

SUGAR PRODUCTION AS AFFECTED BY WHEAT RESIDUES AND NITROGEN FERTILIZER¹

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SUMMARY

Field experiments were conducted in 2000 and 2001 on previous-year wheat fields, from which straw had been removed, to determine the influence of low-N mature wheat straw, high-N late summer and early fall 'volunteer' wheat residues, and N fertilizer, applied in the fall, on sugar yields and plant and soil N. The treatments were incorporated with a rototiller into a Wheatville loam soil low in nitrate-N. A 1.5 ton/acre straw treatment decreased sugar yields by 13% in both years. A 3.0 ton/acre straw treatment decreased sugar yields by 27 and 19% in 2000 and 2001, respectively. The depressing effect of wheat straw on sugar yield was partially overcome by application of 40 pounds N fertilizer/acre. Both accumulation of N by sugarbeet plants and in-season soil inorganic-N data indicated that straw addition had increased N deficiency in the sugarbeet plants through soil-N immobilization during residue decomposition. There was no evidence that net mineralization of straw N occurred during the experiments. The accuracy of the soil-nitrate test for predicting N-fertilizer requirements by sugarbeet plants is affected by straw removal, an increasingly common occurrence in the Red River Valley. Additional research is needed to determine if wheat straw also decreases early-season sugarbeet growth due to phytotoxicity. In contrast to the mature-straw effect, high-N 'volunteer' growth increased N accumulation by sugarbeet plants, increased early-season soil inorganic-N levels, and increased sugar yields. Nitrogen-fertilizer requirements and the efficacy of the soil-nitrate test are affected by the fate of crop residues in the Red River Valley.

INTRODUCTION

The Red River Valley sugarbeet crop often follows a small-grain crop, usually wheat. Little is known about how residual wheat straw influences N-fertilizer requirements for sugarbeets in this region. Such information is needed since an expanding market for small-grain straw has resulted in increased straw removal from fields. Also, little is known about the effect of wheat straw on the accuracy of the soil-nitrate test for predicting N-fertilizer requirements. Wheat-straw yields in the Valley usually range from 1.5 to 3 tons/acre with a total N concentration of 0.5 to 0.8% (Moraghan, unpublished data). Many wheat fields during 2001 were lodged as a result of strong winds; straw from severely lodged fields contained up to 1.5% N (Moraghan, unpublished data).

Availability of soil inorganic-N 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. Basic assumptions behind this test are that N immobilization and denitrification do not appreciably reduce soil nitrate-N during residue decomposition. The immobilization assumption for decomposition of residues low in N may not be correct. For instance, prior to the introduction of the soil-nitrate test, the Montana Experiment Station increased N-fertilizer recommendations for dryland small grains by 1 pound N/acre for each 100 pounds/acre of wheat straw incorporated (Soil Testing Committee, 1966). In striking contrast to the Montana recommendation, a group of Valley sugarbeet researchers recently claimed that approximately 1.1 pounds of N/100 pounds of wheat straw was mineralized, and presumably made available for sugarbeet growth, by May 15 of the following year (Hapka et al., 2001). Other researchers have found that wheat straw had little effect on small-grain yield.

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?

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The objective of our study was to determine the influence of mature wheat straw, ‘volunteer’ late summer and early autumn wheat growth, and N fertilizer on soil-N dynamics and sugar production. A preliminary report on the first-year of this study was given last year (Moraghan et al., 2001).

EXPERIMENTAL

The influence of urea-N, late summer and early fall ‘volunteer’ wheat growth, and mature wheat straw on performance of a following-year sugarbeet crop was studied in 2000 and 2001 at Crookston. Wheat was grown on the experimental sites in the previous year, and residual straw was removed after the grain harvests prior to incorporation with a rototiller of the treatments described in Table 1. The 12 treatments, arranged in a randomized complete block design with six replications, were relatively similar in both experiments except for differences in composition of the two types of residue. 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 previous autumn to plots in the 2000 and 2001 N Fertilizer-Wheat Residue Experiments.

Urea lb/acre	Type of wheat residue	Residue (2000 Experiment) ¹			Residue (2001 Experiment) ¹		
		Application rate (DM) tons/acre	N %	N lb/acre	Application rate (DM) tons/acre	N %	N lb/acre
0	--	--	--	--	--	--	--
40	--	--	--	--	--	--	--
80	--	--	--	--	--	--	--
120	--	--	--	--	--	--	--
160	--	--	--	--	--	--	--
200	--	--	--	--	--	--	--
0	Mature straw	1.5	0.35	11	1.5	0.80	24
0	Mature straw	3.0	0.35	21	3.0	0.80	48
40	Mature straw	1.5	0.35	11	1.5	0.80	24
40	Mature straw	3.0	0.35	21	3.0	0.80	48
0	‘Volunteer’	1.16	2.91	67	0.94	3.45	65
0	‘Volunteer’	1.72	4.17	143	1.88	3.45	130

¹Treatments applied on October 10 and 11 of the previous autumn in both experiments.

Detailed information about the experiments and the type of quantitative measurements made is given in Table 2. Due to uncertainty about obtaining suitable ‘volunteer’ wheat growth from farmers’ fields, wheat was planted in early August and harvested for the ‘volunteer’ treatments just prior to treatment application on October 11. The ‘volunteer’ wheat was cut, chopped and mixed for homogeneity in the moist state in the field. Twelve sub-samples 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 commercial fields, were used for the residual mature straw treatments. Twelve subsamples were retained 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 to 2.0 (complete leaf cover). Fourteen recently mature leaves were harvested from Row 2 at approximately 14-day intervals up until root harvest. Petioles were chopped, dried, ground and analyzed for plant nitrate-N.

Table 2. Pertinent details concerning two sugarbeet field experiments involving the effect of wheat residues on sugar production.

Characteristic	2000 Experiment	2001 Experiment
Previous crop	Wheat (1999)	Wheat (2000)
Sugarbeet variety	VDH 66283	VDH 66283
Soil	Wheatville loam	Wheatville loam
Planting date	4/25/00	5/4/01
Treatments applied	10/11/99	10/11/00
<u>Measurements</u>		
<u>Previous year</u>		
Soil NO ₃ -N (0-6") (check plots)	10/28/99	10/19/00
<u>Experimental year</u>		
Soil NH ₄ -+NO ₃ -N (0-6" and 0-12")	5/9/00	5/15/01
	5/23/00	5/29/01
	6/6/00	6/12/01
Soil NO ₃ -N (0-6")	10/18/00	10/3/01
Petiole NO ₃ -N	7/14/00	7/5/01
	7/27/00	7/20/01
	8/10/00	8/2/01
	8/24/00	8/16/01
	9/7/00	8/29/01
	9/21/00	9/13/01
Tops (2-6 leaf stage)	--	6/6/01
Tops (final harvest)	9/27/00; 9/28/00	9/25/01
Roots (final harvest)	9/28/00	9/27/01

Tops were harvested from 12-foot lengths of Row 5 1 day prior to 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, total N, and nitrate-N.

Selected plots were sampled in each experiment for soil nitrate-N in the prior autumn and after the root harvest. Three cores were taken from a plot in 6-inch increments to 1 foot, and in 1-foot increments to 6 feet. The three cores were composited in the field, placed in polyethylene bags, and transferred on dry ice to the laboratory for storage overnight at 2°C. The soils were then air-dried within 24 hours in a greenhouse, ground to pass a 20-mesh sieve, and analyzed for nitrate-N. In order to determine the effect of wheat residue on soil inorganic-N in the 0 to 1-foot depth during May and early June, twelve 1-foot cores in 6-inch increments, 1.3 cm in diameter, were taken from between Rows 2 and 3 of selected plots. Soil from given plots was composited and frozen until required for analysis. The thawed samples were mixed for uniformity, and subsamples were then taken for moisture determination and analysis for nitrate- and ammonium-N. Experimentally-determined soil bulk density data were used to convert concentration data to a pound-per-acre basis.

Twenty-five plants were retained from each plot during early-June thinning of the 2001 Experiment to 150 plants/100 feet of row. The tops were removed from the 2 to 6-leaf plants above the cotyledonary node, oven-dried, weighed, ground to pass a 60-mesh sieve, and analyzed for total N and P.

Plant samples were analyzed for total N by a Kjeldahl procedure with a salicylic acid modification to include nitrate-N (Nelson and Sommers, 1973). Plant nitrate-N was extracted with 1M KCl from oven-dried samples, and after suitable dilution determined by a Cd-reduction procedure (Environmental Protection Agency, 1979). Soil nitrate and ammonium-N were extracted with 2M KCl. Ammonium-N was determined by a MgO distillation procedure (Bremner, 1965). Soil nitrate was determined by the previously described Cd-reduction procedure. Phosphorus in the 2 to 6-leaf sugarbeet samples was determined by a molybdenum-blue procedure (Moraghan and Grafton, 1999).

RESULTS AND DISCUSSION

Plant Appearance

'Volunteer' wheat residue stimulated while mature wheat straw depressed growth of sugarbeet tops throughout much of the growing season in both the 2000 and 2001 Experiments. In particular, the growth of tops in the check plots, those receiving no residue or N fertilizer, was intermediate between that resulting from the above two treatments. Retarded growth of plants with the straw treatments appeared to be due at least partially to increased N deficiency. Nitrogen fertilizer increased top growth in both experiments, but growth early in the growing season was generally superior in plots treated with the high rate of 'volunteer' residue.

Sugar and Root Yields

The response patterns in the two experiments were relatively similar (Table 3). The 1.5 tons/acre and especially the 3 tons/acre mature-straw treatments decreased both sugar and root yields. The 3 tons/acre treatment decreased sugar yields by 27 and 19% in the 2000 and 2001 Experiments, respectively. This straw treatment in the presence of 40 pounds urea-N/acre decreased sugar yields by only 16 and 6% in the 2000 and 2001 Experiments, respectively. The 1.5 tons/acre treatment decreased sugar yields by 13% in both experiments. This straw treatment in the presence of 40 pounds of urea-N/acre decreased sugar yields by only 6 and 3% in the 2000 and 2001 Experiments, respectively. Consequently, the detrimental effects of low-N wheat straw on sugar production were at least partially overcome by application of N fertilizer.

Table 3. Influence of N fertilizer and two types of wheat residue on storage root and sugar yields in 2000 and 2001.

Treatment		2000 Experiment			2001 Experiment		
N fertilizer lb N/acre	Wheat residue	Root yield (wet) tons/acre	Sugar %	Recoverable sugar lb/acre	Root yield (wet) tons/acre	Sugar %	Recoverable sugar lb/acre
0	--	23.6	17.5	8,110	23.9	17.2	7,730
40	--	23.9	18.4	8,310	24.6	17.3	7,960
80	--	24.7	17.2	8,070	25.2	17.2	8,140
120	--	24.5	18.2	8,360	25.4	17.3	8,170
160	--	23.8	18.0	7,960	25.3	16.6	7,830
200	--	24.6	17.3	7,910	24.6	16.3	7,410
0	Mature straw (a) ¹	21.5	17.7	7,080	21.0	17.0	6,700
0	Mature straw (b) ¹	17.1	18.3	5,900	19.3	17.3	6,280
40	Mature straw (a) ¹	23.1	17.5	7,650	23.5	17.1	7,510
40	Mature straw (b) ¹	19.8	18.0	6,840	21.9	17.5	7,230
0	'Volunteer' (c) ²	24.0	18.3	8,290	25.9	17.4	8,450
0	'Volunteer' (d) ²	27.6	17.6	9,100	27.0	17.6	8,850
	Tukey (0.05)	2.1	NS	1,080	2.2	1.4	940

¹Mature straw (a) = 1.5 tons/acre; Mature straw (b) = 3.0 tons/acre.

²2000 'Volunteer' (c) = 1.2 tons/acre-2.91% N; 'Volunteer' (d) = 1.7 tons/acre-4.17% N.

2001 'Volunteer' (c) = 0.94 tons/acre-3.45% N; 'Volunteer' (d) = 1.88 tons/acre-3.45% N.

In contrast to the detrimental effect of low-N wheat straw on sugar yields, application of the high rate of 'volunteer' wheat residue increased sugar yields in both experiments. Sugar yields were increased by 12 and 14% in the 2000 and 2001 Experiments, respectively, by the application of this 'volunteer' residue treatment. The highest yields of sugar in both experiments, even exceeding those obtained with N fertilizer, resulted from the application of the high N 'volunteer' residue.

Plant N-Recovery

Mature wheat straw decreased and ‘volunteer’ wheat residue increased the N content in storage roots and tops at the final harvest (Table 4). In general, the data support the hypothesis that low-N wheat straw decreases the availability of soil inorganic-N while high-N ‘volunteer’ residue increases the availability of soil inorganic-N. As expected, application of N fertilizer increased the N content in sugarbeet plants at the final harvest.

Table 4. Influence of N fertilizer and two types of wheat residue on the N content in sugarbeet tops and roots at the final harvest.

Treatment		N in tops + roots	
N fertilizer lb N/acre	Wheat residue	2000 Experiment	2001 Experiment
		----- lb N/acre -----	
0	--	104	114
40	--	115	118
80	--	136	143
120	--	133	169
160	--	149	177
200	--	177	211
0	Mature straw (a) ¹	85	95
0	Mature straw (b) ¹	78	82
40	Mature straw (a) ¹	133	133
40	Mature straw (b) ¹	86	114
0	‘Volunteer’ (c) ²	112	145
0	‘Volunteer’ (d) ²	194	144
	Tukey (0.05)	40	45

¹Mature straw (a) = 1.5 tons/acre; Mature straw (b) = 3.0 tons/acre.

²2000 ‘Volunteer’ (c) = 1.2 tons/acre-2.91% N; ‘Volunteer’ (d) = 1.7 tons/acre-4.17% N.
2001 ‘Volunteer’ (c) = 0.94 tons/acre-3.45% N; ‘Volunteer’ (d) = 1.88 tons/acre-3.45% N.

Soil Inorganic-N

Soil nitrate-N in check plots of the 2000 and 2001 Experiments in the autumn prior to planting sugarbeets the following spring is given in Table 5. The sites were relatively low in soil nitrate, and consequently were ideal for N mineralization-immobilization studies involving residue decomposition. In particular, the low nitrate-N in the upper foot of soil allowed a precise determination of the effect of straw on soil inorganic-N during mid-and late spring.

Table 5. Soil nitrate-N in check (0 N) plots in the autumn prior to planting sugarbeets in the following spring.

Soil depth feet	2000	2001
	Experiment (10/28/99)	Experiment (10/19/00)
	----- lb NO ₃ -N/acre -----	
0-0.5	7 (0.4)	12 (0.8)
0-1.0	14 (0.8)	25 (2)
0-2.0	32 (6)	29 (12)
0-4.0	57 (12)	40 (16)
0-6.0	68 (15)	49 (13)

¹Numbers in parentheses are standard errors of relevant mean values.

Soil inorganic-N, principally nitrate-N, at the spring samplings during 2000 (Table 6) and 2001 (Table 7) was significantly reduced in the upper foot of soil by application of 3 tons/acre of straw. Of particular interest was the 2001 finding that application of 40 pounds urea-N/acre with the straw treatment was insufficient to bring the soil inorganic-N level up to that of the check plots (Table 7). Addition of straw apparently resulted in net immobilization of soil inorganic-N during straw decomposition. There was no evidence that net mineralization of N from the low-N wheat straw had occurred by late spring. Addition in the autumn of the high-N volunteer wheat residue resulted in net mineralization of residue N at each of the three spring samplings in 2001 (Table 7).

Post-harvest levels of soil nitrate-N were relatively low (Table 8). The 200 pounds urea-N/acre and the higher rate, high N 'volunteer' treatments increased slightly post-harvest levels of soil nitrate-N. However, very little of the N in the original treatments was accounted for by these increases.

Two to Six-Leaf Plants

As a result of the detrimental effect of straw on growth of sugarbeet plants in 2000, yield and chemical composition of 2 to 6-leaf plants at thinning were measured in 2001 (Table 9). Straw addition reduced dry matter yield and both N concentration and N content of young sugarbeet shoots. There was no evidence that an induced P deficiency was associated with the poorer growth of the straw-treated plants.

Petiole Nitrate-N

Petiole nitrate-N decreased during the growing season, irrespective of treatment, in both the 2000 (Table 10) and 2001 (Table 11) Experiments. The mature straw treatments reduced petiole nitrate at the second sampling in both experiments. The data suggest that straw addition accentuated N deficiency in the sugarbeet plants. The data also indicate that a value of less than 1,000 ppm nitrate-N in recently mature petioles harvested 8 weeks prior to root harvest does not necessarily indicate sub-optimal sugar yields.

GENERAL DISCUSSION

During my research with sugarbeets in the Red River Valley the questions most frequently asked concerned the efficacy of the soil nitrate-N test. Diverse comments such as "The soil nitrate-N test underestimates the quantity of required fertilizer N needed for sugarbeet production" to "The soil nitrate-N test overestimates the quantity of required fertilizer N needed for sugarbeet production" were commonly given. These contrasting opinions are not unexpected since soils differ in their capacity to mineralize 'native' soil organic N, and crop residues returned to soil differ in both content and concentration of N, factors influencing the availability of N in decomposing residue. For instance, the fact that significant quantities of N in high-N crop residues were mineralized between the taking of an autumn soil-nitrate test and the spring of the following year was known over 15 years ago (Moraghan, 1985; Moraghan and Ananth, 1985). As a result, wheat crops planted on prior-year sugarbeet fields with high-N sugarbeet tops, and requiring up to 100 pounds fertilizer N/acre according to the autumn soil-nitrate test, needed no N fertilizer for optimal yields exceeding 50 bushels/acre (Moraghan, 1999; Moraghan and Smith, 1996).

This multi-year study in the Red River Valley showed that incorporation of small-grain straw residues into soils low in soil nitrate increased the N-fertilizer requirement for optimal sugar production, as compared to the requirement on the same soils from which residues were removed. We found no evidence to support the recent claim (Hapka et al., 2001) that most of the N in low-N wheat straw was mineralized, and presumably made available for sugarbeet growth, by May 15 of the following year. On the contrary, the plant and soil inorganic-N data indicate that immobilization of soil inorganic-N during microbial decomposition of low-N straw was responsible for the increased N-fertilizer requirement.

How much N fertilizer is needed to account for additional immobilization of N during decomposition of low-N wheat straw? This is a difficult question to answer since residual straw is often unevenly distributed over the soil surface, and incorporation methods differ. Residues left on the soil surface are positionally separated from inorganic N in the upper foot of soil, and are less likely to immobilize rapidly soil inorganic-N as compared to their incorporated counterparts. Band application of N fertilizer, including anhydrous ammonia application, increases the likelihood that N fertilizer is 'fertilizing' the sugarbeet plants and not the soil microbial population attacking incorporated residues. If low-N straw residue is removed from the soil surface, the short-term effect is that the soil nitrate-N plus fertilizer-N value used for soil-test purposes probably could be reduced to at least 80 to 100 pounds

N/acre. However, straw removal in the long term may reduce the N-mineralization capacity of soils, and adversely affect soil quality.

Incorporation of plant residues may enhance denitrification and loss of soil nitrate-N during the initial decomposition flush after residue decomposition (Breland, 1994). Based on earlier ¹⁵N studies (Moraghan, unpublished data), I tend to reject this explanation for the mature straw effect. However, an unequivocal rejection of the denitrification hypothesis is not possible, and further studies are recommended. In any case, 'volunteer' residue—a very readily available source of oxidizable carbon for denitrification—increased and not decreased soil nitrate-N for sugarbeet growth.

'Volunteer' N-deficient (yellow), small-grain residues produced in late summer and early autumn, with yields up to 800 pounds/acre, are unlikely to have a major effect on soil-N dynamics and N-fertilizer requirements. However, high-yielding 'volunteer' growth – a consequence of an extended autumn growing season, availability of soil inorganic-N, and lack of cultivation – would reduce late autumn soil nitrate-N, and possibly increase subsequent soil-N mineralization. The beneficial effect of high-N 'volunteer' growth, as found in our research, requires additional study. This beneficial effect was not due solely to enhanced N availability since urea-N treatments were not as efficacious. In general, higher-rate N-fertilizer treatments increased petiole nitrate throughout the growing season more than 'volunteer' treatments.

Did wheat straw, in addition to causing N immobilization, restrict sugarbeet growth due to the presence or production of phytotoxins during decomposition? If this were so, removal of wheat straw from next-year sugarbeet fields may be a useful management technique for increasing sugar yields. I do not know unequivocally if phytotoxicity contributed to our lowered sugar yields with straw addition. Unfortunately, the highest rate of N fertilizer was only 40 pounds urea-N/acre with straw addition, a rate that increased sugar yields but not to levels greater than those with the check treatment. Forty pounds urea-N/acre in 2001 did not increase inorganic N in the top foot of soil in May and June to levels equal to those with the check treatment. Additional research is obviously needed. However, I speculate that phytotoxicity was also a factor causing lowered sugar yields for the following two reasons: (1) Early seedling growth was severely retarded despite the addition of 40 pounds urea-N/acre with mature straw; and (2) petiole nitrate-N with the combined addition was generally higher than that with the check treatment at the early samplings.

Controversy over phytotoxicity associated with stubble-mulch farming has occurred for many years. According to McCalla and Haskins (1964), "The presence of phytotoxic substances in plant residues and soil, and the production of such substances by microorganisms, may account in part for adverse effects of a particular crop in crop rotations, yield reductions encountered in stubble mulching...". Although much attention has been given to wheat straw in relation to phytotoxicity, rape and some leguminous crops exert more detrimental effects than wheat straw on germination and growth of wheat (Lovett and Jessop, 1982). The contrasting effects of wheat straw and other crop residues on the effects of N immobilization and phytotoxicity on growth of a wheat crop were extensively studied by Kimber (1967, 1973a, 1973b). He concluded "that germination is depressed to the greatest extent by straw lying on the surface of soil whereas N immobilization affects wheat yield the most if straw is buried".

My final recommendation is that sugar yields from commercial fields on which prior-year wheat straw was retained or removed should be monitored throughout the Valley. The method of incorporation of the straw, if any, should also be recorded. Such data may help to establish if phytotoxins associated with residue decomposition lower sugar yields in our region.

Table 6. Influence of wheat straw on soil inorganic-N in the 2000 N Fertilizer-Wheat Residue Experiment at the spring-sampling dates.

Mature straw tons/acre	Soil depth (inches)								
	0-6	6-12	0-12	0-6	6-12	0-12	0-6	6-12	0-12
	-----NH ₄ -N, lb/acre-----			-----NO ₃ -N, lb/acre-----			-----NH ₄ +NO ₃ -N, lb/acre-----		
					<u>5/9/00</u>				
0 (a)	2.0	1.5	3.5	19.8	6.9	26.7	21.8	8.4	30.2
3 (b)	<u>2.6</u>	<u>2.0</u>	<u>4.6</u>	<u>6.3</u>	<u>7.1</u>	<u>13.4</u>	<u>8.9</u>	<u>9.1</u>	<u>18.0</u>
a-b	-0.6*	-0.5 ^{NS}	-1.1*	13.5 ^{NS}	-0.2 ^{NS}	13.3 ^{NS}	12.9*	-0.7 ^{NS}	12.2*
					<u>5/23/00</u>				
0 (a)	1.7	1.1	2.8	17.5	9.2	26.8	19.2	10.4	29.6
3 (b)	<u>1.9</u>	<u>1.2</u>	<u>3.0</u>	<u>6.4</u>	<u>6.5</u>	<u>12.9</u>	<u>8.2</u>	<u>7.1</u>	<u>15.9</u>
a-b	-0.2 ^{NS}	-0.1 ^{NS}	-0.2 ^{NS}	11.1*	2.7 ^{NS}	13.9*	11.0*	3.3 ^{NS}	13.7*
					<u>6/6/00</u>				
0 (a)	1.5	1.3	2.8	18.7	10.1	28.8	20.2	11.4	31.6
3 (b)	<u>2.0</u>	<u>0.7</u>	<u>2.7</u>	<u>11.0</u>	<u>9.3</u>	<u>20.3</u>	<u>13.0</u>	<u>9.9</u>	<u>22.9</u>
a-b	-0.5**	0.6 ^{NS}	0.1 ^{NS}	7.7*	0.8 ^{NS}	8.5*	7.2 ^{NS}	1.5 ^{NS}	8.7*

¹ NS and * indicate not significant and significant at the P=0.05 level, respectively.

Table 7. Influence of wheat residues on soil inorganic-N in the 2001 N Fertilizer-Wheat Residue Experiment at three spring-sampling dates.

Treatment		Soil depth (inches)								
Type of residue (tons/acre)	Urea-N lb/acre	0-6	6-12	0-12	0-6	6-12	0-12	0-6	6-12	0-12
		-----NH ₄ -N, lb/acre-----			-----NO ₃ -N, lb/acre-----			-----NH ₄ +NO ₃ -N, lb/acre-----		
						<u>5/15/01</u>				
-(0)	0	2.0	1.5	3.6	8.8	12.2	21.0	10.8	13.8	24.5
Mature straw (3)	0	2.0	1.8	3.8	3.1	6.1	9.2	5.1	7.9	13.0
Mature straw (3)	40	2.5	1.6	4.1	5.0	16.1	20.1	7.5	17.7	25.2
'Volunteer' (1.88)	0	2.4	2.2	4.6	18.5	19.9	38.3	20.9	22.1	42.9
LSD (P=0.05)		NS	NS	NS	2.2	7.9	8.2	2.4	8.2	8.2
						<u>5/29/01</u>				
-(0)	0	1.7	2.3	4.0	12.8	11.8	24.6	14.5	14.1	28.6
Mature straw (3)	0	2.7	1.9	4.6	4.2	6.6	10.9	6.9	8.6	15.4
Mature straw (3)	40	3.0	1.9	4.9	5.1	7.5	12.6	8.1	9.4	17.5
'Volunteer' (1.88)	0	2.5	2.3	4.8	20.0	22.8	42.8	22.4	25.1	47.6
LSD (P=0.05)		0.6	NS	NS	4.8	2.5	5.8	4.8	2.6	6.1
						<u>6/12/01</u>				
-(0)	0	1.2	3.0	4.2	14.4	13.3	27.6	15.6	16.3	31.9
Mature straw (3)	0	1.1	1.9	3.0	5.9	7.2	13.1	7.0	9.0	16.0
Mature straw (3)	40	1.1	1.6	2.7	7.8	11.0	18.7	8.8	12.6	21.4
'Volunteer' (1.88)	0	1.1	1.6	2.7	26.7	25.6	52.4	27.8	27.2	55.0
LSD (P=0.05)		NS	0.9	1.2	5.4	8.1	5.8	5.3	3.7	6.0

Table 8. Influence of selected treatments on soil nitrate-N after sugarbeet root harvests in 2000 and 2001.

Treatment		Soil depth (feet)			
Urea-N lb/acre	Wheat residue (tons/acre)	0-1	0-2	0-4	0-6
		----- NO ₃ -N, lb/acre -----			
<u>2001</u>					
0	-(0)	3.7	5.2	7.8	9.8
0	Mature straw (3)	4.0	5.9	8.4	11.0
0	'Volunteer' (1.88)	5.0	7.2	10.5	13.9
200	-(0)	4.9	6.8	10.1	13.9
	Tukey (0.05)	NS	NS	NS	3.9
<u>2000</u>					
0	-(0)	6.0	7.6	9.6	11.3
0	'Volunteer' (1.7)	12.0	13.8	18.4	21.4
200	-(0)	11.1	13.1	16.5	19.2
	Tukey (0.05)	2.1	3.8	4.5	5.6

Table 9. Selected characteristics of shoots of sugarbeet seedlings at the 2 to 6-leaf growth stage (thinning) in the 2001 N Fertilizer-Wheat Residue Experiment at Crookston.

Treatment		Dry matter g/25 plants	N %	N mg/25 plants	P %	P mg/25 plants
Urea-N lb/acre	Wheat residue ¹					
0	--	2.85	4.23	122	0.36	10.5
40	--	3.28	4.37	144	0.33	11.0
80	--	2.74	4.33	119	0.31	8.7
120	--	3.24	4.50	147	0.31	10.2
160	--	3.00	4.57	138	0.31	9.4
200	--	3.16	4.64	148	0.30	9.7
0	Mature straw (a) ¹	1.36	3.87	53	0.31	4.3
0	Mature straw (b) ¹	1.24	3.83	48	0.34	4.2
40	Mature straw (a) ¹	2.04	4.17	85	0.34	7.0
40	Mature straw (b) ¹	1.26	3.90	49	0.30	3.8
0	'Volunteer' (c) ²	3.02	4.37	133	0.35	10.8
0	'Volunteer' (d) ²	3.50	4.40	154	0.34	11.8
	SE	0.22	0.07	11	0.02	1.1
	CV	21	4	24	13	33
	<u>F test probabilities</u>	<0.01	<0.01	<0.01	NS	<0.01

¹Mature straw (a) = 1.5 tons/acre; Mature straw (b) = 3.0 tons/acre.

²'Volunteer' (c) = 0.94 tons/acre-3.45% N; 'Volunteer' (d) = 1.88 tons/acre-3.45% N.

Table 10. Nitrate-N in recently mature sugarbeet petioles from the 2000 N Fertilizer-Wheat Residue Experiment at Crookston.

Treatment N fertilizer lb/acre	Wheat residue ¹	Date of sampling					
		7/14/00	7/27/00	8/10/00	8/24/00	9/7/00	9/21/00
----- 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) ¹	2,340	130	160	220	190	90
0	Mature straw (b) ¹	1,310	210	110	60	40	10
40	Mature straw (a) ¹	4,840	1,900	880	220	320	110
40	Mature straw (b) ¹	2,500	360	40	10	7	1
0	'Volunteer' (c) ²	4,270	590	160	110	70	25
0	'Volunteer' (d) ²	6,360	2,080	920	510	730	360
	SE	798	621	533	187	211	115
	F test probabilities	<0.001	<0.001	<0.001	<0.05	<0.05	NS

¹Mature straw (a) = 1.5 tons/acre; Mature straw (b) = 3.0 tons/acre.

²'Volunteer' (c) = 1.2 tons/acre -2.91% N; 'Volunteer' (d) = 1.7 tons/acre-4.17% N.

Table 11. Nitrate-N in recently mature sugarbeet petioles from the 2001 N Fertilizer-Wheat Residue Experiment at Crookston.

Urea-N lb/acre	Treatment Wheat residue ¹	Date of sampling					
		7/5/01	7/20/01	8/2/01	8/16/01	8/29/01	9/13/01
----- NO ₃ -N, ppm -----							
0	--	2,960	1,480	323	128	198	125
40	--	10,350	2,660	408	154	74	34
80	--	14,140	6,770	1,576	450	138	60
120	--	15,440	8,400	4,290	720	253	89
160	--	15,820	10,900	5,240	1,770	1,174	413
200	--	15,480	11,250	7,190	4,720	2,021	1,099
0	Mature straw (a) ¹	2,880	660	46	9	19	24
0	Mature straw (b) ¹	2,980	670	7	2	7	4
40	Mature straw (a) ¹	10,500	2,510	413	104	11	25
40	Mature straw (b) ¹	8,350	1,470	259	353	284	229
0	'Volunteer' (c) ²	9,370	2,520	335	428	413	409
0	'Volunteer' (d) ²	11,070	2,420	490	101	20	7
	SE	808	940	558	285	289	184
	F test probabilities ²	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01

¹Mature straw (a) = 1.5 tons/acre; Mature straw (b) = 3.0 tons/acre.

²'Volunteer' (c) = 0.94 tons/acre-3.45% N; 'Volunteer' (d) = 1.88 tons/acre-3.45% N.

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