IRRIGATION SCHEDULING AND WATER QUALITY CONCERNS

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INTRODUCTION

Increasing levels of agricultural chemicals in groundwater have been reported in many areas of the United States. At least 23 states have identified pesticides or nitrates in groundwater or surface waters commonly utilized for domestic water supplies. Research and demonstration programs have been implemented in many states to encourage producers to more closely manage the application of chemicals to agricultural land. In Nebraska, programs such as the Integrated Pest Management Program, the Hall County Water Quality Special Project and the Agricultural Energy Conservation Project are examples of educational programs aimed at reducing the potential for groundwater contamination.

Research conducted at Nebraska and elsewhere has indicated that the movement of agricultural chemicals to the groundwater is highly dependent on water flow beyond the root zone (Ritter, 1988; Watts and Martin, 1985). Data suggest that the pathways for most contaminants to groundwater are essentially the same. The main differences being the degree to which a chemical is adsorbed to soil particles, the persistence of the chemical in the soil, and the amount of preferential flow areas that exist in the soil profile. This paper presents a summary of some research and demonstration programs conducted to conserve energy, water, and fertilizer while preserving groundwater quality.

IRRIGATION WATER MANAGEMENT

Each type of soil and crop require different water management practices depending on the quality of the irrigation water. Effective management will allow the producer to minimize the application of water and chemicals while harvesting maximum yields. Irrigation scheduling is a process for determining the water application amount and the best time for the application to occur. The benefits derived from using irrigation scheduling are potentially lower production costs and greater yields. In some cases, failing to use an irrigation scheduling procedure can also result in the under-application of water. Consequently, irrigation scheduling insures that neither over-application nor under-application occurs. The steps involved in irrigation scheduling include:

1) Determine the soil moisture status by soil sampling, moisture monitoring equipment or mathematical estimate once or twice per week depending on the irrigation system and soil type.

2) Calculate the remaining usuable soil moisture. The moisture content should not go below 50% of available.

3) Predict the next irrigation date using estimated crop water use rates and remaining usable water.

4) Determine the gross application amount to refill the rootzone.

Hall County Special Project

The use of this irrigation scheduling was demonstrated on 24 to 62 farmer fields between 1979 and 1982 as part of the Hall County Water Quality Special Project. The project area was located west of Grand Island, NE in the Central Platte Natural Resources District. Nitrate concentration of the groundwater in the area was between 0.1 and 37 mg/l. The overall average nitrate concentration was 15 mg/l and had been rising at nearly 1.0 mg/l per year. Several municipalities were in danger of losing their water supplies or would be required to treat the water in order to meet EPA standards for domestic supplies.

The project was conducted by the University of Nebraska Cooperative Extension Service under funding from the Nebraska Department of Environmental Control, and the Environmental Protection Agency. Cost share funds were made available through the Agricultural Stabilization and Conservation Service to encourage farmers to purchase water meters, soil probes, moisture blocks, soil sample analysis and water sample analysis. Water application and fertilizer application were among the data recorded for each field.

The Central Platte area contains soil ranging from shallow sandy loams to deep silt loams. Most of the fields participating in the project had deep silt loam soils (Schepers, et al., 1986) with at least 2.5 feet of topsoil (Bockstadter, et al., 1984). The depth to groundwater rarely exceeded 30 feet below the soil surface. All of the fields were furrow irrigated primarily by pressurized gated pipe systems. Table 1 presents average water application data recorded during the 5 year period. Variation in the water applied per irrigation suggest that even if the timing of water were correct, significant leaching would occur on most fields.

Excess water was applied to 50% of the fields. The required water application amount was approximately 12 inches per season on average. Thus, there was an average of 3 inches of over-application per season. It is important to note that while the average excess was only 3 inches per season, some fields received as much as 40 inches above the required amount. Data presented by Martin, et al., (1982) suggest that approximately 17 lb/ac of nitrogen would be leached by the 3 inches of excess water. The results provided by the farmers indicate that the use of irrigation scheduling reduced water applications by 2 inches per year on average. If all of this water were deep percolated, an additonal 11 lb/ac would be leached per year. For the extreme case, 40 inches of deep percolation could potentially leach over 200 lb/ac per year.

These data show that the design of irrigation systems must be improved significantly in this area of Nebraska before improved management can hope to reduce the leaching of chemicals into the groundwater. The objective of changes must be to reduce the amount of water applied per irrigation event. In that part of the state, that could require changing the: field length; furrow inflow rate; set time; and possibly the furrow intake rate. Variation in yearly application amounts indicate the adjustment of some factors will be necessary from year to year.

Sprinkler Irrigation

The same management approach is utilized for sprinkler irrigation systems. However, sprinkler irrigations systems do not have the water application amount concerns. By setting the percent timer, center pivots will accurately apply the desired amount. The water application amount versus timer setting calibration should be checked periodically to insure the application amount has not changed. Changes in application amount could result due to sprinkler wear or change in pump performance. If an irrigation scheduling program has been followed, rainfall and water application data should be readily available, eliminating the need to perform special field investigations.

Management of center pivot systems will minimize the potential for leaching of chemicals into groundwater which are under the control of the producer. However, leaching of chemicals will not be totally eliminated. If rainfall occurs immediately after irrigation, leaching of nitrogen is possible. Likewise rainfall occuring during the off-season could leach available nitrogen. Hergert, (1978), presented data indicating that the off-season period was a significant period for nitrogen leaching. Approximately 70% of the nitrogen leached from a fine sand during the winter months at the Sandhills Agricultural Laboratory. These results were confirmed by research conducted in Delaware on a sandy loam soil (Ritter, et al., 1988). Rainfall sufficient to refill the soil profile to a depth greater than 3 feet could leach some nitrogen beyond the depth the plant could access. In areas where rainfall does refill a major portion of the rootzone during the winter months, soil moisture levels should be depleted to 30-40% of available at the end of the growing season. This provides storage for a portion of the precipitation recorded during the winter.

WATER CONTAINING NITRATES

Plant uptake of nitrogen contained in irrigation water is most efficient when good irrigation management is practiced. Despite the potential for plants to utilize some of the nitrogen contained in irrigation water, over-irrigation results in reduced plant uptake and to increased leaching of the nitrogen available in the soil. Figure 1 presents data developed using a computer model (Martin, et al., 1982). Part A of the figure indicates that when low amounts of fertilizer are applied to the soil, the uptake efficiency for the nitrogen applied in 10 mg/l (ppm) water varied from approximately 70% for an irrigation replacement fraction (IRF) of 1.0 (irrigation=crop use) to 60 % for an IRF of 4 (irrigation=4 x crop use). The efficiency of plant uptake decreased with increasing nitrate concentration of the irrigation water.

Part B presents the case where nitrogen is applied to the soil at a rate of 120 lb/ac. In this scenario, the soil applied nitrogen provides a major portion of the total nitrogen required by the plant. As the nitrate concentration in the irrigation water increased (IRF < 2), more plant uptake resulted from the irrigation water. However, as the water application amounts increased (IRF > 2), the amount of soil applied nitrogen being leached was greater than the increase in plant uptake from the irrigation water.

Later model simulations (Martin, and Watts, 1982) suggest that if the nitrate concentration is less than 20 mg/l, irrigation should be managed carefully and nitrogen application should be adjusted for the amount applied in the irrigation water. Nitrogen contained in 75% of the long term average water requirement takes into account most of the nitrogen applied in irrigation water without underpredicting in above normal rainfall seasons. When nitrate concentrations are greater than 20 mg/l, the amount of nitrogen applied to the soil should be reduced to a minimal level and excess irrigation water should be applied. This management approach makes maximum use of nitrogen applied in the water without leaching of soil applied nitrogen. Increased pumping cost and the fate of other chemicals applied to the soil during the growing season were not considered by the model.

SUMMARY

Research and demonstration programs conducted in Nebraska during the past 15 years suggest that the contamination of groundwater by nitrates is unavoidable if excess nitrogen or water is applied. The use of irrigation scheduling will limit the amount of leaching that occurs during the cropping season, but off-season losses are far greater than during the irrigation season when good irrigation management is practiced. When the concentration of nitrate in the groundwater is high, fertilizer application should be reduced to take advantage of the nitrogen in the water. If irrigation efficiency is low, fertilizer and pesticide applications must be closely managed to minimize the potential for leaching chemicals into the groundwater.

Improvement in irrigation efficiency for furrow irrigation systems is necessary before irrrigation management can serve to reduce leaching of chemicals into the groundwater. Changes in system design will need to occur in most cases before water application efficiency will improve to the degree necessary. Changes in furrow length, set time, and stream size might be appropriate for some installations. Close management of center pivot irrigation systems will minimize the amount of leaching that is within the control of the producer.

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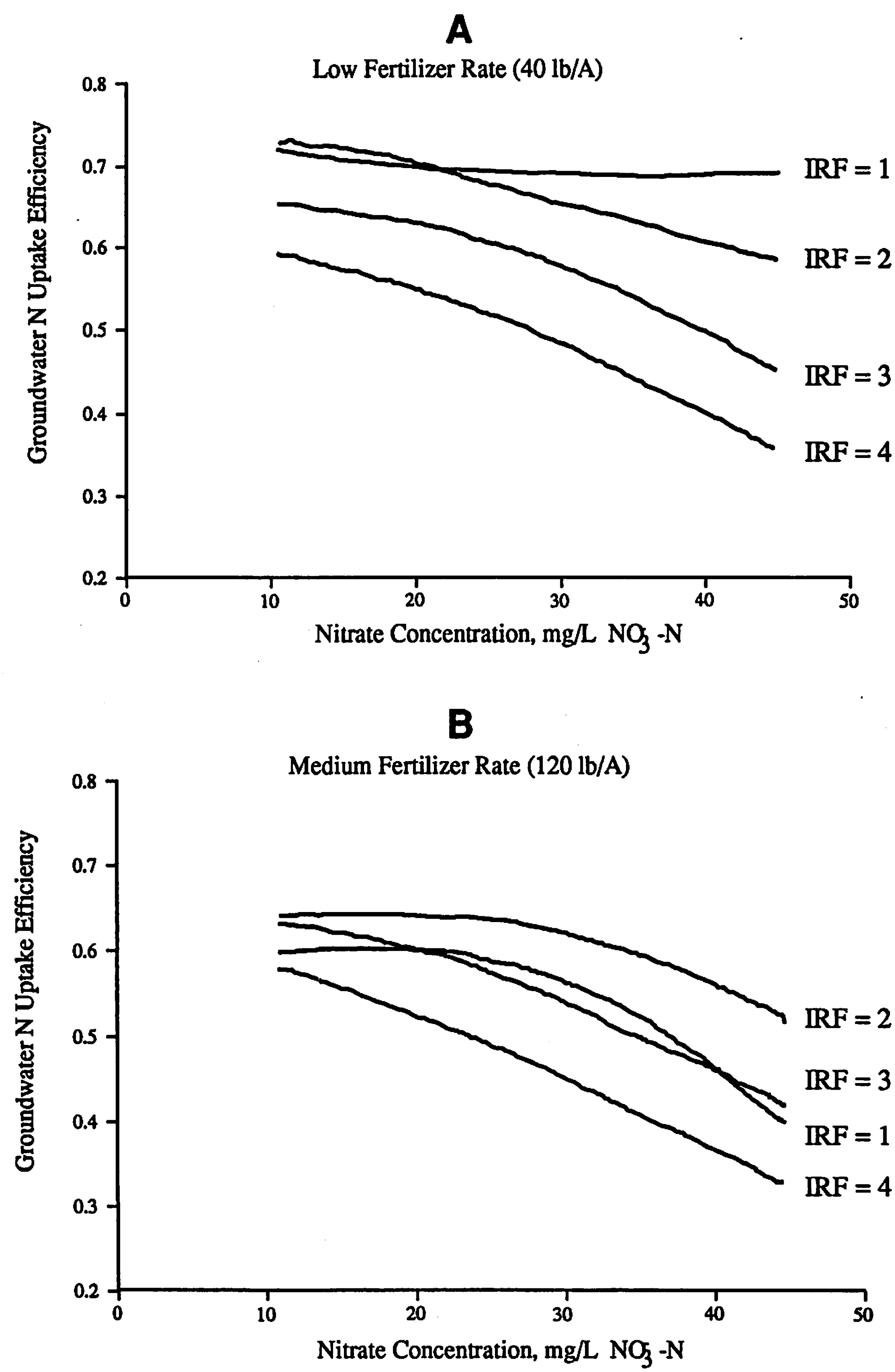

Figure 1. Groundwater-N uptake efficiency for two N fertilizer rates (Martin, et al., 1982).

Table 1. Irrigation water application data recorded during the Hall County Water Quality Special Project between 1979 and 1983 (Ferguson et al., 1988).

Year	Number of Fields	Rainfall Jul-Aug.	Water Applied (inches) Per Irrigation Range (Average)	Water Applied (inches) Annually Range (Average)
1979	24	4.1	2.5-6.2 (2.9)	6.9-25.3 (14.2)
1980	42	5.3	2.5-10.2 (3.8)	10.1-53.3 (21.0)
1981	62	13.0	1.2-8.4 (3.7)	3.7-34.1 (13.3)
1982	44	9.8	0-8.5 (1.8)	0-17.1 (4.8)
1983	32	3.8	1.2-6.4 (3.0)	7.3-51.0 (21.2)
Average	41	7.2*	3.1	14.9

* Long term average = 5.4 inches