a dry basis (Draycott, 1972; Lefebvre, 1984). This may be explained by many factors. Sugarbeets often are cultivated in soil containing more than 500 kg/ha of exchangeable K in the 0-20 cm layer, and on many soil series the subsoils contain a high pool of exchangeable K. The fertilization applied by farmers on these soils may be as high as 200 kg K_2O/ha, exceeding the recommended maintenance rate of 25-80 kg K_2O/ha (RSQ, 1984b). Loué (1983) reported that a positive N and K interaction on root yield was obtained with high N and K fertilization, but the juice purity and sugar extractability were decreased. Lemaire (1983) and Hébert (1981) suggested that K fertilization should be adjusted to cover the uptake of this element by the plant and to maintain a suitable soil fertility level. Since K uptake by sugarbeets is high, K fertilization based on this concept could adversely affect root quality. But if K fertilization is reduced, an impoverishment of exchangeable soil K may occur. Judicious recommendations of N and K fertilizers are needed to obtain concurrently optimum yield, high quality of roots, and maintenance of exchangeable soil K. This study aimed to evaluate the effect of K fertilization on sugarbeet quality and yield, to measure the N x K interaction, and to establish the nutritional K balance sheet for sugarbeets.

MATERIAL AND METHODS

Sugarbeets (*Beta vulgaris* L. 'Betaseed 1237') were grown on six experimental fields within two years in the Montreal plain region. The soils were St-Urbain clay (2 sites), St-Laurent clay loam (2 sites), Providence silty loam, and Aston loamy sand. The chemical and physical properties of these soils are described in Table 1. At each site, the experimental design was a randomized block with 16 treatments and four replications. Four nitrogen (NH_4NO_3) rates (0, 60, 120, and 180 kg/ha) were combined with four potassium (KCl) rates (0, 80, 160, and 240 kg/ha). Basal dressings of phosphorus (triple superphosphate) and boron (borax) were applied to all plots at rates of 100 and 2 kg/ha, respectively. All the fertilizers were broadcast and incorporated into the soil before seeding. Each plot was four 8-m long rows with a row spacing of 56 cm. Only the sugarbeets grown on the two middle rows were harvested mechanically and used for yield determination and juice analysis. Plant population varied from 60,000 to 80,000 plants per hectare among different fields.

Table 1. Decription of soils used.

Soil series	Taxonomy	Texture	Exc.K 0-20 cm	Exc.K 0-60 cm	Exc.Ca 0-20 cm	Exc.Mg 0-20 cm	O.M.	pH	NO_3-N 0-60 cm
			kg/ha	kg/ha	kg/ha	kg/ha	%		kg/ha
St-Urbain-1	humaquept	clay	570	1490	7560	1025	2.7	6.03	33
St-Laurent-1	haplaquept	clay loam	157	437	4740	870	2.9	6.01	26
Providence	haplaquept	silty loam	395	1204	6160	1280	2.9	6.05	22
Aston	humaquept	loamy sand	335	875	4140	340	3.0	7.30	65
St-Urbain-2	humaquept	clay	560	1620	8880	740	3.8	7.50	82
St-Laurent-2	haplaquept	clay loam	190	415	4592	700	1.9	7.00	75

Soil samples were taken in each 20 cm layer to a 60 cm depth, before seeding and at harvest. Soil pH was measured in a soil-water mixture (1:10 w/v). Organic matter content was determined by the Walkley and Black method (Allison *et al.*, 1965). Exchangeable bases (K, Ca, and Mg) were extracted by ammonium acetate (Chapman, 1965). Nitrate-N (NO_3-N) was extracted with 2M KCl (Bremner, 1965) and determined colorimetrically.

Eight weeks after seeding and at harvest, 30 petioles of recently matured leaves were sampled in each plot, dried, ground, and analysed for NO_3-N, total N, K, and Na contents. The NO_3-N content extracted with water was determined by colorimetry after reduction on a cadmium column (Jackson, 1980). Tops (leaves, petioles and crowns) and roots from the final harvest were analyzed for K. Sugar percentage was measured by the polarimeter method. The α-amino-N, K and Na contents were estimated on lead acetate extracts of beet samples. Extractable sugar content was estimated by the American Crystal equation (Devillers, 1983):

% molasses sugar = 0.157 K + 0.130 Na + 0.215 α-amino-N (meq/100 g). Each term of this equation represents the sugar loss due to K, Na, and α-amino-N. The effect of the N x K interaction on root and sugar yield, on extractable sugar, K, Na, α-amino-N percentages and alkalinity index were estimated by Fisher's F test (Cochran and Cox, 1957). The least significant difference at a 5% probability level and variation coefficient also were calculated.

The K balance sheet was established in three experimental fields by the Lindemann *et al.* (1983) procedure used for nitrogen. This procedure takes into account the exchangeable K contents in the 0-60 cm soil layer in spring and the added fertilizer K as input; the exchangeable soil K in fall, the unused fertilizer K, and the plant uptake are regarded as output. The apparent utilization coefficient (AUC) of K-fertilizer is obtained by measuring the difference between the K-uptake of fertilized plots (K_f up.) and unfertilized (K_{unf} up.) and dividing by the K fertilizer rate (K_r):

$$AUC = \frac{(K_f\ up. - K_{unf}\ up.)}{K_r} \times 100$$

The apparent proportion of the absorbed K which is derived from the fertilizer (Kdff) is measured by the following equation:

$$Kdff = \frac{(K_f\ up. - K_{unf}\ up.)}{K_f\ up} \times 100$$

The relative root yield was obtained by the ratio of the root yield collected from control plots over the mean root yield obtained from K-fertilized plots.

Table 2. Effect of N and K fertilization on root yield in six experimental fields.

Treatments		Soil Series						
N	K	Providence	St-Urbain-1	St-Laurent	Aston	St-Urbain-2	St-Laurent-2	Mean
kg/ha		Root yield (t/ha)						
0	0	32.7	43.9	37.9	62.6	44.3	49.3	45.1
0	80	32.3	39.5	41.6	63.1	46.8	48.1	45.2
0	160	41.1	51.8	39.2	67.3	51.8	48.8	50.0
0	240	38.4	41.2	42.3	65.1	54.6	53.3	49.2
60	0	40.8	53.5	45.2	65.2	55.9	51.3	52.0
60	80	29.7	46.6	37.5	68.4	58.0	51.2	48.6
60	160	27.9	58.0	43.9	72.4	52.7	51.4	51.1
60	240	39.5	53.9	48.6	73.6	60.9	49.9	54.4
120	0	38.0	53.5	44.4	71.3	52.5	52.7	52.1
120	80	36.8	57.5	42.9	77.2	55.2	51.6	53.5
120	160	34.6	43.7	48.7	73.5	58.8	51.1	51.7
120	240	38.9	54.8	47.9	74.6	55.6	53.3	54.2
180	0	46.3	56.4	45.4	69.1	55.0	50.8	53.8
180	80	41.2	48.9	44.1	72.6	53.1	50.4	51.7
180	160	43.7	60.7	47.0	68.9	54.8	50.1	54.2
180	240	48.3	56.4	56.2	75.8	50.7	55.6	57.2
F for N		3.54*	5.46**	2.80*	3.96*	3.77*	NS	14.4**
F for K		NS	NS	NS	NS	NS	NS	4.71**
F for N x K		NS	NS	NS	NS	NS	NS	NS
LSD (5%)		12.2	12.2	11.6	11.7	9.7	8.5	4.87**
CV (%)		22.3	13.9	18.3	11.7	12.6	11.6	7.4

*, ** significant at 5% and 1% level of probability, respectively.
NS = not significant

RESULTS AND DISCUSSION

The variance analysis did not show a significant effect of K fertilization on yield in any field (Table 2). The relative root yields obtained from plots that did not receive K fertilizer were quite high and varied from 93 to 100%. This small increase (less than 7 percent) due to K fertilization can be explained by the high exchangeable K content (415 to 1620 kg/ha) in the 0-60 cm soil layer (Table 1). Grouping all experimental fields, the combined effect of high N and K fertilization tended to produce a higher root yield (Table 2). This tends to confirm Loué's results (1983), which measured a positive N x K interaction from 2.75 to 3.72 t/ha on root yield in several field experiments. It may be possible to increase slightly the root yield by using high N and K fertilization, but the effect on root quality must be considered.

The N fertilization had a significant effect on root yield in five of the six experiments. The N rate to achieve maximum root yield in the different fields varied from 60 to 180 kg N/ha. Application of 60 kg N/ha with 0 kg K/ha produced the maximum sugar yields. It would be very important to base N fertilization on soil analysis results. Giroux and Tran (1987) found the UV absorbance at 220 nm of a soil extract with 0.01M $NaHCO_3$ was a good method to evaluate the N supplying power of soil for sugarbeet. This method takes into account the NO_3-N and the easily hydrolyzable organic N. We have to calibrate it in the field before using it for N fertilization.

Root quality

The K content of roots was significantly increased by K fertilization (Table 3). Roots without K fertilization averaged over N rates had a concentration of 7.23 meq K/100 g. A 240 kg K/ha fertilization increased this to 8.21 meq K/100 g in the root. The 7.23 meq K/100 g concentration measured in unfertilized K roots fits well with the optimum concentration of 6.5 meq K/100 g proposed by Lefebvre (1984). In this condition, the 1 meq K/100 g concentration increase due to fertilizer-K is not useful and even harmful to the sugar extraction process. The sugar loss attributable to the root-K concentration varied from 1.13% without K-fertilization to 1.28% with a 240 kg K/ha rate (Table 3). Therefore, the larger part of the K sugar loss depends above all on the soil K level (1.13%) and much less on the fertilizer-K (0.15%). Consequently, there are some advantages for root quality in limiting or stopping the K fertilization. The soil K is able to assure good K nutrition to sugarbeet in these rich soils.

The N x K interaction was not significant for any of the quality factors measured. This interaction does not take place in rich soils because the soil-K prevails over fertilizer-K. The N-fertilization increased the α-amino-N from 1.36 for the control plot to 2.14 meq/100 g with the 180 kg N/ha rate (Table 3). The sugar percentage decreased with the N fertilization from 17.3 without N to 16.6% with 180 kg N/ha fertilization.

The extractable sugar content decreased from 15.6% to 14.7% when the N fertilization increased from 0 to 180 kg N/ha. The sugar loss attributable to the α-amino-N content of the root increased from 0.30% without N to 0.46% with a 180 kg N/ha rate. The sugar loss due to α-amino-N content was less important than the loss due to K content of the root. For nitrogen, the sugar extraction decrease was compensated by an increase of root yield up to 60-120 kg N/ha, according to K rates. For potassium, the sugar extraction decrease was not compensated by a significant increase of root yield (Table 2). High levels of N and K fertilizers slightly increased the root yield, but decreased root quality and did not increase sugar yield, so this practice is not recommendable. Producers must consider both root yield and root quality in order to profit from sugarbeet production. Therefore they must consider the very high level of root-K and try to decrease it by an appropriate K fertilization.

The N fertilization increased the Na content of the root from 1.13 to 1.47 for a 0-180 kg N/ha (Table 3). The mechanism of this interaction is not clearly understood but it is possible that NH_4^+ ions displace Na^+ from the colloids to the soil solution, therefore

Table 3. Effect of N and K fertilization on quality of sugarbeets (means of six experimental fields).

Treatments		Sugar percentage	Root content			Sugar loss by			Extractable sugar	Sugar yield	Alkali. index
N	K		Na	K	amino-N	amino-N	K	Na			
kg/ha		%	(meq/100g)			%			%	t/ha	
0	0	17.3	1.17	7.08	1.36	0.29	1.11	0.15	15.7	7.1	7.3
0	80	17.3	1.18	7.45	1.37	0.29	1.17	0.15	15.6	7.0	8.0
0	160	17.2	1.03	7.65	1.33	0.29	1.22	0.13	15.5	7.8	7.9
0	240	17.1	1.15	8.11	1.54	0.33	1.27	0.15	15.4	7.5	6.9
60	0	17.4	1.35	7.28	1.74	0.38	1.14	0.17	15.6	8.2	5.8
60	80	17.0	1.24	7.37	1.55	0.33	1.15	0.15	15.3	7.4	6.5
60	160	17.2	1.19	7.75	1.72	0.37	1.21	0.15	15.4	7.8	5.9
60	240	16.9	1.32	7.25	1.36	0.29	1.24	0.17	15.2	8.2	8.8
120	0	17.0	1.51	7.22	1.93	0.41	1.13	0.19	15.2	7.9	5.2
120	80	16.8	1.47	7.83	1.82	0.39	1.23	0.19	15.2	8.1	5.6
120	160	17.1	1.27	7.82	1.80	0.39	1.22	0.16	15.3	7.8	5.5
120	240	16.8	1.27	8.38	1.84	0.40	1.31	0.16	14.9	8.1	5.5
180	0	16.7	1.36	7.32	2.22	0.48	1.14	0.17	14.8	8.0	4.6
180	80	16.6	1.51	7.58	2.04	0.44	1.19	0.19	14.8	7.6	5.1
180	160	16.4	1.57	7.83	2.24	0.48	1.23	0.20	14.6	7.9	5.0
180	240	16.5	1.45	8.38	2.07	0.45	1.31	0.19	14.5	8.3	5.3
F for N		8.9**	7.8**	NS	37.8**	37.7**	NS	7.5**	10.4**	4.5**	13.1**
F for K		NS	NS	19.5**	NS	NS	18.8**	NS	NS	NS	NS
F for N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.82	
LSD 0.05		0.58	0.28	0.53	0.30	0.064	0.084	0.039	0.67	0.79	
CV(%)		3.0	19.4	5.9	14.8	14.7	6.1	20.3	3.8	8.7	25.6

*, ** significant at 5% and 1% level of probability, respectively.
NS = not significant.

stimulating Na absorption by the root. These results confirm the $Na\text{-}NH_4$ interaction measured by Loué (1983) and Moraghan (1985).

The alkalinity index is the ratio of (K+Na) to α-amino-N in the juice; this index is useful to predict the pH variation of juice during the evaporation step. When this index is too low (<2), a pH drop occurs due to NH3 volatilization. Alkaline products then are added to the juice to keep the pH high, but these products decrease the sugar extraction. In this experiment, the alkalinity index varied from 4.6 to 8.8 according to N and K fertilization (Table 3). Nitrogen rates have a negative effect and potassium a positive effect on the alkalinity index. Nevertheless, this index is high even for low K, or high N fertilization. The soil K content is sufficient to give a high alkalinity index in these soils.

Potassium balance sheet

The potassium balance sheet has been established for three fields: Aston, St-Laurent-2, and St-Urbain-2. The exchangeable K in the 0-60 cm layer in spring was respectively 875, 415, and 1620 kg K/ha in these three soils (Table 1). After harvest, the exchangeable K dropped to 685, 375, and 1450 kg K/ha, respectively, in the 0 K treatment. The mean difference between spring and fall exchangeable K was 50 kg K/ha in the 0-20 cm layer, and 130 kg K/ha in the 0-60 cm layer in plots receiving no fertilizer-K (Table 4). The decrease in soil K was much lower than the K absorbed by sugarbeet (Table 5). Absorption of subsoil exchangeable K or replenishment of exchangeable K from the non-exchangeable pool probably accounts for the discrepancy. In turn, the soil exchangeable K remained relatively constant even with a high K uptake by the sugarbeet. It is also important to note that K content of tops varied from 251 to 470 kg K/ha in the unfertilized K-plots (Table 5). This quantity is higher than the mean 130 kg K/ha decrease of exchangeable soil K in the 0-60 cm layer and will be returned to the soil. It may also compersate for the root K uptake which represents a value of 138 to 190 kg K/ha in the unfertilized K plots. The sugarbeet acts as a pump; it absorbs subsoil K and recycles a part of it as green manure to the soil surface. In this condition, the sugarbeet does not exhaust

Table 4. Exchangeable K content in soils sampled at seedling and harvest times.

	Spring K (kg/ha)				Autumn K (kg/ha)			
Site	0-20	20-40	40-60	Total	0-20	20-40	40-60	Total
Aston	335	315	225	875	260	225	200	685
Saint-Laurent	190	135	90	415	170	125	80	375
Saint-Urbain	560	450	610	1620	500	400	375	1450

Table 5. Root yield, K-concentrations and K uptakes by tops and roots of sugar beet as affected by K-fertilization in 3 experimental fields.

Treatment	Root yields (fresh basis)	Root K-concentration (fresh basis)	Root K-uptake	top yields (dry basis)	top K-concentration (dry basis)	top-K uptake
kg K/ha	t/ha	%	kg K/ha	kg K/ha	%	kg/ha
			St-Urbain-2			
0	51.9	0.342	177	5712	5.50	314
80	53.3	0.350	186	6075	5.57	338
160	54.5	0.363	198	6151	5.85	360
240	55.5	0.389	216	6333	6.02	381
			Aston			
0	67.1	0.283	190	6684	7.05	471
80	70.3	0.294	207	6754	7.20	486
160	70.5	0.298	210	7164	7.26	520
240	72.3	0.320	231	7072	7.65	541
			St-Laurent-2			
0	51.1	0.271	138	6967	3.60	251
80	50.3	0.291	147	7284	3.90	284
160	50.3	0.312	157	7360	4.18	308
240	53.0	0.341	181	7565	4.31	326

Table 6. Potassium balance sheet of sugarbeet cultivated on three soils with different K fertilizer rates.

K rate	K-input	total K uptake	unused fertilizer-K	K-output	K-difference	AUC	Kdff
	kg/ha					%	%
			Aston				
0	875	660	—	1345	470	—	—
80	955	693	47	1425	470	40.0	4.6
160	1035	727	90	1505	470	43.8	11.5
240	1115	772	128	1585	470	46.6	16.7
			Saint-Laurent				
0	415	389	—	764	349	—	—
80	495	431	38	844	349	52.5	9.7
160	575	465	84	924	349	47.5	19.4
240	655	507	122	1004	349	49.2	23.3
			Saint-Urbain				
0	1620	491	—	1941	321	—	—
80	1700	524	47	2021	321	41.3	6.3
160	1780	558	93	2101	321	41.9	12.0
240	1860	597	134	2181	321	44.2	17.8

K-input = spring K + K rate
K-output = autumn-K + total K-uptake + unused K.
K-difference = K-output − K-input.

soil K in the upper part of the soil. The difference between total input and output of 321 to 470 kg K/ha measured in the K balance sheet probably represents mostly the subsoil K (deeper than 60 cm) absorbed by sugarbeet (Table 6). Soil tests for K in the 0-20 cm layer obviously strongly underestimate soil K availability for sugarbeet.

In rich soils, the fertilizer-K has a low contribution to sugarbeet nutrition. The apparent Kdff value represents the proportion of K uptake which is derived from fertilizer. For the Aston soil, the Kdff values were 4.6, 11.5, and 16.7% for the 80, 160, and 240 kg K/ha, respectively. For the poorer St-Laurent-2 soil, the Kdff values were higher: 9.7, 19.4, and 23.3% for the same fertilizer rates. Finally, for the St-Urbain-2, the Kdff values were 6.3, 12.0, and 17.8% (Table 6). The soil K dominates the K nutrition of sugarbeet; this may explain the relatively small effects of fertilizer K on yield and root quality as previously discussed.

The apparent utilization coefficient (AUC) is the ratio of fertilizer-K absorbed by sugarbeet to the fertilizer-K added. These values varied from 40.0% to 52.5% among the fields. The AUC value was only slightly affected by the fertilizer rates, whereas the Kdff value was proportional to fertilizer- K. These results show that less than half of the fertilizer K is absorbed by the sugarbeet.

The K balance sheet proves that it is possible to stop the K fertilization without depleting exchangeable K in these soils. These results show that when the subsoil K is high, it is not necessary to compensate for the K absorption by an equivalent fertilizer rate to maintain the soil K level. The K content of the tops returning to the soil surface is able to compensate for root K uptake. In this condition it is advisable to stop the K fertilization.

Petiole analysis

The data of petiole analyses were averaged over site. A previous analysis showed that the effects of N and K treatments were almost the same for all sites so we used each site as a replication. The NO_3-N content of petioles samples 8 weeks after seeding was positively affected by N- fertilization and negatively by K-fertilization (Table 7). A balance of these two elements is necessary in the soil to attain a suitable NO_3-N level in the plant (Table 7). A critical level of 10,000 μg NO_3-N/g in the petiole at the 8 week stage has been proposed by Ulrich *et al.* (1959) and Chamberland and Doiron (1973). Lower concentrations are associated with an under-fertilization and higher levels to an over-fertilization with N. Different N and K fertilizations gave suitable NO_3-N levels in the petioles. Rates of 60 N and 0 K, 120 N and 80 K, and 180 N and 240 K (kg/ha) gave, respectively, 12280, 11420, and 10460 μg NO_3-N/g in the petioles (Table 7). Other N-K combinations gave unsuitable NO_3-N levels. Rates of 60 N and 80 K as well as 120 N and 240 K (kg/ha) provided only 9540 and 8810 μg NO_3-N, respectively. It seems that the fertilizer-N rate should be established considering the fertilizer-K rate. When no K fertilization is used, a relatively low 60 kg N/ha is sufficient. But when the K fertilization is high (160-240 kg K/ha), the N

Table 7. Effect of N and K fertilization on petiole analysis.

Treatment		Petioles at 8 weeks				Petioles at harvest			
N	K	Total-N	NO_3-N	K	Na	Total-N	NO_3-N	K	Na
kg/ha		%	ppm	%	%	%	ppm	%	%
0	0	2.01	8310	9.01	1.52	0.91	1430	6.56	1.87
60	0	2.08	12280	8.36	1.49	1.05	2120	5.85	2.03
120	0	2.28	14150	8.71	1.48	1.08	2100	5.67	1.87
180	0	2.32	12290	9.05	1.35	1.15	3200	6.15	1.78
0	80	1.87	5640	9.92	1.27	0.91	1200	6.52	1.66
60	80	2.06	9540	9.42	1.56	1.05	1720	6.24	1.99
120	80	2.25	11420	9.04	1.65	1.22	2460	6.02	2.14
180	80	2.45	12940	8.94	1.57	1.22	2390	5.98	2.14
0	160	2.00	9130	9.95	1.48	0.90	1000	6.89	1.49
60	160	2.00	9190	9.83	1.60	1.03	1910	6.35	1.84
120	160	2.16	12000	9.57	1.49	1.23	2360	6.37	2.04
180	160	2.25	10460	9.28	1.47	1.18	2350	6.15	2.06
0	240	1.95	6260	10.23	1.40	1.00	1680	6.90	1.68
60	240	1.99	7720	10.27	1.45	0.95	1390	7.49	1.68
120	240	2.18	8810	9.9	1.63	1.65	2370	7.08	1.80
180	240	2.13	10160	9.7	1.30	1.05	1970	7.41	1.64
F for N		12.22**	13.80**	2.74*	NS	17.2**	7.08**	NS	2.80*
F for K		NS	7.25**	10.20**	NS	NS	NS	NS	NS
F for N x K		NS	NS	NS	NS	NS	NS	NS	NS
Var. Coef.(%)		9.5	26.2	8.6	18.6	9.6	33.8	12.2	16.8
LSD (5%)		0.23	3030	0.94	0.32	0.14	1200	1.10	0.94

*,** significant at 5% and 1% level of probability, respectively.
NS = not significant

fertilization must be increased to 150-180 kg N/ha to ensure a good NO_3-N petiole content. As it is recommended to stop K fertilization in these rich soils, a similar decrease of N fertilization to a 60 kg N/ha rate also is advisable.

The total N concentration of petioles at the 8-week stage varied with N rates but the variation was much less than with NO_3-N concentration. However, the total N analysis seems to be a less accurate diagnostic index than NO_3-N analysis. A total-N content of 2.1 to 2.3 seems sufficient at this stage. The K-concentration of petioles at the 8 week stage varied from 8.36 to 9.05% in the control plots. At 240 kg K/ha, this value increased to a range of 9.7 to 10.27%. Petiole analyses support the fact that sugarbeet produced on these soils have an excess of potassium.

This study showed that soils used for sugarbeet production in the province of Québec have a very high exchangeable soil K (often higher than 800 kg/ha in the 0-60 cm layer). The sugarbeet is able to absorb K deeply in the subsoil. The determination of the exchangeable soil K only in the 0- 20 cm layer underestimates the K availability for sugarbeet. A high N and K fertilization tended to increase root yield slightly, but decreased juice purity and sugar extractability. The larger part of the sugar loss depended on soil K. The sugar percentage was decreased by N fertilization but the increase of root yield compensated for the sugar yield up to 60 kg N/ha. The soil K was adequate to produce a high alkalinity index even with high N fertilizer rates.

In these rich soils, the fertilizer-K contributed only 40-52% to sugarbeet K uptake. The potassium derived from fertilizer in the whole plant was affected by soil and fertilizer K rates. Kdff varied from 4.6 to 23.3%, illustrating that soil K prevails on fertilizer K for sugarbeet nutrition. The tops K uptake, which is returned to the soil at harvest, is able to compensate for the decrease of soil K on the 0-60 cm layers or for the root-K uptake. An impoverishment of soil K is not likely to occur in the short term, even when the K fertilization is stopped.

Petiole analyses indicated that an equilibrium in N and K fertilization is necessary to maintain a good NO_3-N content in petioles at the 8 weeks stage. Nitrogen fertilization must be fixed in consideration of the K fertilization in order to achieve an optimum NO_3-N content in petioles. As it is advisable to stop K fertilization in these rich soils, the N fertilization should be lowered to 60 kg N/ha.

LITERATURE CITED

1. Allison, L. E. 1965. Organic carbon. Walkley-Black method. Pages 1372-1376. *In* C. A. Black, et al. (ed.). Methods of Soil Analysis. Part 2. Am. Soc. Agron., Madison, WI. 1572 pp.
2. Bremner, J. M. 1965. Inorganic forms of nitrogen. Pages 1179-1255. *In* C. A. Black, et al. (ed.). Methods of Soil Analysis. Part 2. Am. Soc. Agron., Madison, WI. 1572 pp.

3. Chamberland, E. and E. B. Doiron, 1973. Rapid determination of nitrate-N in corn leaves and sugarbeet petioles as an indicator of side-dressing nitrogen need. Commun. Soil Sci. Plant Anal. 4:293-366.
4. Chapman, H. D. 1965. Cation-exchange capacity. Pages 891- 901. *In* C. A. Black, et al. (ed.). Methods of Soil Analysis. Part 2. Am. Soc. Agron., Madison, WI. 1572 pp.
5. Cochran, W. G. and Cox, G. M. 1957. Experimental Design, 2nd ed. Wiley, New York. 611 pp.
6. Devillers, P. 1983. Rôle des composés azotés dans la fabrication industrielle du sucre de betteraves. Pages 1-12. In Symposium "Nitrogen and sugar-beet," IIRB, Bruxelles.
7. Draycott, A. P. and G. W. Cooke. 1966. The effects of potassium fertilizers on quality of sugar beet. Potassium Symp. p 131-135.
8. Draycott, A. P. 1972. Potassium and sodium. Pages 58-82. In A. P. Draycott. Sugar Beet Nutrition. Wiley, New York.
9. Giroux, M. and T. S. Tran. 1987. Comparaison de différentes méthodes d'analyse de l'azote du sol en relation avec sa disponibilité pour les plantes. Can. J. Soil Sci. 67:521- 551.
10. Hébert, J. 1981. Fumure. Cultivar, special betteraves 144:46-51.
11. Jackson, R. K. 1980. Avoiding interference and problems in the determination of nitrate. The comparison of two methods. The anion specific ion electrode and the cadmium column. Commun. Soil Sci. Plant Anal. 11:127-134.
12. Lefebvre, G. 1984. La fertilisation phospho-potassique. Pages 45-53. In Journee d'Information sur la Betterave Sucrière. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, Canada.
13. Lemaire, G. 1983. Fumure de la betterave. Pages 53-73. In Rapport du Colloque sur la Betterave Sucrière. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, Canada.
14. Lindemann, Y., G. Guirand, C. Chabouis, J. Christmann and A. Mariotti. 1983. Cinq années d'utilisation de l'isotope 15 de l'azote sur betteraves sucrières en plein champ. Pages 99-116. In Symposium "Nitrogen and sugar-beet." IIRB, Bruxelles.
15. Loué, A. 1983. Influence de la fertilisation potassique sur les effets de la fertilisation azotée en culture betteravière. Pages 317-330. In Symposium "Nitrogen and sugar-beet." IIRB, Bruxelles.
16. Moraghan, J. T. 1985. Potassium nutrition of sugarbeets. In R. D. Munson (ed.). Potassium in agriculture. Am. Soc. Agron. Madison, WI. 1223 pp.
17. O'Neil, J. V. and Webb, R. A. 1970. Simultaneous determination of nitrogen, phosphorus and potassium in plant material by automatic methods. J. Sci. Food Agric. 21:217- 219.
18. R.S.Q. 1984a. Enquete technique sur la betterave à sucre. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, Canada.
19. R.S.Q. 1984b. Guide de production à la culture de la betterave sucrière. Ministere de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, Canada.
20. Tinker, P.B.H. 1965. The effects of nitrogen, potassium and sodium fertilizers on sugar beet. J. Agric. Sci. (Camb.) 65:207-212.
21. Ulrich, A., D. Ririe, F. J. Hills, A. G. George and M. D. Morse. 1959. Plant analysis, a guide for sugarbeet fertilization. California Agric. Exp. Stn. Bull. 776.