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Nitrates in soil and ground water under irrigated safflower, sugarbeet and small grain

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Abstract
Nitrate-N (NO_3-N) ground water pollution is an environmental challenge facing agriculture globally. The irrigated Lower Yellowstone River Valley in Montana, USA, has a shallow water table that is easily contaminated. Nitrate-N concentrations in soil and ground water under three irrigated crop production fields were monitored for six years. The cropping system used was sugarbeet (*Beta vulgaris)/*safflower (*Carthamus tinctorius*)/small grain. Best agricultural management practices were used. Nitrogen (N) fertilizer was applied at rates recommended for each crop. Fields were planted to each crop twice during the six-year testing period. Fields were sampled to a depth of 120 cm prior to planting, on a monthly basis, and immediately after harvest for soil NO_3-N content analyses. Wells were installed into the ground water in each field every year. Ground water samples were collected weekly from each well to determine ground water NO_3-N concentration. Irrigation water and three wells used for domestic purposes were also sampled weekly. Ground water and soil NO_3-N concentrations varied among crops and some variation among fields and years existed. Soil NO_3-N under small grain decreased and ground water nitrate-N increased during the growing season. Soil nitrate-N levels under sugarbeet decreased through the growing season, whereas ground water NO_3-N concentration under sugarbeets remained constant or decreased. Soil NO_3-N remained constant or increased under safflower in four years, whereas ground water NO_3-N under safflower decreased or remained constant in all years but one. These results show that safflower has the ability to recover deep soil and ground water NO_3-N.

Key words: safflower – sugarbeet – small grain – nitrate-N – ground water

Introduction
Ground water pollution is a major environmental challenge facing agriculture today, with contamination of shallow water tables being of particular concern. The United States Environmental Protection Agency (USEPA) has defined the maximum contaminant level of nitrate-N (NO_3-N) for human consumption as 10 ppm (8). Nitrate has been linked to infant methemoglobinemia, and some forms of cancer (2). 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 (4). In Montana, no association was detected between high rates of nitrate-N in ground water and irrigation, while regionalized areas with high NO_3-N in the ground water were reported to be in areas of dryland farming with crop/fallow rotation (1). Most of the Lower Yellowstone River Valley is irrigated, and the water table is shallow (1.5-7 m).

Materials and Methods
This six-year study monitored NO_3-N in soil and ground water under irrigated safflower, small grain (spring wheat *Triticum aestivum* or barley *Hordeum vulgare*), and sugarbeet, to investigate movement of N under these crops when fertilized as recommended. Three fields of about 8 ha each were planted in a rotation of safflower/small grain/sugarbeet. Conventional procedures for fertilization, tillage, and pest control were used. The rotation was completed twice, so all crops were planted every year, and each field was planted to each crop twice.

Prior to planting each year, soil samples from all fields were analyzed for residual soil NO_3-N content, and N fertilizer was applied at rates recommended for each crop. Nitrogen rates applied for expected yield were 108 kg/ha for safflower (3), 280 kg/ha for sugarbeet (5), 280 kg/ha for spring wheat (7), and 243 kg/ha for barley (7). The N application rate was calculated using residual soil N to 120 cm, N estimated to be mineralized from organic matter, and N estimated to be immobilized or released by the residue from the previous crop. Fields were flood irrigated as needed with about 6.4 cm of water applied at each irrigation. After planting, wells to tap into the ground water were installed in each field, with 2-3 wells located about 30.5 m from the upper edge of each field, and 2-3 wells located about 30.5 m from 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 wells used for domestic purposes were also sampled weekly. Run-off water from each irrigation was sampled. Wells were removed soon after harvest so that normal field work could be completed.

Soil samples to 120 cm in 30 cm increments were collected within 30 cm of each well site several times during the growing season for soil NO_3-N analyses. The first soil samples were collected at the time of well installation and the last samples were collected when the wells were removed.

Results

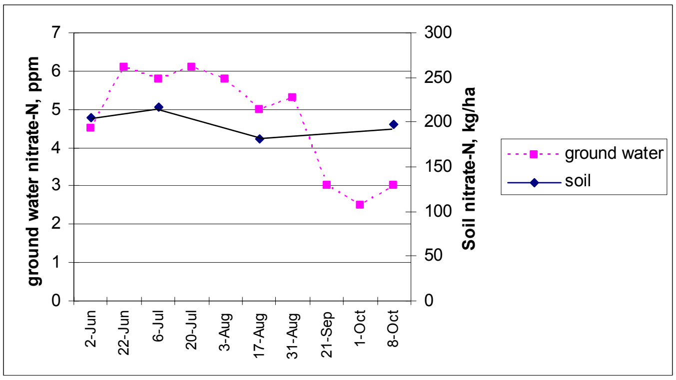
The NO_3-N concentration of irrigation water was usually less than 0.2 ppm, and contributed little N to the soil. Run-off water from the fields in this study was 2 ppm NO_3-N or less, indicating that some N was lost in run-off. Irrigation water is diverted from the Yellowstone River by the Lower Yellowstone River Irrigation Project. These data indicate that the lower Yellowstone River is not contaminated with excess NO_3-N.

Nitrate-N in the domestic 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 one year and exceeded 10 ppm in another. No relation between domestic well NO_3-N content and surrounding agricultural crops was detected.

Soil and ground water nitrate-N concentrations were averaged for each crop over the six-year period. Ground water and soil NO_3-N concentrations varied more among crops than among fields, although some variation among fields and years existed.

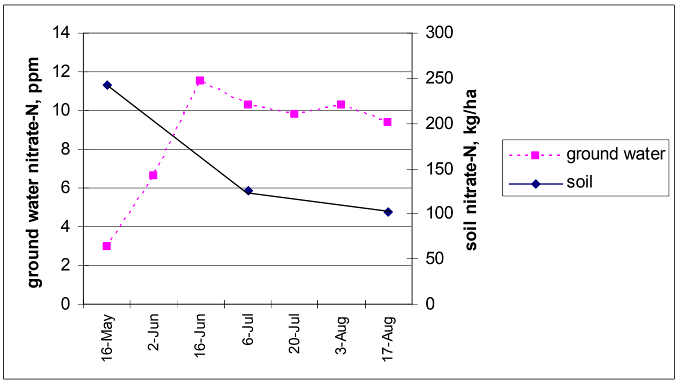
When averaged over six years, soil NO_3-N remained constant under safflower (Fig. 1). Soil NO_3-N under safflower increased over the season in 3 years of this study, with the greatest increases in the top 60 cm of soil. Ground water NO_3-N under safflower decreased or remained constant through the growing season in all years but one. These data indicated that safflower extracts NO_3-N from ground water because of its deep root system. Ground water NO_3-N concentration under safflower was more than 12 ppm at the beginning of the growing season in 2 years, but 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 safflower growing season were not detected the previous year following the sugarbeet crop. Recent data have shown that sugarbeet residue returns more N to the soil than previously recognized, and that break-down of leaf material can occur early in the growing season of the following crop (6). Since initiation of testing of the ground water under the safflower did not occur until mid May or early June, this high concentration of NO_3-N in the ground water may have resulted from the release of N from sugarbeet leaves.

Figure 1. Soil and ground water nitrate-N concentrations under safflower averaged across six years.



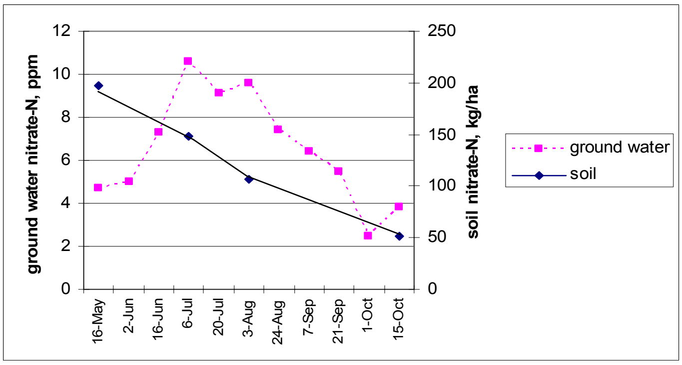
Average soil NO_3-N under small grain decreased throughout the growing season to amounts of about 100 lb kg/ha, while average ground water nitrate-N increased (Fig. 2). Nitrate-N concentration in ground water under small grain was greater than 10 ppm by the end of the growing season in three years, and this high concentration carried over into the following year twice. Residual and applied soil NO_3-N was not completely utilized by the small grain, and leached into the ground water. Small grain was the shallowest-rooted crop in this study, and the root systems likely did not tap into the ground water.

Figure 2. Soil and ground water nitrate-N concentrations under small grain averaged across six years.



Average soil nitrate-N under sugarbeet decreased through the growing season to a level of about 50 kg/ha (Fig.3). Average ground water NO_3-N concentration under sugarbeets increased early in the growing season, then decreased by the end of the season. This suggests that soil N under sugarbeet leached into the ground water early in the season, but was recovered to some extent by the crop later in the season. Ground water NO_3-N under sugarbeets measured over 10 ppm at the beginning of the season in the two years that followed those years in which ground water nitrate-N under small grain was greater than 10 ppm at the end of the previous growing season.

Figure 3. Soil and ground water nitrate-N concentrations under sugarbeet averaged across six years.



Conclusion

The results of this study show that safflower and sugarbeet crops recover ground water NO_3-N in shallow water tables as well as NO_3-N that has moved below the root zone of shallower rooted crops, such as small grain. Ground water NO_3-N recovered by safflower apparently was released almost immediately into the upper 60 cm of soil, while ground water NO_3-N recovered by sugarbeet was not released until breakdown of the sugarbeet residue in the following year. The data also show that N management systems for irrigated small grain should be improved, especially in areas with shallow water tables. Application of fertilizer with irrigation water or splitting the application of N are two possible management practices in which N may be more efficiently used by small grain.

References

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