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MontGuide

Crop and Fertilizer Management Practices to Minimize Nitrate Leaching

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Use nitrogen fertilizer and crop management practices to minimize nitrate leaching, benefit crop production and protect groundwater quality.

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Is nitrate leaching a problem in Montana?

Nitrogen (N) is important for optimal crop production. Although most N fertilizers used in Montana do not contain nitrate, they quickly convert to nitrate in soil. Nitrate is a form of N that is available for plant uptake. It is highly soluble and easily lost to leaching as water moves through the soil profile. High amounts of nitrate in drinking water can be harmful, especially to infants and pregnant women. While most groundwater in Montana has nitrate levels below the drinking water standard (10 mg nitrate-N/liter or parts per million), high nitrate levels have been found in certain areas of the state (Figure 1). This bulletin only addresses nitrates from cropping systems, not from septic systems or livestock.

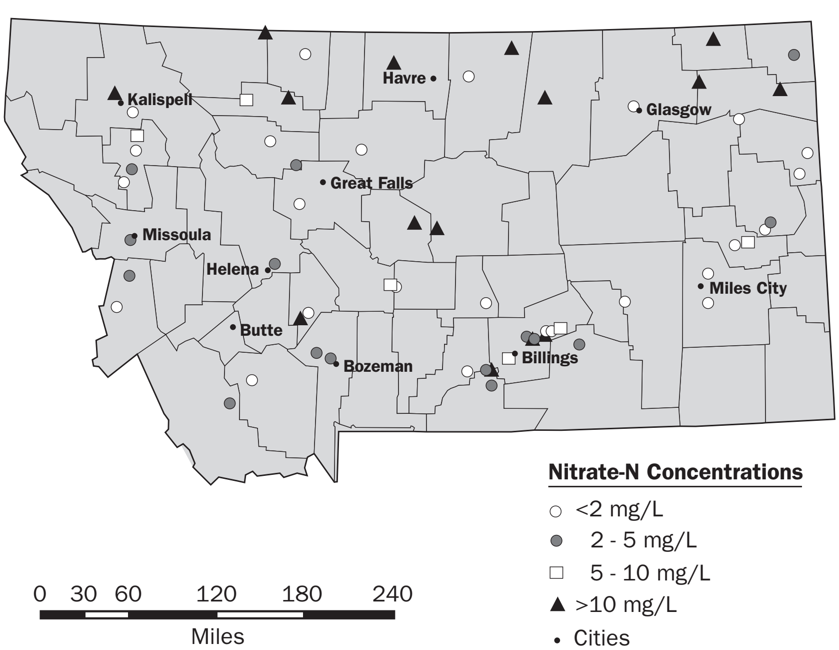

FIGURE 1. Nitrate-N concentrations from randomly selected Montana wells from 2006-2010. (Data from the Montana Department of Agriculture, Groundwater Protection Program)

Irrigated fields have the highest potential for leaching, especially on coarse soil. In dryland conditions, nitrate leaching is likely insignificant during much of Montana's growing season because plant uptake of water usually exceeds precipitation, preventing downward movement of water. However, in fall and winter the opposite is true, resulting in increased potential for nitrate leaching. In all farming systems, overwinter organic matter decomposition can add soluble N to the soil, increasing the amount of soil nitrate available to be leached. This is not only a health and environmental concern, but a direct financial loss to the producer.

Whether leached nitrate ends up entering groundwater depends on many factors, including the depth to groundwater, soil texture, and rooting depths of plants. Fortunately, depths to groundwater in Montana are often large, soil texture is often fine, and deep-rooted crops such as winter wheat are common. Yet there are areas in the state that have a high potential for leaching.

Soil and water factors that increase leaching potential

Soil texture influences a soil's ability to retain water (Table 1). Sandy soils, soils with large pores and shallow soils have low water holding capacity. Cracks and other vertical channels that extend from the soil surface to below the root zone allow water to move unused nitrate downwards. Producers can do little to change these soil properties.

Precipitation also contributes to nitrate leaching, even in the drier parts of Montana. Potential for overwinter nitrate loss is higher during wet than dry winters on any soil type. On fields at Moccasin, Montana, with shallow topsoil and gravelly subsoil, soil

TABLE 1. Plant available water holding capacity for various soil textures.

Soil Texture	Inches Water per Foot of Soil
Sand, fine sand	0.72
Loamy sand	0.96
Sandy loam	1.44
Loam, silt loam, silt, sandy clay, silty clay, clay	2.04
Sandy clay loam, clay loam, silty clay loam	2.16

If the soil is one foot sandy loam over two feet sandy clay loam, it would take 5.8 inches of water (1.44 + [2 x 2.16]) to refill the soil to a three foot depth. More precipitation or irrigation could leach nitrate.

nitrate levels *decreased* by up to 25 pounds N per acre (lb N/acre) during a wet fall/winter (11.6 inches from August to April; Chen unpubl. data). But, in a year with somewhat below average precipitation (five inches from August to April) soil nitrate *increased* from fall to spring by up to 40 lb N/acre (Jones unpubl. data) due to organic matter decomposition. Because of the soil's overwinter nitrate gain from organic matter decomposition, actual N lost to leaching in the wet year was likely higher than 25 lb N/acre. A total of up to 65 lb N/acre could have leached into groundwater from shallow soils in a wet winter based on this research. At $500 per ton urea, this would cost a producer $36 per acre in replacement N.

Carefully managed irrigation is important to reduce nitrate leaching. Sprinkler systems allow better water control with lower leaching risk than furrow and flood irrigation systems. Irrigation should be managed to meet the crop need, but not exceed the ability of the soil to hold the water on site (Table 1). Helpful guidelines for irrigation management to retain soil N are offered in Bauder et al. (2008).

Crop management

Reducing fallow and reduced tillage both help reduce N losses. This is supported by a plot study in eastern Montana near Culbertson that compared the estimated initial soil N level in 1983 to the 2004 level (Table 2). Wheat-fallow lost almost 2.5 times more N per acre per year than did continuous wheat. Combined fall and spring till lost over 2.5 times more N per acre per year than no-till. While it is not known what fraction of that N was lost to leaching, leaching loss is likely, given the relatively coarse soils at that study site.

Fallow fields have higher leaching potential because they may reach field capacity (the amount of water a particular soil can hold against drainage) the first fall or spring after harvest. Additional precipitation then runs off or seeps below the rooting zone, taking nitrate with it. The additional residue associated with minimum and no-till may reduce these losses.

Planting perennials or deep rooted crops, such as sunflower, safflower and winter wheat, helps use water and N that may escape shallow rooted crops. While alfalfa is an excellent scavenger of soil nitrate, the large supply of N remaining after alfalfa is terminated can release nitrate. This can be problematic on shallow soils if this extra N is not credited in fertilizer N rate calculations, or the field is left fallow. Annual legumes are good scavengers of available N in the upper two to three feet and do not need N fertilizer as long as sufficient phosphorus, potassium, sulfur and the correct inoculants are available for N fixation. Their residue provides a good source of slow release N for future crops. Cereal forages, green manures and cover crops can be used to manage crop available water in areas with insufficient precipitation for continuous cropping, but more than adequate precipitation for crop fallow.

Seeding rates and row spacing can also affect N leaching. Optimal plant density can increase yields and will optimize resource use, which will decrease potential for N leaching. For example, spring wheat had a higher efficiency of N fertilizer use at six-inch row spacing than at 12-inch spacing (Chen and Neill 2006), and higher N fertilizer uptake should translate into less N loss.

What to do on high leaching potential soils:

- Recrop rather than fallow
- Reduce tillage
- Diversify to include perennial and/or deep rooted annual crops
- Consider legumes
- Space rows for optimal resource use and plant yield
- Sprinkle rather than flood irrigate
- Irrigate to meet but not exceed crop needs

TABLE 2. Average annual N loss as affected by cropping and tillage frequency (adapted from Sainju et al. 2009).

Management	N loss per year (lb N/acre)
Wheat-fallow spring till	43.1
Continuous wheat spring till	17.4
Continuous wheat no-till	8.6
Continuous wheat fall and spring till	23.0

Nitrogen fertilizer management

Annual soil testing and realistic yield goals should help producers calculate fertilizer N rates to avoid over-fertilization and reduce nitrate leaching. When calculating fertilizer rates, credit all sources of N available to the crop, including manures, legume input (~10 lb N/acre for annual legumes; 40 lb N/acre for alfalfa), organic matter (~20 lb N/acre in soils with more than three percent organic matter) and soil nitrate-N. Spring soil tests are a better measure of N available to that year's crop than fall soil tests, because they account for overwinter changes to soil nitrate levels. For example, nitrate-N increased an average 18 lb N/acre annually from late summer to early spring in a three-year Montana study (Jones, unpubl. data). Soil test annually, and sample deeper than two feet where soils allow, to learn how much N escaped below a shallow rooted crop. Credit all of the available soil N at the two to three foot depth if planting a deep-rooted crop, but only half of the N at the two to three foot depth if planting a shallow-rooted crop.

Ideally, conventional N fertilizer is applied right before the plants need it most, which is from seedling to tillering stages in cereal grains and seedling to early branching in oilseeds (*Nutrient Uptake Timing by Crops*, EB0191). This can be followed by in-crop fertilizer topdress applications with timing based on plant demand or growth stage, rather than calendar date. By matching N rates to plant needs and using split applications, there is less risk of over-fertilizing. The crops will be able to quickly utilize the applied N, leaving less unused N in the soil that can be leached. In a study at Moccasin, Montana, there was little change in nitrate levels from fall to spring on fields that received 40 lb N/acre the previous year, while fields that received 120 lb N/acre lost more than 25 lb N/acre (Chen unpubl. data). The higher fertilization rate left more residual N in the soil, which was likely leached over the winter from this region's shallow soils. This illustrates that if the crops don't use it, you can lose it.

There are also advances in fertilizer and application technology that help increase the amount of applied fertilizer actually used by the crop. Enhanced efficiency fertilizers slowly release their nutrients over time. Some contain nitrification inhibitors which slow the conversion of N fertilizer to nitrate, thereby possibly decreasing leaching. These fertilizers deserve consideration, especially as the price difference compared to conventional urea fertilizers decreases. But, they are not the best fertilizer choice for all situations and timing of application is a little different than with conventional fertilizer. For discussion of the properties of these fertilizers, their effectiveness and suggested management see the MSU Extension publication, *Enhanced Efficiency Fertilizers* (EB0188).

Variable rate fertilizer application or site specific precision application methods help ensure N is applied where it is needed most and not in places where it will be lost. Often, most nitrate leaching comes from only a fraction of the total area of a field (Power et al. 2001). To limit N loss, producers can identify areas of a field that are limited by factors other than N and apply just enough N to meet that area's production potential.

By using available technology and best management practices, producers can make sure their fertilizer dollars are spent growing a crop, rather than lost to leaching, and reduce the potential for nitrate contamination of groundwater. The 4R nutrient stewardship approach to best management practices for fertilizer involves selecting the right source-rate-time-place combination from practices validated by agronomic research. The International Plant Nutrition Institute has information on 4R nutrient stewardship (www.ipni.net/4r). Another resource is the Natural Resources Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP). EQIP provides farmers with financial and technical assistance on agricultural production to protect environmental quality. Programs offered by the NRCS do change, so get current information from its web site, www.mt.nrcs.usda.gov/programs/, or a local NRCS office.

What to do:

- Know your soil type
- Soil sample annually in the spring to three feet or more in deeper soils
- Base N rate on soil tests and reasonable yield potential
- Credit N from all sources, such as manure and previous legume crops
- Apply N in spring or use a slow release fertilizer
- Schedule application of conventional fertilizers close to peak crop N uptake
- Split applications – top dress between tillering and flowering in moist years
- Use variable rate/zone specific technology

Conclusion

Producers cannot easily control some of the factors that affect soil nitrate leaching, such as soil properties and climate. However, producers can control other factors, such as fertilization timing and amount, irrigation management, and crop selection. Many agronomic management practices can be used to minimize N leaching losses and potential groundwater contamination. These practices help ensure that fertilizer dollars are optimally spent on growing the crops while keeping our groundwater safe.

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Extension Materials

For a range of information from well testing to irrigation management, contact the MSU Extension Water Quality Program at http://waterquality.montana.edu/ or phone 406-994-7381. You may also find the following publications by going to http://landresources.montana.edu/SoilFertility/publications.html and clicking on the title.

- *Enhanced Efficiency Fertilizers* (EB0188),
- *Fertilizer Guidelines for Montana Crops* (EB0161),
- *Nutrient Uptake Timing by Crops: to assist with fertilizing decisions* (EB0191).
- *Nutrient Management Modules* (#4449-1 to 4449-15) and *Soil and Water Management Modules* (#4481-1 to 4481-5).

MSU Extension publishes a variety of materials regarding nitrogen fertilization and water quality that may be helpful. You may request these publications and many others from your local county Extension agent or directly from MSU Extension Publications at the address below. A shipping and handling fee will be charged for hard copies.

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