Return of Sugarbeet Tops and the Accumulation of Certain Chemical Constituents in Soil*

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INTRODUCTION

Sugarbeet is a deep-rooting crop which accumulates large quantities of soil nutrients. For instance, each metric ton of harvested storage roots usually removes between 1.3 to 2.8 kg of K^+; the quantity of K^+ in tops, including crowns, is approximately one and one-half to two times the total quantity in roots (13). In addition, sugarbeets is a natrophilic species (10) that can accumulate large quantities of Na^+ and, like other members of the Chenopodiaceae, Cl^- (11). Sugarbeet tops may also accumulate large quantities of N (7).

Tops of sugarbeets, grown under dryland conditions in the Red River Valley of Minnesota, North Dakota and Manitoba, are normally returned to the soil as a green manure crop; part of the crown is usually included with the tops in this region. Consequently, inclusion of sugarbeets in a cropping system may result in changes or redistribution of chemical constituents such as NO_3^-, Cl^-, K^+ and Na^+ in the soil profile. The purpose of this study was to measure changes in these constituents within certain Red River Valley fields, high in soil NO_3^-, as a result of the growth of sugarbeets.

MATERIALS AND METHODS

Five fields, each of approximately 40 ha located in Walsh County, North Dakota, were planted to sugarbeets in the spring of 1983. Prior to planting, while the ground was still frozen, 25 soil cores per field to a depth of

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180 cm were taken at each location. The soil sampling was repeated in 1984 on approximately the same dates. Soil cores from each sampling were divided into 15 cm increments to 30 cm and into 30 cm increments from 30 to 180 cm. The relevant soil samples were then composited, air dried, ground and analyzed for NO_3^-, Cl^-, and extractable K^+ and Na^+. Nitrate was determined on 2 M KCl-extracts by a distillation procedure (3); Cl^- was determined coulometrically on aqueous soil extracts after being made acid with HNO_3-HOAc (1); K^+ and Na^+ were extracted from the soil samples with 1 M NH_4OAc (pH = 7; soil (g): solution (mL) = 2:50) and determined by atomic absorption spectroscopy.

The dominant soil series in the fields selected for this study, together with the contents of selected extractable nutrients in certain depth increments in the spring of 1983, are given in Table 1. An assumption com-

Table 1. Contents in the spring of 1983 of selected extractable nutrients in soils from five fields used for sugarbeet production.

Field†	Soil depth	NO_3^--N	Cl^-	K^+	Na^+
	cm	kg ha^{-1}			
A	0-60	210	180	2100	520
	60-120	515	690	3360	1710
	120-180	705	900	5890	3630
B	0-60	200	340	1520	930
	60-120	456	1530	3630	2820
	120-180	645	2800	6180	4730
C	0-60	200	280	1370	1130
	60-120	367	1070	2330	3460
	120-180	440	2860	3870	7550
D	0-60	220	140	1520	420
	60-120	365	370	2300	1380
	120-180	475	680	2960	2450
E	0-60	225	120	1420	420
	60-120	375	270	2090	700
	120-180	475	460	2720	1110

†The dominant soil series were: in field A Fairdale (Mollic Udifluent); in fields B, D and E Glyndon (Aeric Calciaquoll); and in field C Bearden (Aeric Calciaquoll).

monly used by regional soil testing laboratories, that the average bulk density of soil is 1.47, was used to convert laboratory measurements of μg of extractable soil nutrients g^{-1} of soil to a kg ha^{-1} basis.

Five subsamples, each consisting of 12 individual sugarbeet plants, were hand harvested in each field during late September 1983. Plant tops were chopped, subsampled, dried at 70°C, ground and analyzed for total N, Cl^-, K^+ and Na^+. Total N was determined by a semimicro-Kjeldahl procedure with a salicylic acid modification to include NO_3^- (2); Cl^- was determined coulometricallly in HNO_3-HOAc plant extracts (1); and K^+ and Na^+ determined in HNO_3-$HClO_4$ digests by atomic absorption spectroscopy (12).

RESULTS AND DISCUSSION

Chemical Composition of Sugarbeet Tops

Selected chemical data for sugarbeet tops late in the growing season are given in Table 2. The tops were rich

Table 2. Contents of N, Cl^-, K^+ and Na^+ in sugarbeet tops from five selected fields in late September, 1983.

Field†		Constituent in tops†			
		N	Cl^-	Na^+	K^+
		g kg^{-1}			
A		30.0 (0.4)	31.8 (3.3)	45.3 (5.6)	27.2 (2.6)
B		30.3 (1.3)	45.9 (4.3)	44.3 (5.1)	32.7 (1.6)
C		27.7 (1.3)	47.7 (0.9)	45.8 (4.9)	33.2 (0.8)
D		30.7 (1.3)	31.8 (0.7)	37.7 (2.0)	28.3 (0.7)
E		31.5 (0.8)	30.1 (1.0)	33.9 (2.2)	28.6 (0.4)
	Mean	30.0	37.5	41.4	30.0
		kg ha^{-1}			
A		191 (15)	201 (23)	287 (46)	170 (14)
B		184 (23)	269 (18)	265 (45)	192 (17)
C		129 (12)	222 (14)	214 (41)	151 (12)
D		181 (17)	185 (25)	274 (13)	169 (18)
E		168 (13)	162 (16)	183 (16)	153 (14)
	Mean	171	208	245	167

†Numbers in parentheses are the standard errors of the paticular mean values.

in N, Cl^-, Na^+ and K^+. However, the absolute quantities shown in Table 2 underestimate the acculumation in above-ground parts because of the death of older leaves during the growing season. This underestimation would be most serious for Na^+ which is poorly mobile in sugarbeet tops and accumulates most markedly in older leaves (15, 16).

Retention of sugarbeet tops within the investigated fields resulted in the addition of large quantities of N, Cl^-, K^+ and Na^+ to the surface soils. Undoubtedly, the N content of the tops, most of which was in the organic form, would affect subsequent soil N mineralization and especially the availability of N for the next crop.

Soil Chemical Composition

Resampling of the soils from the five fields in 1984 showed that extractable Na^+ and Cl^- in the upper 15 cm of soil increased an average of 200 and 430 percent, respectively (Table 3). Changes in the 15- to 30-cm depth were

Table 3. Changes in extractable soil Na^+, K^+ and Cl^- in the surface layers of five farm fields in the spring of 1984 following a sugarbeet crop grown in 1983.

Field	Depth	Cl^- 1983	Cl^- 1984	Cl^- Δ	K^+ 1983	K^+ 1984	K^+ Δ	Na^+ 1983	Na^+ 1984	Na^+ Δ
	cm	μg g^{-1}								
A	0-15	21	65	44	381	388	7	20	101	81
	15-30	17	29	12	240	209	-31	43	50	7
B	0-15	21	151	130	245	260	15	38	146	108
	15-30	24	69	45	143	158	15	68	85	17
C	0-15	11	79	68	234	253	19	80	146	66
	15-30	22	50	28	145	151	6	105	139	34
D	0-15	20	51	31	235	255	20	20	119	99
	15-30	61	22	-39	170	160	-10	35	70	35
E	0-15	3	53	50	221	238	17	42	88	46
	15-30	14	13	-1	175	145	-30	60	42	-18
Mean	0-15	15	80	65	263	279	16	40	120	80
	15-30	28	37	9	175	165	-10	62	77	15

much smaller. In contrast to the data for Na^+ and Cl^-, increases in extractable soil K^+ in the 0- to 15-cm depth were small. These small increases in extractable K^+ were less than what should be expected on the basis of the K^+ contents of the sugarbeet tops. The presence of certain types of layer silicate minerals, however, are known to moderate changes in water soluble and exchangeable K^+ resulting from addiiton of K salts to soils.

Recent work suggests that the incidence of certain plant diseases is decreased by the addition of Cl^- to certain soils (4, 5, 6, 14). Consequently, return of crop residues of Cl^--accumulating plants to surface soils, especially of a deep-rooting species such as sugarbeets, may have indirect, beneficial effects on the health of subsequent crops.

Accumulation of Cl^- in the surface soil, where substantial portions of the roots of many crops are located, may also influence uptake of NO_3^- by other crops in the rotation. There is a strong anion antagonism between NO_3^- and Cl^- such that the upake of NO_3^- is restricted (11). According to James et al. (9), this antagonism may be sufficiently strong as to affect the use of residual soil NO_3^--N as an index of soil N availability.

The surface soil data for extractable nutrients in the upper soil zone are expressed on a 0- to 15-cm soil depth basis. However, with certain tillage practices the residues would be mixed with a smaller volume of soil and changes in concentration of chemical constituents would then be more pronounced. Concentration of tops near or on the soil surface may result in levels of exchangeable Na^+ sufficiently high to cause detrimental effects on the physical condition of the soil.

Changes in soil NO_3^--N at various depths between the spring of 1983 and the spring of 1984 are given in Table 4. In general, decreases in soil NO_3^--N, with the exception of that in the 0- to 15-cm depth, occurred in the upper 120 cm of soil. The trend toward a higher level of soil NO_3^--N in the upper 15 cm was probably associated with mineralization of organic N, including part of the organic N added by the sugarbeet tops. Little leaching of soil NO_3^--N occurs in the Red River Valley during the winter because of frozen soils. The apparent utilization of deeply located soil NO_3^--N has important implications in regard to sugarbeet root quality. The detrimental consquences of excessive soil N on sugarbeet quality are

Table 4. Amounts of soil NO_3^--N in the springs of 1983 and 1984 in five farm fields planted to sugarbeets in 1983.

Field	Year	Soil depth, cm						
		0-15	15-30	30-60	60-90	90-120	120-150	150-180
		NO_3^--N, µg g^{-1}						
A	1983	15	20	28	30	37	30	13
	1984	32	13	7	10	15	18	6
B	1983	38	11	15	26	32	19	8
	1984	26	9	3	6	9	13	4
C	1983	15	19	26	19	20	10	6
	1984	36	8	7	8	2	9	3
D	1983	24	20	26	18	14	12	13
	1984	30	12	17	26	19	18	11
E	1983	14	17	30	21	11	10	13
	1984	32	9	20	13	11	14	7
Mean	1983	21	17	25	23	23	16	11
	1984	31	10	11	13	11	14	6

well known (7).

Portions of the increases in NO_3^--N and Cl^- could have resulted from upward movement of these anions due to capillarity. However, in a dry-land region this effect should be much lower in the presence of a crop than in a fallow situation. Also, a small part of the Cl^- increase may have been due to atmospheric deposition. According to Eriksson (8), annual depositions of 13 to 39 kg Cl^-ha^{-1} occur away from coastal zones.

SUMMARY

The influence of the return of sugarbeet tops at harvest on the distribution of soil NO_3^--N, Cl^- and 1 M NH_4OAc (pH = 7)-extractable K^+ and Na^+ in five Red River Valley fields high in soil NO_3^--N was investigated. Sugarbeet tops late in the growing season contained on the average 171, 208, 245 and 167 kg ha^{-1} of total N, Cl^-, Na^+ and K^+, respectively. Measurement of soil Na^+ and Cl^- in the spring prior to and subsequent to the sugarbeet crop revealed large increases, from 31 to 130 µg g^{-1} for Cl^- and 46 to 108 µg g^{-1} for Na^+, in the 0- to 15-cm depth after the incorporation of sugarbeet tops. Increases in

extractable K^+, due presumably to the buffering effect of K^+-containing minerals, were smaller. Decreases in soil NO_3^--N occurred at depths from 15- to 120-cm during the 12-month period. However, there was a strong trend for NO_3^--N in the 0- to 15-cm depth to be higher at the second sampling, apparently as a result of mineralization of sugarbeet-residue N. Possible consequences associated with these soil chemical changes are discussed.

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