Cropping Systems to Remove Excess Soil Nitrate In Advance of Sugarbeet Production

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INTRODUCTION

A 4-to 9-week period of nitrogen (N) deficiency prior to harvest increases sucrose content and reduces impurities in the sugarbeet (*Beta vulgaris* L.) root (1, 2, 3). Providing adequate N early in the growing season followed by the proper period of N deficiency will result in a satisfactory yield of high quality sugarbeets.

Sugarbeets root deeper than most annual crops growing in rotation. In Nebraska, sugarbeets planted in mid-April used N from below 180 cm beginning in August (4). In Texas, N use by sugarbeets from at least 300 cm has been reported (5). This deep rooting characteristic of sugarbeets, combined with deep residual N lowers sucrose content and purity.

The objectives of this study were to determine the efficiency of five cropping systems for removal of excess residual nitrate-nitrogen (nitrate-N) to a depth of 360 cm and to determine subsequent effects on sugarbeet production.

MATERIALS AND METHODS

The study was conducted at Bushland, Texas on Pullman clay loam soil (fine, mixed, thermic Torrertic Paleustolls) which is deep, slowly permeable, and well drained. The study area, while in fallow, was heavily fertilized with ammonium nitrate on three occasions from February to June 1980. Total N applied during this period was 816 kg/ha. After each fertilizer application, 10 to 12 cm of irrigation water was applied. Soil samples were taken in

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60-cm increments to 360-cm depth in July 1980 to determine the nitrate-N content of the soil prior to establishing the cropping systems. Additional soil samples were taken in December 1981 and January 1983 to determine nitrate-N removal by cropping. Soil samples were dried at 70°C and nitrate-N was determined using a nitrate ion electrode.

Five cropping systems were tested for ability to remove residual nitrate-N: 1) winter wheat (*Triticum aestivum* L.) double cropped to corn (*Zea mays* L.), 2) winter wheat double cropped to sunflower (*Helianthus annus* L.), 3) alfalfa (*Medicago sativa* L.) inoculated, 4) alfalfa not inoculated, and 5) tall wheatgrass [*Agropyron elongatum* (Host) Beau 'Jose'], a perennial cool season grass. All crops were cut at the bloom stage and removed as a forage crop to maximize N removal. The initial wheat, alfalfa, and wheatgrass seedings were made in September 1980. Irrigation was adequate for near maximum growth during the period September 1980 to June 1982. After harvest of wheat, alfalfa, and wheatgrass in June 1982, the area was disk and chiseled to kill all vegetation and then fallowed until sugarbeets were planted in the spring of 1983.

The planting of sugarbeets was delayed by very cold, wet weather in 1983. In addition, the initial planting was destroyed by hail on May 13. 'Mono-Hy TX9' was replanted May 25 on 76 cm beds. The resulting stand was thinned to a 20 cm spacing on June 24. Plots were 3 m by 10 m with four replications in a randomized complete-block design. Treatment means were separated by using Duncan's multiple-range test at the 5% level of significance.

RESULTS AND DISCUSSION

Forage yields harvested from the five cropping systems are presented in Table 1. The wheat, alfalfa, and wheatgrass planted in September 1980 grew well and produced good forage yields on June 10, 1981. Forage yields on subsequent harvests were in some cases limited by N deficiency, lack of regrowth, or bad weather. The highest total forage yield was produced by the wheat-corn system

Table 1. Forage yields and total nitrogen removed in the forage harvested from five cropping systems in 1981 and 1982 at Bushland, Texas.

Cropping system	Oven Dry Forage 6/10/81	7/14/81	10/4/81	6/2/82	Total	Total nitrogen in forage	Nitrate-N loss from soil*
	t/ha					kg/ha	kg/ha
Wheat-corn	15.0 a**	0.0	4.0 b	5.4 a	24.4 a	276 c	363 c
Wheat-sunflowers	13.4 a	0.0	1.6 d	5.6 a	20.6 b	354 bc	504 b
Alfalfa-inoc.	4.7 c	2.2	2.5 cd	4.5 a	13.9 c	456 a	654 a
Alfafla not inoc.	4.9 c	2.2	3.4 bc	4.3 a	14.8 c	473 a	648 a
Wheatgrass	9.0 b	0.0	5.1 a	4.9 a	19.0 b	436 ab	625 a

* Measured difference in soil nitrate-N to 360 cm depth between July 1980 and January 1983.

** Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple-range test.

Table 2. Soil nitrate-N content measured on three dates prior to planting sugarbeets.

Soil depth	July 1980	December 1981 wheat-corn	wheat-sunflr	alfalfa inoc	alfalfa not inoc	whtgrass	January 1983 wheat-corn	wheat-sunflr	alfalfa inoc	alfalfa not inoc	whtgrss
cm	kg/ha										
0-60	228	21	37	19	27	16	84	68	68	71	44
60-120	155	21	56	28	11	12	45	62	58	64	22
120-180	193	140	121	56	40	52	96	36	21	32	28
180-240	113	128	136	83	48	92	124	85	28	32	47
240-300	110	95	99	99	52	102	96	79	27	21	60
300-360	91	88	80	88	86	82	80	56	32	20	63
TOTAL	889	493	527	373	263	355	526	385	235	241	264

and the lowest by alfalfa. Wheatgrass growth was primarily during the cooler spring and fall seasons and was intermediate in total forage yield.

Alfalfa, despite lower forage yield, was higher in nitrogen content and, therefore, had the most total N removed in the forage (Table 1). Nitrogen removal, as measured in the forage for all cropping systems, averaged 72 percent of the loss of nitrate-N measured with soil samples. A high correlation (r = .99) was found between total forage N and soil nitrate-N loss. The nitrate-N loss not accounted for by forage removal may have been lost from the soil by leaching, denitrification, or incorporation into the soil N fraction.

Soil nitrate-N distribution by depth increments before, during, and after cropping is presented in Table 2. Alfalfa was the most efficient crop tested for removing nitrate-N, especially that below 180 cm. It left the soil with the least amount and most optimum profile distribution of nitrate-N prior to planting sugarbeets. The annual, double-crop systems did not effectively reduce nitrate-N below 120 to 180 cm. These systems could do more harm than good by removing shallow nitrate-N needed early by sugarbeets to produce high root yield while leaving the deep nitrate-N for late season uptake detrimental to sugar accumulation. Wheatgrass removed almost as much total nitrate-N as alfalfa, however, the distribution of nitrate-N remaining for sugarbeets was not nearly as favorable. Following wheatgrass, 64% of the residual nitrate-N was below 180 cm compared to only 30 and 37% with the two alfalfa systems.

Sugarbeet production as influenced by the five cropping systems is presented in Table 3. Root yield was highest following alfalfa, intermediate after the annual crops, and lowest after wheatgrass. Sugarbeets following alfalfa had greater top growth during the middle part of the growing season. This was probably due to improved N nutrition although petiole nitrate-N analyses were inconclusive (Table 3). Sucrose content was highest in the

Table 3. Sugarbeet root yield, sucrose, brei nitrate, and petiole nitrate in 1983 after five cropping systems at Bushland, Texas.

Cropping system	Root yield	Sucrose	Sucrose yield	Petiole nitrate N 7-27	8-10	8-26	9-16
	t/ha	%	t/ha	-------- ppm/1000			--------
Wheat-corn	34.0 b*	16.12 b	5.48 b	19.0 a	2.6 b	2.8 bc	1.2 b
Wheat-sunflower	31.8 b	16.19 b	5.15 b	16.3 a	5.0 b	3.6 b	2.3 a
Alfalfa inoc	41.7 a	15.86 b	6.61 a	23.7 a	9.2 a	5.8 a	2.7 a
Alfalfa not inoc	43.2 a	16.10 b	6.96 a	21.8 a	5.3 b	3.8 b	2.8 a
Wheatgrass	24.9 c	16.93 a	4.22 c	16.2 a	3.4 b	1.9 c	0.7 b

* Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple-range test.

sugarbeets following wheatgrass, apparently due to low soil nitrate-N in the upper 180 cm of that treatment.

Inoculation of alfalfa had no effect on extraction of soil nitrate-N or subsequent sugarbeet production. There was also no difference in alfalfa forage production due to inoculation. In this study, N deficiency and probable forage yield loss was evident on the corn and sunflowers harvested in 1981 and the wheat harvested in 1982. Wheat forage yield in 1982 was only about 1/3 of the 1981 yield.

Sugarbeet establishment in 1983 was delayed two months by adverse weather conditions. With an earlier more normal planting date, a greater impact on the sucrose content of sugarbeets would have been expected with the superior nitrate-N distribution in the soil profile following alfalfa. In previous research, excessive nitrate-N below 180 cm has reduced sucrose by as much as 2.0 percentage points (5). Earlier planting should have resulted in greater rooting depth which would have reduced sucrose content of the sugarbeets following wheat-corn, wheat-sunflower, and wheatgrass.

SUMMARY

Five cropping systems were tested for their ability to remove a high level of profile nitrate-N (889 kg/ha to 360 cm) from Pullman clay loam soil and for their effect on subsequent sugarbeet production.

Alfalfa was the most efficient crop tested for re-

moving deep nitrate-N. It provided the most optimum amount and profile distribution of nitrate-N prior to planting sugarbeets. The wheat-corn and wheat-sunflower systems did not effectively reduce nitrate below 120 to 180 cm. Wheatgrass removed a large amount of nitrate but 64% of the remaining nitrate was below 180 cm compared to 30 to 37% for alfalfa.

Nitrogen deficiency and probable yield loss occurred on the corn and sunflowers harvested in 1981 and the wheat harvested in 1982. Wheat was N deficient in 1982 and forage yields were only about 1/3 the yield in 1981.

Sugarbeet root yield and sugar yield were greatest following alfalfa. Root yield was reduced by mid-season N deficiency following the other cropping systems. Sucrose content of sugarbeet roots was highest but root yield lowest following wheatgrass due to the very low nitrate-N level in the 0 to 180 cm soil profile of that treatment.

REFERENCES

1. Carter, J. N. 1982. Effect of nitrogen and irrigation levels, location and year on sucrose concentration of sugarbeets in southern Idaho. J. Am. Soc. Sugar Beet Technol. 21:286-306.

2. Hills, F. J., G. V. Ferry, A. Ulrich, and R. S. Loomis. 1963. Marginal nitrogen deficiency of sugarbeets and the problem of diagnosis. J. Am. Soc. Sugar Beet Technol. 12:476-484.

3. Loomis, R. S. and D. J. Nevins. 1963. Interrupted nitrogen nutrition effects on growth, sucrose accumulation, and foliar development of the sugarbeet plant. J. Am. Soc. Sugar Beet Technol. 12:309-322.

4. Peterson, G. A., F. N. Anderson, G. E. Varvel, and R. A. Olson. 1979. Uptake of 15N-labeled nitrate by sugarbeets from depths greater than 180 cm. Agron. J. 71:371-372.

5. Winter, S. R. 1981. Nitrogen managment for sugarbeets on Pullman soil with residual nitrate problems. J. Am. Soc. Sugar Beet Technol. 21:41-49.