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Nitrates in Soil and Ground Water Under Irrigated Crops

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Ground water is widely used in Montana for domestic and other purposes. Non-point source contamination (the exact pollution source cannot be identified) of ground water can have several causes, including septic systems, feedlots, manure storage facilities, crop-fallow systems, saline seeps, and leaching caused by irrigation or precipitation. While no widespread contamination of ground water in Montana has been attributed to fertilizer application, localized problems have been identified.

Ground water pollution is one of the major environmental challenges facing agriculture today, with contamination of shallow water tables being of particular concern. The USEPA has defined the maximum contaminant level of nitrate-N (NO_3-N) for human consumption as 10 ppm. Nitrate-N concentration of ground water under grassland and forest is generally 2 ppm or less. In contrast, the NO_3-N concentration in ground water under cropland is often greater than 2 ppm, commonly greater than 5 ppm, and has been measured at concentrations of over 100 ppm. The amount of fertilizer nitrogen (N) used in this country has greatly increased in the last 40 years. It has been suggested that increased use of fertilizer N, in combination with irrigation, has contributed to the increased NO_3-N contamination of ground water.

Most of the Lower Yellowstone River Valley is irrigated, and the water table is shallow (4-20 ft). Nitrate-N concentrations in the ground water under sugarbeet fields at the Eastern Agricultural Research Center were monitored in 1971 and 1973. Nitrate concentrations fluctuated throughout the growing season, with the greatest concentrations, 25 ppm in 1971 and 4 ppm in 1973, occurring in July. The lowest levels in both years measured in early October were less than 0.1 ppm.

A more recent study conducted from 1989-1995 monitored NO_3-N in soil and ground water under irrigated small grain, sugarbeet, and safflower cropping systems after recommended fertilization. The crops were planted in three fields of about 20 acres each with a rotation

of sugarbeet -- safflower -- small grain. Conventional procedures for fertilization, tillage, and pest control were used for all crops. Each field was planted to all crops at least twice, and all crops were planted every year. The small grain crop was barley in 1989 and 1990, and spring wheat in all other years.

Prior to planting each year, soil samples from all three fields were analyzed for residual soil NO_3-N, and N fertilizer was applied at rates currently recommended for each crop. The N application rate was calculated using residual soil N to 4 feet, estimated mineralizable N from organic matter, and N estimated to be immobilized or released by the residue from the previous crop. Nitrogen rates used for expected yield were 10 lb/T for sugarbeet, 2.5 lb/bu for spring wheat, 1.8 lb/bu for barley, and 240 lb N/a for irrigated safflower. Fields were irrigated as needed based on soil core samples, with about 2.5 inches of water applied at each irrigation.

After planting, wells that tapped into the ground water were installed in each field, with two or three wells located about 100 ft from the upper edge of each field, and two or three wells located about 100 ft from the lower edge of each field. Ground water was collected weekly from each well to determine nitrate concentration. Wells were pumped dry and recharge water was used for analysis. Irrigation water and three sand point wells previously established at the Research Center and used for domestic purposes were also tested weekly. When fields were irrigated, run-off water was collected for NO_3-N analysis. Wells were removed soon after harvest so that normal field work , such as disking and plowing, could be completed. Soil samples to four feet in one foot increments were collected near each well site several times during the growing season for soil NO_3-N analysis. The first soil samples were collected at the time of well installation and the last samples were collected after harvest when the wells were removed.

The NO_3-N concentration of irrigation water was usually less than 1 ppm, contributing little N to the soil. Additionally, run-off water from the fields in this study had no more that 2 ppm NO_3-N, indicating that little N was lost in run-off. This irrigation water is diverted from the Yellowstone River by the Lower Yellowstone River Irrigation Project. These data suggest that the lower Yellowstone River is not contaminated with excess NO_3-N from runoff. Riparian areas have been shown to remove 90% or more of NO_3-N and sediment from drainage water. Ground water in the Yellowstone River Valley may be contaminated, but the NO_3-N may be removed by riparian areas before the ground water returns to the River, or the great volume of water in the River may dilute excess NO_3-N to low concentrations.

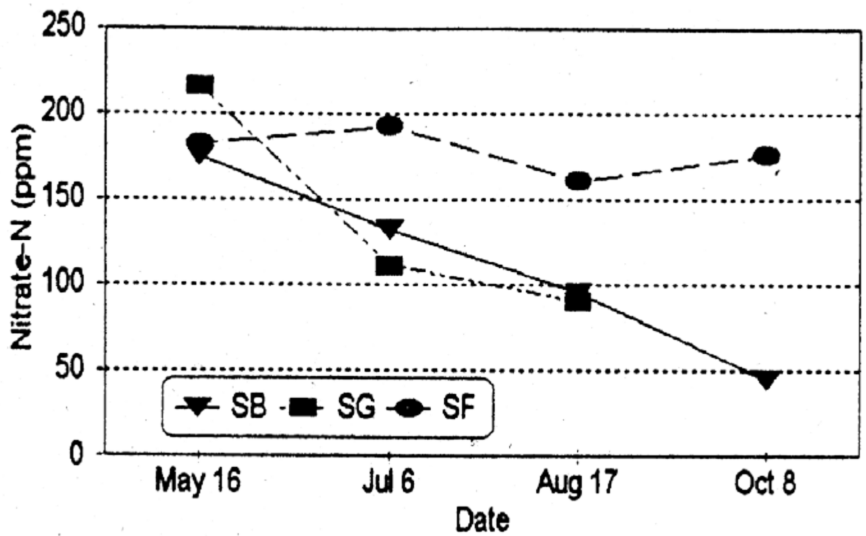

Figure 1. Soil NO_3-N concentration under sugarbeet (SB), small grain (SG), and safflower (SF) across years and fields.

Nitrate-N in the sand point wells varied during each season, and varied from year to year. Generally, values were less than 10 ppm, but concentration in one well approached 10 ppm in 1991 and exceeded 10 ppm in 1992. No relation between sand point well NO_3-N concentration and surrounding agricultural crops was detected.

Ground water and soil NO_3-N concentrations varied more among crops than among fields, although some variation among fields and years existed (Fig.1). Soil NO_3-N to a depth of four feet under spring wheat and barley generally decreased throughout the growing season to amounts of less than 100 lb N/a, while ground water NO_3-N generally increased (Fig. 2). Nitrate-N concentration in ground water under small grain was greater than 10 ppm by the end of the growing season in three of the seven years (once under barley and twice under spring wheat), and this high concentration carried over into the following year twice. Residual and applied soil NO_3-N evidently was not used completely by the small grain and apparently leached into the ground water. Spring wheat and barley have similar rooting systems, and are the most shallow rooted crops in this study. The small grain root systems may not have grown into ground water.

Soil nitrate-N under sugarbeet to a depth of four feet decreased through the growing season in all years, usually to a level of less than 50 lb/a (Fig.1). Ground water NO_3-N concentration under sugarbeets generally remained constant or decreased. This suggests that sugarbeet used available soil N with little leaching. Ground water NO_3-N under sugarbeets measured greater than 10 ppm at the beginning of the season in two of seven years. These two years followed years in which ground water nitrate-N under small grain was greater than 10 ppm at the end of the previous growing season. This high concentration at the beginning of the season was probably due to residual N left from the grain crop grown the previous year. Sugarbeet is a deep-rooted crop and may grow into the ground water in some years, using some of the NO_3-N in the water.

Soil NO_3-N remained constant or increased under safflower in four of six years. Soil NO_3-N increased by almost 100 lb/a in 1989, and by about 50 lb/a in both 1990 and 1991. The greatest increases in soil NO_3-N were generally in the top two feet of soil. Ground water NO_3-N under safflower decreased or remained constant through the growing season in all years but 1989. These data and other research suggest that this deep-rooted crop extracts nitrate from ground water. Ground water NO_3-N concentration under safflower was almost 14 ppm at the beginning of the growing season in 1992, and almost 12 ppm at the beginning of the growing season in 1993, but it dropped to less than 5 ppm by the end of the season in both years. The high concentrations of ground water NO_3-N at the beginning of the season were not detected following the sugarbeet crop of the previous year. Recent data have shown that sugarbeet leaves return more N to the soil than previously recognized, and that breakdown of leaf material can occur quickly. Since initiation of testing of the ground water under the safflower did not occur until mid-May or early June, this ground water NO_3-N may have resulted from the breakdown and release of N from sugarbeet leaves.

The results of this study indicate that N management systems for irrigated small grain should be improved, especially in areas with shallow water tables. Fertigation, (the application of fertilizer with irrigation water) or splitting the application of N are two possible management practices which may improve the utilization of applied N by irrigated small grains. The data also suggest that sugarbeet and safflower may use NO_3-N in the ground water of shallow water tables as well as NO_3-N that has moved below the root zone of shallower rooted crops.

Fertilizer Facts:

- Nitrate-N was detected in the ground water under irrigated crops in the lower Yellowstone River Valley.
- Nitrate-N concentration in ground water increased during the growing season under spring wheat and barley.
- Deep-rooted crops like safflower and sugarbeets may extract NO_3-N from ground water.

Edited by Jeff Jacobsen, Extension Soil Scientist

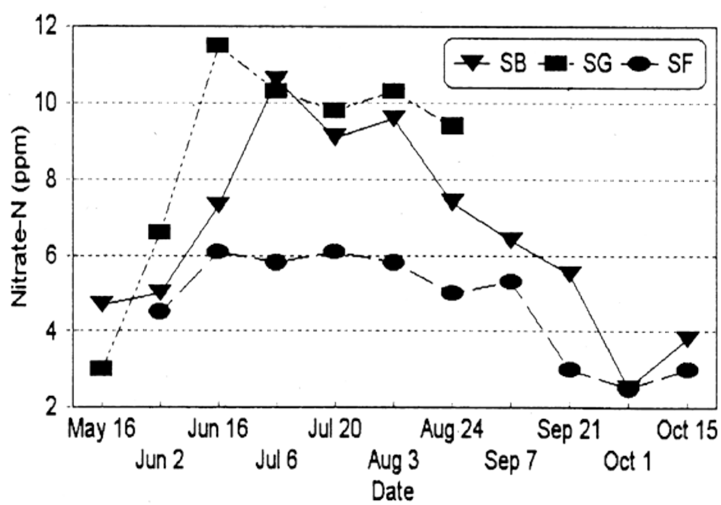

Figure 2. Ground water NO_3-N concentration under sugarbeet (SB), small grain (SG), and safflower (SF) across years and fields.