Nitrogen fertilization and water pollution

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In an irrigated agricultural system, the fate of nitrogen in the soil is inescapably linked to water management. This has been confirmed by recent U.C. research into the relationship between applied nitrogen, crop yield, and nitrogen pollution potential.

In one stage of the research, conducted under a grant from the National Science Foundation RANN program, different amounts of nitrogen were applied to corn in field plots at the U.C. San Joaquin Valley Research and Extension Center near Parlier.

Isotopically labeled nitrogen fertilizer was used to enable the investigators to trace the distribution of the fertilizer in the soil-plant-water system. The graph shows results representative of those obtained in each of the four years of the investigation. This soil was extremely nitrogen deficient, and there were large yield increases as greater amounts of nitrogen were applied—up to the rate of 200 pounds of nitrogen per acre. Addition of nitrogen beyond this point resulted in very little additional nitrogen taken up by the crop. Consequently, each addition of nitrogen beyond that required for maximum yield increased the amount of nitrogen that could potentially be leached.

At maximum yield, the amount of residual nitrogen in the soil was very low. Therefore, to reduce the nitrogen application below that required to achieve near maximum yield would result in very little decrease in the amount of leachable nitrogen.

Test plantings at Davis

In a similar experiment under the same NSF-RANN grant, the field plots were at U.C., Davis. In this case, the effects of different rates of fertilization and different amounts of irrigation were observed.

Effects of fertilization rates at Davis reflected the inherently greater nitrogen fertility in the soil there, compared with the Parlier site. In the first year (1973), the yield of corn was the same for all nitrogen treatments within each irrigation treatment—0, 80, 160, and 320 pounds nitrogen per acre. In 1974, there was a response to the first increment of nitrogen, and in 1975, to the second.

Also, considerably more inorganic nitrogen remained in the soil after harvest at Davis than at the other location. However, as the experiment continued, there was less difference among residual soil nitrogen levels associated with rates of applied nitrogen—up to the amount of fertilization required for maximum yield.

These results were similar to those observed at Parlier and in experiments by several other investigators. They indicate that, at rates of nitrogen required for maximum yield, the amount of residual nitrogen in the soil is relatively small; therefore, little improvement can be achieved by reducing fertilization below that point and sacrificing yield.

Another interesting aspect of the Davis research data is the relation between the amount of nitrogen remaining in the soil profile and different amounts of applied water. At nitrogen levels higher than needed for maximum yield, the amount of water applied had a marked effect on the amount of nitrogen left in the soil profile. For example:

- With minimum irrigation (one-third of the crop's evapotranspiration requirement, or 1/3 ET), the crop yield was less; consequently, the plants took up less nitrogen. Also, not enough water was applied to leach the residual inorganic nitrogen below the root zone (10 feet), so it accumulated in the profile.
- With excess irrigation (5/3 ET), water moved much of the excess nitrogen below the root zone or resulted in denitrification. Consequently, there was a reduction in the amount of inorganic nitrogen remaining in the root zone.
- In the intermediate irrigation treatment (1 ET), it appears that some leaching or denitrification or both occurred at the high rate of applied nitrogen.

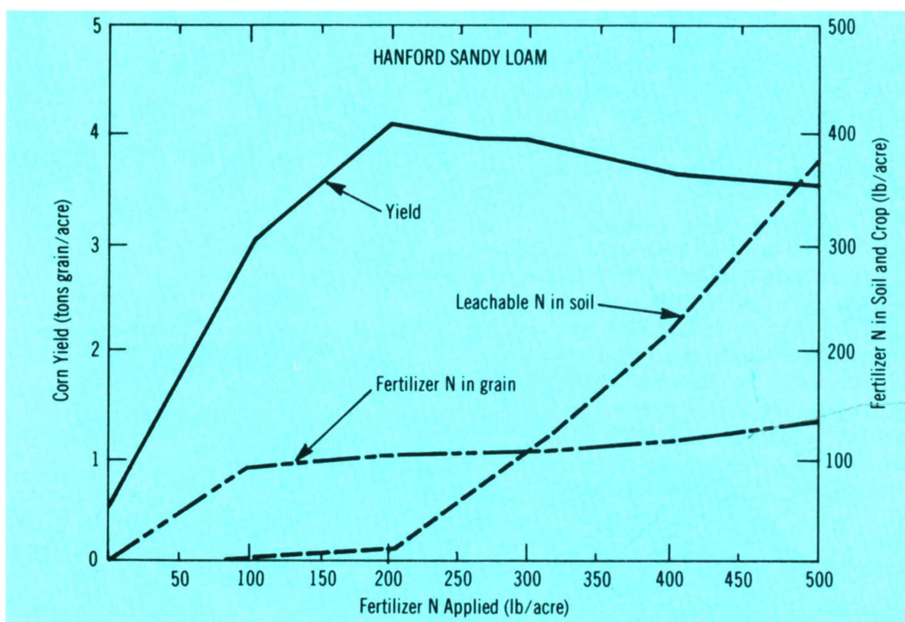
Because so much emphasis has been placed on the concentration of nitrate-nitrogen in the percolating water, it is desirable to examine the levels of nitrate-nitrogen in the soil solution at the bottom of the root zone. It is assumed that the concentration of nitrate-nitrogen at this point in the soil profile is that which will be found at greater depths and which ultimately will reach the aquifer.

Data in the table are based on soil water and soil samples taken at the Davis field plot location after the third harvest of a corn crop in 1976. They show the difference between mass emission (pounds per acre) and concentration (parts per million of solution) concepts of evaluating nitrogen pollution. For example, if one compares the nitrate-nitrogen concentra-

Nitrate-Nitrogen Remaining in 8- to 10-foot Layer of Soil at Time of Corn Harvest, 1976 (Third Year of Trials)

N applied	1/3 ET		1 ET		5/3 ET†	
	Total	Tagged*	Total	Tagged	Total	Tagged
	lb/acre					
0	23	--	26	--	20	--
80	54	2.5	21	0.3	28	0.3
160	100	3.4	20	0.4	40	1.2
320	113	21.8	120	24.3	51	14.8
	ppm, soil-solution basis					
0	13.0	--	13.7	--	10.3	--
80	31.7	1.5	11.2	0.15	14.4	0.15
160	62.2	2.1	12.2	0.27	22.8	0.66
320	67.5	13.0	67.4	13.7	27.7	8.1

†Soil wet to rooting depth before planting. Water applied is related to evapotranspiration (FT) during cropping season.



Relationship between corn yield, amount of applied nitrogen fertilizer, and nitrogen recovered in grain or remaining as leachable N in soil.

tion in soil solution for the 1-ET and 5/3-ET treatments at the 320-pound rate of applied nitrogen, it can be seen that the higher concentration occurs in the 1-ET irrigation treatment. Moreover, a comparison of the pounds-per-acre values for the same depth shows considerably fewer pounds in the 5/3-ET treatment. Since the same amount of fertilizer was applied in both cases, it is evident that a larger amount of nitrate must have been leached below the root zone or denitrified with the excessive water application at 5/3 ET. Furthermore, even where no nitrogen fertilizer has been added for four years, the nitrate-nitrogen concentration in the soil solution below those plots is still in excess of the 10 ppm standard for water

These data point to the problem encountered in setting a standard for determining the degree of nitrogen pollution. Wherever soils and plants exist together, nitrogen will move below the root zone and ultimately will reach receiving bodies of water. However, because of the extreme variability of climate, soils, crops, and management, both the amounts and the concentrations of nitrogen that may reach water supplies will vary greatly. Consequently, a single uniformly applied criterion for judging the degree of nitrogen degradation to be allowed is inappropriate.

In an agricultural system, nitrogen fertilization and water management practices that use adequate amounts to achieve maximum production have been shown to have minimum potential for pollution. Consequently, management practices that result in the greatest nitrogen uptake efficiency will provide both environmental protection and food production.

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U.C. guidelines for interpretation of agricultural water quality

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In early 1973, the University of California Committee of Consultants was requested by the State Water Resources Control Board staff to submit a set of guidelines for interpretation of water quality for agriculture. These were to set forth a method of agricultural water quality evaluation and also suggest numerical guidelines that could be used in the comprehensive water-quality management plans then being prepared to manage the water resources of each of the state's 16 water basins.

The guidelines were prepared by the U.C. Committee of Consultants in collaboration with the U.S. Salinity Laboratory (Riverside), and staff of the State Water Resources Board. These guidelines (first submitted April 1973 and modified slightly since then) have been adopted as official guidelines by several state agencies, used extensively in planning and management of irrigated agriculture, and found to be useful and practical in production agriculture. They were the basis for the recently published (October 1976) FAO-Irrigation and Drainage Paper 29 "Water Quality for Agriculture" prepared by the Food and Agriculture Organization of the United Nations-Rome, for use worldwide by FAO field personnel.

These guidelines are not rigid but are simply what their name implies—guidelines. They do not mean that the problems indicated necessarily will occur if suggested values are exceeded. They do mean that certain problems can be expected if guidelines are exceeded—unless adequate management practices are adopted that will correct, delay, or prevent the problem.

Management practices include leaching, selection of tolerant crops, and improved water management to produce "more crop per drop" of water used. Each type of problem is best met by fairly specific management practices.

More detailed data are available from U.C. Cooperative Extension farm advisors in each county.

Guidelines for Interpretation of Water Quality for Irrigation

	Degree of problem		
Irrigation problem	No problem	Increasing problem	Severe problem
SALINITY (affects water availability to crop)			
ECw (mmhos/cm)	< 0 75	0 75-3 0	> 3 00
PERMEABILITY (affects infiltration rate of water into soil)			
ECw (mmhos/cm)	>0 5	0 5-0 2	< 0 2
adj SAR	< 6	6-9	> 9
SPECIFIC ION TOXICITY (affects only sensitive crops)			
Sodium (adj SAR)	< 3	3-9	> 9
Chloride (meq/l)	< 4	4-10	> 10
Boron (mg/l)	< 0 5	0 5	2 0-10 0
MISCELLANEOUS EFFECTS (affects only susceptible crops)			
NO_3-N (or) NH_4-N (mg/l)	< 5	5-30	> 30
HCO_3 (meq/l) [overhead sprinkling]	< 1 5	1 5-8 5	> 8 5
pH		[Normal range 6 5 - 8 4]	

< means less than
> means more than
ECw means electrical conductivity, a measure of water salinity
adj. SAR means adjusted Sodium Adsorption Ratio
NO_3-N means nitrogen in the water in form of nitrate
NH_4-N means nitrogen in the water in form of ammonia
pH is a measure of acidity (0-7) or of alkalinity (7-14), pH = 7 is neutral

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