Safflower Helps Recover Residual Nitrogen Fertilizer[1]

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Using less than 40 pounds of nitrogen fertilizer per acre may be more efficient for dryland spring wheat under some conditions.

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The purposes of this paper are to report the distribution and quantity of nitrate-N found in a 10-foot soil profile following 11 years of a spring wheat-fallow sequence where three nitrogen rates were applied each of six crop years and the effectiveness of safflower in removing residual nitrate-N from the soil profile.

Summer fallowing in the northern Great Plains has contributed to a decline in soil organic matter; consequently the amount of nitrogen (N) released from soil organic matter annually has also declined (Bauer and Black, 1981; Campbell and Souster, 1982; Haas et al., 1957 and 1974). To maintain and/or increase cereal grain yields in the northern Great Plains, the amount of nitrogen fertilizer applied has increased during the last two decades (Black et al., 1974; Hargett and Berry, 1981).

Nitrogen fertilization of fallowed soils creates a potential for having excess nitrogen available for plant growth. Under dryland conditions, nitrogen fertilizer not removed by crops normally remains within the root zone. However, some of the nitrogen can be leached below the root zone during the fallow period and become unavailable to cereal grain crops (Campbell et al., 1984). Occurrence of saline seeps in the northern Great Plains is evidence that water percolates below the root zone in a crop-fallow sequence (Halvorson and Black, 1974). Nitrate-N (NO_3-N) accumulations during the fallow period can range from 52 to 103 lbs. nitrogen per acre and averaged 79 lbs. N/A in 3-foot soil profiles from 10 different soil types located throughout North Dakota (Swenson et al., 1979). Similar levels of soil nitrate-N accumulation have been reported by French and Riveland (1980) and Campbell et al. (1983). Efficient use of nitrogen fertilizers requires that excess nitrogen not be applied to a crop. Therefore, information on the long-term effects of nitrogen fertilization on residual soil nitrate-N accumulation is needed.

Methods and Materials

The study was conducted on the Soil Conservation District Research Farm near Culbertson, Mont., on a Williams loam soil (fine-loamy mixed, Typic Argiboroll). Alternate spring wheat-fallow plots were established on fallow in 1967 and 1968 so that one series of plots was fallowed and the other cropped each year through 1978. Six spring wheat crops were grown on each series over the 11-year period except when winter wheat was grown as the sixth crop on the 1968 plot series. In both cases safflower was grown the very next year as the seventh crop without a fallow period between crops. Ammonium nitrate (34-0-0) was applied at rates of 0, 40 and 80 lbs. N/A each of six crop years as main plots in a randomized block, split-plot design with three replications. Phosphorus (P) was applied at rates of 0, 20, 40, 80 and 160 lbs. P/A as subplots as described by Black (1982). Phosphorus was applied only once, at the start of the study. Nitrogen fertilizer was broadcast and incorporated in the 0- to 3-inch soil depth with a tandem disk each crop year just before planting spring wheat. No nitrogen or phosphorus fertilizer had been applied to the plot areas prior to 1967.

Soil samples were taken after harvest of the sixth wheat crop of each series at 1-foot increments to a depth of 10 feet on Sept. 6, 1977, from the 0 and 160 lb. P/A treatments at each of the nitrogen rates of the 1967 plot series and from these same treatments of the 1968 plot series on Oct. 6, 1978. Soil samples were collected again from these same nitrogen and

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phosphorus treatments to a depth of 10 feet following safflower harvest. All plots of the 1968 plot series were sampled on June 4, 1980, to further evaluate the abnormally high levels of nitrate-N found in its post-sampling Nov. 13, 1979. Soil samples were air-dried, ground to pass a two mesh sieve, extracted with deionized water, and analyzed for nitrate-N using a cadmium reduction autoanalyzer method (Technicon, 1973).

The safflower grown in 1978 and 1979 did not receive additional nitrogen fertilizer. That way, crop response to the residual nitrate-N in the soil profile could be evaluated. Safflower grain yields and nitrogen uptake from each nitrogen and phosphorus treatment were measured. Yield and nitrogen uptake data reported here for a given nitrogen fertilizer treatment represent an average of all phosphorus treatments at the nitrogen level.

The yield, nitrogen uptake, and soil nitrate-N data were analyzed using a standard split-plot analysis of variance. All differences were evaluated at the 90 percent and 95 percent confidence levels.

Results and Discussion

After 11 years of spring wheat-fallow cropping, more nitrate-N was measured in the 10-foot soil profiles of those plots that had received 40 and 80 lbs. N/A each crop year than in plots that had received no nitrogen fertilizer (Figures 1 and 2). In the 1967 plot series, 160, 241 and 471 lbs. N/A was present on Sept. 6, 1977, in the 0- to 10-foot soil profile of the former 0, 40 and 80 lbs. N/A plots, respectively, while 72, 150 and 284 lbs. N/A was present on Oct. 6, 1978, in the 1968 plot series following harvest of the sixth wheat crop. The differences in profile soil nitrate-N levels between nitrogen treatments were significant at the 95 percent confidence level for both plot series.

The difference in soil profile residual nitrate-N levels measured between plot series following the sixth crop may possibly be due to differences in wheat yield levels, nitrogen uptake, and precipitation. The 1967 plot series averaged about 7 bu/A less grain yield each year because crop growing season precipitation averaged about 4.4 inches less than for the 1968 plot series (Black, 1982). Nitrogen removal in the grain each year by the wheat crop averaged 46, 53 and 55 lbs. N/A for the 1967 plot series versus 45, 60 and 63 lbs. N/A for the 1968 plot series for the 0, 40 and 80 lbs. N/A fertilizer treatments, respectively. The 1967 plot series was in fallow during the higher precipitation years and consequently, more leaching of nitrate-N (Campbell et al., 1984) could have occurred in the 1967 plot series. This may explain the higher levels of soil nitrate-N measured at greater depths (Figure 1) for the

FIGURE 1.
Soil nitrate-N level as a function of soil depth on Sept. 6, 1977, and Oct. 6, 1978, for the 0, 40 and 80 lbs. N/A treatments of the 1967 plot series.

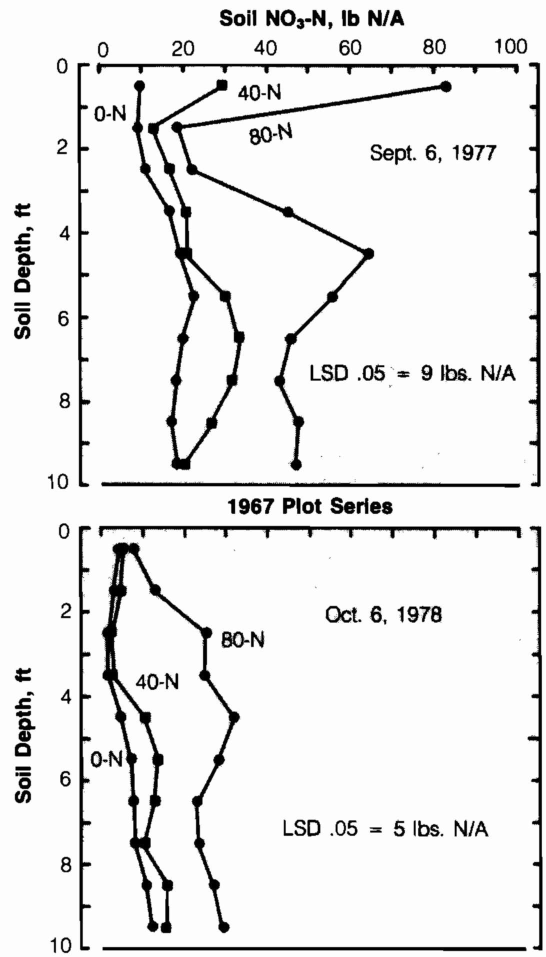

FIGURE 2.
Soil nitrate-N level as a function of soil depth on Oct. 6, 1978, for the 0, 40 and 80 lbs. N/A treatments of the 1968 plot series.

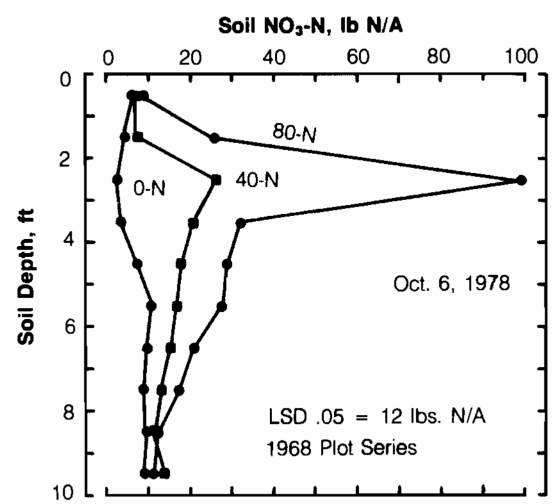

TABLE 1.
Average grain yield and nitrogen uptake of safflower.

Plot Series	Crop Year	Former N Treatment	Grain Yield	Nitrogen Uptake*
		lbs N/A	*lbs/A*	*lbs N/A*
1967	1978	0	1337	34
		40	1723	61
		80	1789	80
		LSD (.10)	321	13
1968	1979	0	1019	47
		40	1334	69
		80	1424	76
		LSD(.05)	231	11

**Includes grain + straw.*

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1967 plot series than found for the 1968 plot series (Figure 2), following harvest of the sixth wheat crop.

Safflower was chosen to immediately follow the last wheat crop because it is a relatively deep-rooted crop (about 6 feet in depth) under dryland conditions (Black et al., 1981) and had the potential to remove some of the residual nitrate-N that had accumulated below the 3-foot soil depth. Safflower grain yields were significantly higher on the former 40 and 80 lbs. N/A plots than on the plots receiving no nitrogen fertilizer for both plot series (Table 1). Low rainfall during the 1979 growing season probably limited the safflower yields.

Safflower nitrogen uptake (grain plus straw) averaged 34, 61 and 80 lbs. N/A in 1978 and 47, 69 and 76 lbs. N/A in 1979 for the former 0, 40 and 80 lbs. N/A fertilizer treatments, respectively (Table 1). Nitrogen uptake by safflower was significantly greater on the former 40 and 80 lbs. N/A treatments than for the no nitrogen treatment. Although safflower yields were higher in 1978 than 1979, the nitrogen uptake for the same nitrogen treatments were similar for both plot series.

Residual nitrate-N levels in the soil profile were reduced in the 1967 plot series by cropping the plots with safflower as shown by the decrease in nitrate-N from Sept. 6, 1977, to Oct. 6, 1978 (Figure 1). Total nitrate-N in the 10-foot soil profile averaged 59, 77 and 231 lbs. N/A for the 0, 40 and 80 lbs. N/A treatments on Oct. 6, 1978.

An unexplainable increase in nitrate-N was measured in the soil samples collected on Nov. 13, 1979, following safflower harvest on the 1968 plot series, when compared to the Oct. 6, 1978, samples. Total nitrate-N in the 10-foot soil profile averaged 810, 944 and 963 lbs. N/A for the 0, 40 and 80 lbs. N/A treatments, respectively, at the Nov. 13, 1979, sampling. Reasons for this large increase in measured nitrate-N levels have not been ascertained at this time. Sample contamination and analytical errors were not the reason for the observed increase in soil nitrate-N. Increases in soil nitrate-N levels from spring to fall soil sampling have been observed in other safflower studies conducted in Montana by the authors (unpublished data).

Soil samples were collected again on April 25, 1980, from the 1968 plot series. Measured soil nitrate-N levels were much lower at this date with total nitrate-N levels in the 10-foot soil profile averaging 145, 139 and 259 lbs. N/A for the 0, 40 and 80 lbs. N/A treatments, respectively. We can offer no explanation for the reduction in nitrate-N level over winter. Comparing the nitrate-N results of the Oct. 6, 1978, soil sampling with the April 25, 1980, sampling shows that the 0- to 10-foot profile had an increase in nitrate-N level of 73 lbs. N/A for the previous zero N treatment and a decrease of 11 and 25 lbs. N/A for the 40 and 80 lbs. N/A treatments, respectively. For unknown reasons, we did not find the expected amount of decrease in residual nitrate-N in the 1968 plot series that we found in the 1967 plot series, even though nitrogen uptake by safflower was very similar for both series. These data point out the potential danger of making erroneous nitrogen fertilizer recommendations for the next crop based on soil samples taken from a safflower field shortly after harvest.

Summary and Conclusions

Accumulations of residual nitrate-N were measured in the 0- to 10-foot soil profile following six applications of 40 and 80 lbs. N/A to an 11-year spring wheat-fallow cropping sequence. An average of 80 and 262 lbs. lbs./A more nitrogen was found in the 0- to 10-foot soil profile of the 40 and 80 lbs. N/A plots, respectively, than in the no nitrogen fertilizer plots following harvest of the sixth wheat crop in a crop-fallow sequence. These data indicate that application of 40 or 80 lbs. N/A supplied much more fertilizer nitrogen than spring wheat could use when grown on previously fallowed soils. Rates of N fertilizer less than 40 lbs. N/A may be more efficient for dryland spring wheat grown in a crop-fallow sequence in some parts of the northern Great Plains.

One crop of safflower lowered the soil profile residual nitrate-N level. Nitrogen uptake (grain plus straw) by safflower averaged 41, 65 and 78 lbs. N/A from previous 0, 40 and 80 lbs. N/A treatments, respectively. These data illustrate that fertilizer nitrogen leached below the root zone of cereal grain crops can be partially recovered by growing a deep-rooted crop like safflower.

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