Wheat Residues and Sugar Production

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INTRODUCTION

Availability of soil-inorganic nitrogen during the growing season is probably the chief soil factor influencing the yield of recoverable sugar in the Red River Valley. The residual soil nitrate-N test is used by most growers to estimate the N-fertilizer requirements for their sugarbeet fields. One of the basic assumptions behind this test is that tie-up of fertilizer N and of native soil nitrate-N does not appreciably reduce the availability of soil inorganic N for the sugarbeet crop. This assumption may not be true.

Small-grain crops frequently precede sugarbeets in the rotation. Decomposition of residual straw can result in tie-up of soil inorganic N. Consequently, straw management can influence the response of the sugarbeet crop to N fertilizer. Management of straw varies in the Red River Valley. The bulk of the straw is sometimes removed and then baled. Alternatively, the straw is removed from the field by burning. In cases where residue is left in the field, the straw is often spread unevenly over the surface due to the nature of the harvesting procedure. Consequently, research on the effect of variable rates of straw addition on soil-N availability is needed.

Growth and decomposition of volunteer growth or cover crops after a small-grain crop are additional factors which could influence the efficacy of the soil nitrate-N test for a sugarbeet crop. Some volunteer small-grain growth in the Red River Valley in 1994 contained in excess of 100 pounds organic N/acre (Moraghan, 1995). This regrowth material is likely to have a higher N concentration than residual straw, and could result in increased soil N availability during the sugarbeet growing season. Should allowance be made for this increased soil N mineralization by a reduction in the quantity of applied N fertilizer?

EXPERIMENTAL

The influence of urea-N fertilizer, wheat 'volunteer' growth subsequent to the wheat harvest, and mature wheat straw left in the field after the wheat-grain harvest on growth of a following year sugarbeet crop was studied in 2000 at Crookston. The soil was a Wheatville loam. The twelve treatments (Table 1) were arranged in a randomized complete block design with six replications. Each plot consisted of six sugarbeet rows 22 inches apart, and the length of each plot was 35 feet.

Table 1. Treatments applied in the autumn of 1999 within the 2000 Nitrogen Fertilizer-Wheat Residue Experiment at Crookston.

Treatment	Urea-N	Type of wheat residue	Application rate (DM)	Residue N	Residue N
	lb/acre		lb/acre	%	lb/acre
1	0	--	--	--	--
2	40	--	--	--	--
3	80	--	--	--	--
4	120	--	--	--	--
5	160	--	--	--	--
6	200	--	--	--	--
7	0	Mature straw	3,000	0.35	11
8	0	Mature straw	6,000	0.35	21
9	40	Mature straw	3,000	0.35	11
10	40	Mature straw	6,000	0.35	21
11	0	Low-N 'volunteer'	2,310	2.91	67
12	0	High-N 'volunteer'	3,440	4.17	143

The experimental site had a wheat crop in 1999. The wheat straw left on the site after the grain harvest was removed prior to the addition of the treatments (Table 1) on October 10 and 11, 1999. All wheat residues and N-fertilizer treatments were incorporated with a rototiller in the upper 5 inches of soil within a day of application. The site was cultivated in April 2000, and 60 pounds P_2O_5/acre was incorporated prior to planting sugarbeets (VDH 66283) on April 25, 2000.

Due to uncertainty about obtaining suitable 'volunteer' wheat top growth from farmers' fields in 1999, the low and high N 'volunteer' wheat residues were obtained from sites 'low' and 'high' in available soil N planted to wheat in early August, 1999. The volunteer wheat was cut, chopped and mixed for homogeneity in the moist state in the field. Twelve subsamples of both 'volunteer' treatments, each approximately 2.2 pounds, were weighed in the field and subsequently oven-dried prior to reweighing for determination of plant moisture. The dried subsamples were again subsampled, ground to pass a 60-mesh sieve, and analyzed for total N. From a knowledge of the weights of 'wet' material applied to the low and high N 'volunteer' plots, and of the laboratory-determined moisture and N contents in the regrowth material, the total quantity of N applied to the relevant 'volunteer' plots was determined.

Bales of wheat straw, obtained from a commercial wheat field after the 1999 grain harvest, were used for the mature straw treatments. Twelve subsamples were obtained for moisture and total N determinations.

Petiole nitrate-N was determined during the growing season after the majority of the plots had Leaf Area Indices in excess of approximately 1.5 (complete leaf cover). Fourteen recently mature leaves were harvested from Row 2 at approximately 14-day intervals up until the root harvest. Petioles were chopped, dried, ground and analyzed for plant nitrate-N.

Tops were harvested from 12-foot lengths of Row 5 one day prior to the root harvest. The tops were weighed wet, chopped, and mixed. Subsamples were then taken, weighed, dried, reweighed and finely ground. The subsamples were analyzed for total N and nitrate-N. Roots from 35-foot lengths of Rows 3 and 4 were mechanically harvested and weighed. Subsamples from the root harvest were weighed, washed, reweighed and analyzed for recoverable sugar and impurities by the American Crystal Company, East Grand Forks, MN. Excess brei (macerated roots) was retained, frozen, freeze dried, ground and analyzed for moisture and total N.

The check plots were sampled for soil nitrate-N to a depth of 6 feet on October 28, 1999. Plots treated with 200 pounds urea-N/acre or high-N 'volunteer' residue, together with the check plots, were sampled for soil nitrate after the sugarbeet harvest on October 18, 2000.

RESULTS

Soil Nitrate

Mean soil nitrate-N values for upper 2- and 4-foot depth increments of the check plots on October 28, 1999 were 32 and 57 pounds/acre (Table 2). The experimental site had some variability with respect to soil nitrate, but responses to N fertilizer were expected in five replications.

Table 2. Soil nitrate-N data in late autumn 1999 for the check (0N) plots in the 2000 Nitrogen Fertilizer-Wheat Residue Experiment at Crookston.

	Soil depth, feet				
Parameter	0-0.5	0-1.0	0-2	0-4	0-6
	---------- NO_3-N, lb/acre ----------				
Mean ($\bar{x}$)	7	14	32	57	68
Standard deviation	1	2	15	30	37
Coefficient of variation	9	15	47	53	54
Range	6-8	10-16	19-58	27-104	32-126

Soil nitrate-N in the check plots decreased between the 1999 and 2000 samplings (Tables 2 and 3). The 200 pounds urea-N/acre and high-N volunteer wheat residue treatments increased residual soil nitrate-N after the root harvest (Table 3).

Table 3. Influence of selected autumn (1999) treatments on residual soil nitrate-N (NO_3-N) after the 2000 sugarbeet root harvest.

N fertilizer	Wheat residue	Soil depth, feet 0-0.5	0-1.0	0-2	0-4	0-6
lb N/acre		---------- NO_3-N, lb/acre ----------				
0	--	4.1	6.1	7.6	9.7	11.3
200	--	8.6	11.1	13.2	16.7	19.3
0	High-N 'volunteer'	9.4	11.6	13.9	18.6	21.5
Tukey (0.05)		3.1	3.5	3.8	4.4	5.5

Yield and N Accumulation

Nitrogen fertilizer in the absence of wheat residue treatments had no effect on yields of roots or recoverable sugar (Table 4). In contrast, yields of sugarbeet tops were increased by N fertilizer at the final harvest. Appearance and yield of tops at the end of the growing season were poorly correlated with yield of recoverable sugar.

Table 4. Influence of nitrogen fertilizer and two types of wheat residue on selected characteristics of sugarbeet storage roots and tops at Crookston in 2000.

Treatment N fertilizer	Wheat residue[1]	Root yield (wet)	Recoverable sugar	Root N (dry)	Root N (a)	Tops yield (dry)	Tops N (dry)	Tops N (b)	a+b
lb N/acre		tons/acre	lb/acre	%	lb/acre	lb/acre	%	lb/acre	lb/acre
0	--	23.6	8,110	0.47	53	2,700	1.83	51	104
40	--	23.9	8,310	0.48	56	3,520	1.66	59	115
80	--	24.7	8,070	0.51	59	4,000	1.94	77	136
120	--	24.5	8,360	0.54	65	3,780	1.81	68	133
160	--	23.8	7,960	0.54	65	4,300	1.95	84	149
200	--	24.6	7,910	0.60	70	4,850	2.20	107	177
0	Mature straw (a)	21.5	7,080	0.49	49	2,380	1.53	36	85
0	Mature straw (b)	17.1	5,900	0.43	35	2,500	1.69	43	78
40	Mature straw (a)	23.1	7,650	0.49	51	4,280	1.90	82	133
40	Mature straw (b)	19.8	6,840	0.46	44	2,880	1.46	42	86
0	Low-N 'volunteer'	24.0	8,290	0.48	56	3,270	1.68	56	112
0	High-N 'volunteer'	27.6	9,100	0.53	74	5,310	2.24	120	194
Tukey (0.05)		2.1	1,080	0.09	13	1,520	0.39	40	40

[1]Mature straw (a) = 3000 pounds/acre; mature straw (b) = 6,000 pounds/acre (mature straw contained 0.35% N); low-N (2.91% N) 'volunteer' wheat = 2,310 pounds/acre; high-N (4.17 % N) 'volunteer' wheat = 3,440 pounds/acre; ('volunteer' wheat rates of application are expressed on a dry-weight basis).

Mature straw decreased yield of roots by 2.1 and 6.5 tons/acre at the 1.5 and 3 tons/acre rates of application, respectively (Table 4). The corresponding reductions in recoverable sugar were 1,030 and 2,210 pounds/acre, respectively. Application of 40 pounds urea-N/acre with the mature straw reduced the decreases to 460 and 1,270 pounds recoverable sugar/acre for the low and high rates of mature straw, respectively. Likewise, the root-yield depression resulting from straw application was reduced, but not eliminated, by the application of 40 pounds urea-N/acre.

Accumulations of N in tops and roots at the autumn 2000 harvest were reduced by the application of mature straw (Table 4). Application of 40 pounds urea-N with the 3 tons/acre mature straw treatment increased N in tops plus roots from 78 to 86 pounds/acre, a quantity still less than that (104 pounds N/acre) obtained with the check treatment.'

Application of low-N ‘volunteer’ wheat tops had no effect on yield of roots, tops and N accumulation (Table 4). In contrast, application of high-N ‘volunteer’ wheat tops increased the yield of both tops and roots compared to the check treatment. The quantity of N in tops and roots was increased by 90 pounds/acre through application of high-N ‘volunteer’ wheat tops.

Petiole Nitrate

Petiole nitrate-N was increased by application of N fertilizer but never exceeded 8,000 ppm during the growing season (Table 5). Yield of recoverable sugar was not increased by application of N fertilizer even though petiole nitrate-N with the check treatment was only 520 ppm on July 27, approximately 2 months prior to the root harvest. Application of 3 tons mature straw/acre reduced petiole nitrate-N to levels below that found in petioles from plants in the check plots at corresponding samplings. Petiole nitrate-N was increased appreciably by application of high-N ‘volunteer’ wheat residue.

Table 5. Nitrate-N in recently mature petioles during the growing season for the 2000 Nitrogen Fertilizer-Wheat Residue Experiment at Crookston.

Treatment N fertilizer	Wheat residue[1]	Date of Sampling					
		7/14/00	7/27/00	8/10/00	8/24/00	9/7/00	9/21/00
lb/acre		---------- Petiole NO_3-N, ppm ----------					
0	--	2,930	520	410	120	470	160
40	--	5,780	1,330	380	270	320	130
80	--	6,440	1,840	710	440	580	300
120	--	7,070	3,940	1,520	90	130	9
160	--	7,060	4,010	2,490	530	300	100
200	--	7,860	5,890	3,280	1,020	920	350
0	Mature straw (a)	2,340	130	160	220	190	90
0	Mature straw (b)	1,310	210	110	60	40	10
40	Mature straw (a)	4,840	1,900	880	220	320	110
40	Mature straw (b)	2,500	360	40	10	7	1
0	Low-N ‘volunteer’	4,270	590	160	110	70	25
0	High-N ‘volunteer’	6,360	2,080	920	510	730	360
	$S_{\bar{x}}$	798	621	533	187	211	115

[1]Mature straw (a) = 3000 pounds/acre; mature straw (b) = 6,000 pounds/acre (mature straw contained 0.35% N); low-N (2.91% N) ‘volunteer’ wheat = 2,310 pounds/acre; high-N (4.17 % N) ‘volunteer’ wheat = 3,440 pounds/acre; (‘volunteer’ wheat rates of application are expressed on a dry-weight basis).

DISCUSSION

Reduction in yield of roots and recoverable sugar as a result of application of 3 tons mature straw/acre almost certainly was associated with decreased availability of soil N due to immobilization (tie-up) during microbial decomposition of straw. However, it is not certain that this was the sole reason for the reduced yields. The sugarbeet leaf canopy associated with the mature straw treatment was slow to develop and never comparable to that produced by the other treatments. Early in the growing season the stunted plants had small, darkish-green leaves, more akin to those observed with P deficiency than N deficiency. An unanswered question is whether phytotoxicity resulting from substances produced during microbial decomposition contributed to the reduction in root yield of 6.5 tons/acre associated with application of 3 tons mature straw/acre.

The increased yields associated from the high-N ‘volunteer’ treatment appeared to be related to increased availability of soil N. An unanswered question is: Why were comparable yield increases not obtained from application of urea-N?

SUMMARY

The influence of urea-N fertilizer, wheat ‘volunteer’ growth subsequent to the wheat harvest, and mature wheat straw on growth of a following year sugarbeet crop was studied. Principal findings from the research were:

1. Mature straw at 1.5 and 3.0 tons/acre decreased yield of storage roots by 2.1 and 6.5 tons/acre, respectively.
2. Mature straw at 1.5 and 3.0 tons/acre decreased yields of recoverable sugar by 1,030 and 2,210 pounds/acre, respectively.
3. Petiole-nitrate data indicated that the detrimental effect of mature straw was partly due to decreased availability of soil N.
4. High-N ‘volunteer’ wheat residues increased yield of recoverable sugar by 990 pounds/acre.
5. High N ‘volunteer’ wheat residue increased the content of N in roots and tops by 90 pounds/acre.
6. Petiole nitrate-N data indicated that the high N ‘volunteer’ wheat residue was equivalent to 80 pounds urea-N/acre as a N source.
7. Plots treated with 200 pounds urea-N/acre or high N ‘volunteer’ wheat residue in the autumn of 1999 had significantly higher soil nitrate-N in October, 2000 after the sugarbeet harvest.
8. Small quantities of low-N ‘volunteer’ wheat residue had little effect on yield of recoverable sugar.

REFERENCE

Moraghan, J.T. 1995. Volunteer small-grain growth in 1994. Sugarbeet Research and Education Board of Minnesota and North Dakota 1994 Sugarbeet Research and Extension Reports 25:227.