Reprinted from the *Soil Science Society of America Journal*
Volume 42, no. 6, November–December 1978
677 South Segoe Rd., Madison, WI 53711 USA

Residual Nitrate-N in Fine Sand as Influenced By N Fertilizer and Water Management Practices[1]

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ABSTRACT

A better understanding of the severity of NO^3-N movement out of the crop root zone in irrigated sandy soils is needed. The objective of this study was to determine residual NO^3-N after the corn (*Zea mays L.*) growing season from N applied at rates of (i) 112, (ii) 224, and (iii) 336 kg/ha in 1974 and (iv) 168, (v) 250, and (vi) 324 kg/ha in 1975. Nitrogen was applied as a single broadcast (B) application at the beginning of the corn growing season or injected (S) through the irrigation system at five equal increments before tasseling. Water application for both N application methods was attempted to be 0.8 W_2 water application treatment, residual NO_3–N averaged 0.22 kg/ during all but the first 6 weeks of corn growth.

When N was broadcast-applied at seeding very little residual NO_3-N remained in the 150-cm sampling depth after the crop growing season, regardless of N application rate or water application amount. When the N was applied through the irrigation system (injected N), only the W_3 water application treatment resulted in leaching all NO^3-N below the crop root zone. With injected N and W_2 water application treatment, residual NO_3–N averaged 0.22 kg/ha for each kg/ha of N applied. With injected N and W_1 application treatment NO_3-N increased linearly at 0.43 kg/ha for each kg/ha of applied N above the B_4 rate. At lower N application rates, residual NO_3-N was very low because this amount of N nearly equalled plant uptake. No overwinter NO_3-N was lost with the injected N treatments. These results showed that the injected N application method with proper water application management can greatly reduce the potential for NO_3-N movement below the corn crop rooting zone on fine sand soils.

Additional Index Words: **Broadcast N, injected N, water applications.**

Smika, D. E., and D. G. Watts. 1978. Residual nitrate-N in fine sand as influenced by N fertilizer and water management practices. Soil Sci. Soc. Am. J. 42:923–926.

THE USE of agricultural fertilizers has frequently been cited as the major cause of groundwater pollution. However, factual information for assessing the severity of the problem is limited. Nitrate-N movement through soil with deep percolation of water is of greatest concern because of the solubility of the NO_3^- ion.

Proper management of N and water are extremely important for irrigated corn production on sandy soils. Excess water may directly cause leaching of NO_3-N below the crop root zone, while winter and spring precipitation may leach residual NO_3-N in the profile below the root zone. However, research reported since 1971 indicated that very little NO_3-N moves below the crop rooting depth when fertilizer and/or irrigation water are managed to provide only the crop needs (1, 3, 4, 5, 6).

The application of fertilizer N will in part be taken up by plant growth, immobilized, denitrified, or left in the soil as NO_3-N. The fate of the residual NO_3-N is of most concern, therefore we conducted this study to determine differences in residual soil NO_3-N when we applied fertilizer N at rates above, below, and approximately equal to estimated crop needs in either single or periodic applications during the growing season with irrigation water at rates above, below, and approximately equal to crop water needs.

METHODS AND MATERIALS

This experiment was conducted on the Univ. of Nebraska Sandhills Agric. Lab. located 72 km north of North Platte, Nebraska. The soil of the experimental area is a Valentine fine sand (Ustipsamment) with an organic matter content of 1.0% in the 0 to 30-cm depth, decreasing to less than 0.2% at the 40-cm depth and remaining at this low level to a 3-m depth (the deepest depth sampled). The cation exchange capacity (CEC) of the soil is 6.4 meq/100 g soil in the surface 30 cm and < 1 meq/100 g soil at greater depths. The average available water holding capacity is 0.09 cm/cm to the 30-cm depth and 0.07 cm/cm from the 30- to 180-cm depth. Discontinuous silt lenses (1 to 2 cm thick) are present at depths ranging from 90- to 130-cm below the soil surface, which temporarily restrict the downward flow of water.

A split-split plot design was used with fertilizer application method as main plots, water rates as subplots, and N rates as sub-subplots. Main plots were 110 m by 91 m, subplots were 91 by 36 m and sub-subplots were 36 x 18 m with 18-m wide areas between each sub-subplot.

Nitrogen fertilizer rates for corn (*Zea mays L.*) were 112, 224, and 336 kg/ha the first year and 168, 250, and 324 kg/ha the second year designated as rates 1, 2, 3, 4, 5, and 6, respectively. The low, medium, and high N rates were applied on the same respective plots each year. The rate changes the second year were made to more nearly reflect what was determined as grower use practices. Fertilizer was applied either as a single broadcast (B) application of NH_4NO_3, just after planting or as equal split application of liquid urea-NH_4NO_3, injected through the solid set sprinkler irrigation system (S) on July 2, 10, 18, 24, and 31. The last application was at tasseling growth stage of the corn. Water application treatments (irrigation plus rainfall) were designed to be 0.8 (W_1), 1.1 (W_2) and 1.5 (W_3) times actual plant evapotranspiration (ET) for the entire growing season. However, early during both seasons excess rainfall prevented a total season deficit with the W_1 water treatment and resulted in varying amounts of total water applied for the two seasons. Since each two week period was attempted to be managed at the desired water level irrespective of previous total water there are differences between years because of rainfall differences between years. Actual total season water treatments for 1974 and 1975, respectively were: W_1, ET + 9.9-cm water and ET + 17.3-cm water; W_2, ET + 13.4-cm water and ET + 20.5-cm water; and W_3, ET + 36.1-cm water and ET + 31.5-cm water. We determined actual ET daily from hydraulic pillow lysimeters (2) located on the S_2W_2 and S_5W_2 treatment plots. Lysimeters were 1.2 by 1.8 m by 1.2-m deep.

Eighteen soil cores, half from within corn rows and half between corn rows randomly located within each sub-subplot were collected at 30-cm increments to a 150-cm depth just before spring seeding and immediately after fall harvest for NO_3^-N and and NH_4-N analyses. Nitrate-N was determined by the phenoldisulfonic acid method. Exchangeable NH_4-N was determined by steam distillation and titration.

[1]Contribution from Soil, Water, and Air Sciences, Science & Education Administration, USDA in cooperation with the Univ. of Nebraska, North Platte Station. Published as Journal Paper no. 5395, Nebraska Agric. Expt. Stn. Received 30 Jan. 1978. Approved 7 Aug. 1978.

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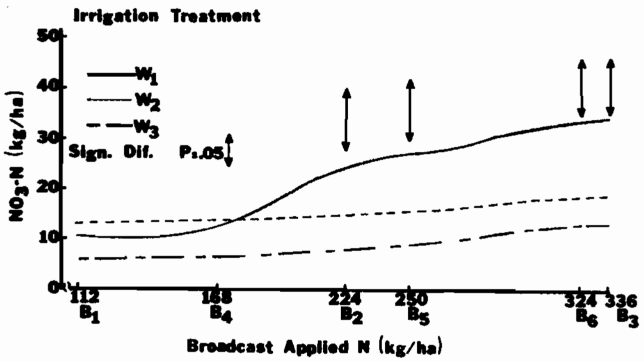

Fig. 1.—Nitrate-N in the soil to 150-cm depth, at fall sampling with broadcast N applications and three water application treatments during the growing season.

RESULTS AND DISCUSSION

Nitrogen fertilizer application method, rate, and water application amount all affected the amount of NO_3-N remaining in the soil at the end of the growing season. The amount of exchangeable NH_4 in the soil profile after harvest was not affected by amount of water applied or N rate but was somewhat lower when fertilizer N was injected as compared with broadcasted N.

When all of the N was applied in a single broadcast application immediately after planting, amounts of NO_3-N in the 150-cm soil depth, were generally very low except with the W_1 water treatment (Fig. 1). For broadcast-applied N the B_1 and B_4 rates had less than 20 kg/ha residual NO_3-N in the 150-cm soil depth, regardless of the amount of water applied. For B_2, B_3, B_5, and B_6 N application rates with W_2 and W_3 water applications, NO_3-N in the 150-cm soil depth was less than 20 kg/ha. However, with the W_1 water application, residual NO_3-N amounts increased from 27 to kg/ha for the B_2 N rate to 33 kg/ha for the B_3 N rate. All of these amounts of residual NO_3-N were significantly greater than that (10 kg/ha) for the B_1 N rate and all N application rates with W_3 water application.

The distribution of NO_3-N in the 150-cm-deep profile for the B_3 treatment was nearly the same to a depth of 90 cm depth for the W_1 and W_3 treatments (Fig. 2). Early season excess water leached NO_3 in the upper profile of sandy soils even when the water application during most of the growing season was less than crop needs. However, at the 120- and 150-cm depths residual NO_3-N was 4.3 and 12 times greater for the W_1B_3 treatment than for W_3B_3 treatment. Other studies have shown that on these fine sandy soils corn roots seldom penetrate below the 90-cm depth (6). The large amounts of residual NO_3-N below the 90-cm depth with the W_1 water treatment was due both to lack of sufficient water to leach the NO_3-N below that level and the absence of corn roots for plant uptake. For the B_4 treatment, very little NO_3-N remained in the 150-cm soil depth, even for the W_1 water application treatment because this N rate essentially equaled plant uptake.

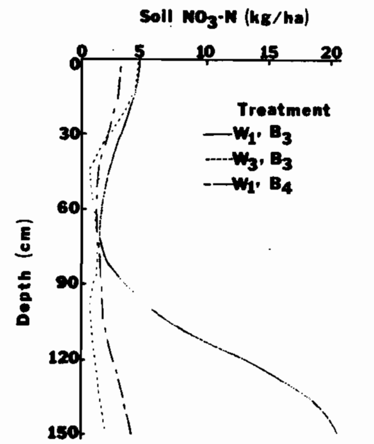

Fig. 2.—Distribution of NO_3-N in the soil to 150-cm depth at fall sampling for selected water and broadcast N application rates.

Nitrate-N in the soil in the spring was not greatly different from that in the fall, except for the B_2 and B_5 treatments, which lost an average of 15 kg/ha NO_3-N, for the W_1 growing season water treatment (data not shown). Although overwinter precipitation averaged 13.3 cm for the 2-year study, evidently individual precipitation amounts were not great enough to cause any significant NO_3-N leaching below the 150-cm soil depth. Exchangeable NH_4-N decreased less than 10 kg/ha over winter.

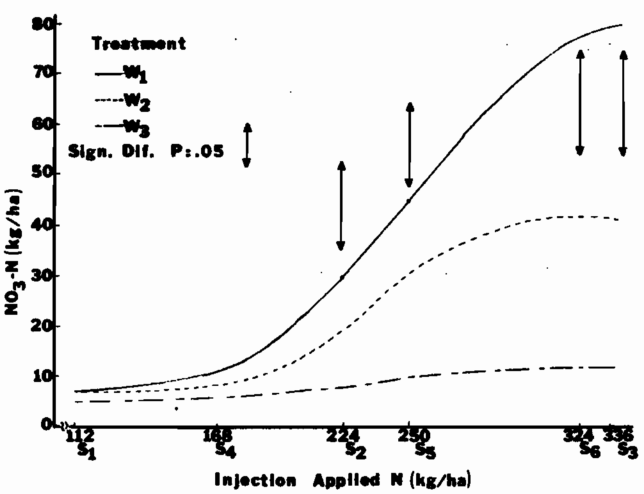

Fig. 3.—Nitrate-N in the soil to 150-cm depth at fall sampling with injection N application and three water application treatments during the growing season.

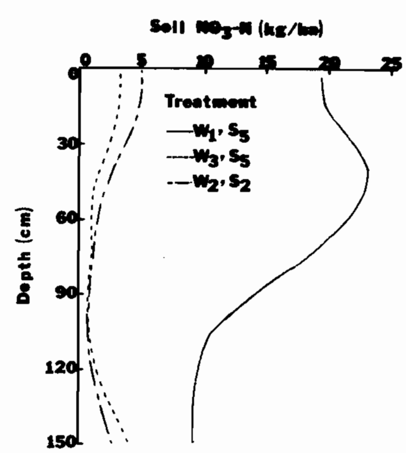

Fig. 4.—Distribution of NO_3-N in the soil to 150-cm depth at fall sampling for selected water and injected N application rates.

Table 1—Overwinter changes in NH_4- and NO_3-N contents and percent of NO_3-N increase attributed to NH_4-N decrease when fertilizer N was injected through the irrigation system.

N application symbols	(rate)	NH_4 decrease	NO_3 increase	NO_3-N increase from NH_4-N decrease
		kg/ha		%
S_1	(112)	11	11	100
S_4	(168)	13	16	81
S_2	(224)	14	21	67
S_5	(250)	15	22	68
S_6	(324)	18	27	67
S_3	(336)	19	28	68

Irrigation-applied fertilizer N generally resulted in greater amounts of residual NO_3-N in the soil (Fig. 3) than did single broadcast N applications (Fig. 1). For the W_1 treatment, residual N was less than 13 kg/ha for the S_1 and S_4 treatments. However, above S_4, residual NO_3-N increased almost linearly at 0.43 kg/ha per each 1 kg/ha applied N. For the W_2 treatment, residual NO_3-N increased by about 0.22 kg/ha per each 1 kg/ha of applied N. For the W_3 treatment, essentially no NO_3-N remained in the soil, regardless of N application rate. The distribution of NO_3 in the 150-cm-deep soil profile (Fig. 4) showed that for the W_1S_5 treatment, there was residual NO_3-N throughout the entire profile. However, little residual NO_3-N was present for other N and water application rates, as was shown by the W_2S_2 and W_3S_5 treatments.

When N was injection applied, spring sampling showed only a small increase in NO_3-N in the soil as compared with that at fall sampling. We attributed the overwinter NO_3-N increase to nitrification of released exchangeable NH_4-N, as reflected by the overwinter decrease in exchangeable NH_4-N, (Table 1). For low N application rates, the overwinter decrease in NH_4 was 80% or more of the NO_3-N increase. However, at N application rates equal to or greater than S_2, only 67% of the overwinter NO_3-N increase could be attributed to the decrease in NH_4. This soil has low CEC and organic matter contents and some NH_4 probably was weakly held by these soil properties, measured as exchangeable NH_4 in the fall sampling, and released by the overwinter freezing-thawing and wetting-drying actions. After the overwinter release of NH_4, time was ample for it to nitrify before the spring samples were collected. These data showed that by applying fertilizer N through the irrigation system the probability of the applied N being leached below the 150-cm soil depth during the overwinter period is reduced as compared with that of a single broadcast application at planting.

The previous discussion has shown in general that regardless of N application method used, the residual NO_3-N decreased as applied water increased. The broadcast applied N is subjected to water applications (rainfall + irrigation) 4 to 5 weeks longer than the first system N application. The system applied N is put on during a 4-week period beginning 4 to 5 weeks after emergence and is therefore not subjected to water applications that could result in leaching of the N during this 4 to 5 week preapplication period.

By subtracting the water applied in excess of ET which would percolate through the soil before the system N applications were made, the residual N in the soil profile for both application methods can be related to the amount of water in excess of ET when the water in excess of ET was equal to or greater than 10 cm (Fig. 5). For percolation water losses of less than 10 cm the data are quite scattered suggesting that the timing of the water loss may have been as important as the quantity of loss. It is interesting to note also that the scatter of data points occurs only for the system applied N.

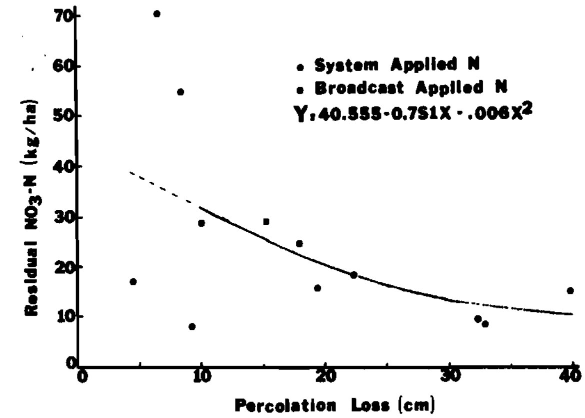

Fig. 5.—Residual NO_3-N as a function of percolation loss occurring after N application for 224 and 250 kg/ha applications.

SUMMARY

This study showed that on fine sandy soils fertilizer N and water management are the key to controlling NO_3-N movement below the root zone of an irrigated corn crop. When the N was applied in one broadcast application at seeding, very little NO_3-N remained in the soil at the end of the growing season, regardless of the amount of growing season water application. Overwinter leaching of NO_3-N below the 150-cm sampling depth was minimal with 13 cm of precipitation received during these months. When N was applied through the solid set sprinkler irrigation system during the growing season before tasseling, water application rate and total N applied determined the amount of NO_3-N that remained in the soil at the end of the growing season. During the overwinter period, NO_3-N actually increased in the soil due to nitrification of some of the NH_4-N. With proper N application and water management, the potential for NO_3-N leaching below the crops' root zone can be greatly reduced.

ACKNOWLEDGEMENT

This study was funded in part by the Office of Water Res. and Tech. U.S. Dept. of Interior, through the Nebraska Water Resour. Res. Inst.

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