Nitrogen Management Under Irrigated Conditions

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Introduction

Nitrogen (N) is the essential plant element which most frequently limits irrigated crop production in Colorado. Commercial N fertilizers are a cost effective means of supplementing soil supplied N for plant growth and are necessary for sustaining high crop yields. However, it has been documented that improper or excessive use of N fertilizer can lead to nitrate pollution of surface or ground water. Both urban and rural fertilizer applicators can minimize this problem by implementing Best Management Practices (BMPs) for fertilizer use.

Nitrate is a naturally occurring form of N that is highly soluble in water and may cause health problems if ingested in large amounts. A number of sources of NO_3 exist, including manure, septic and municipal effluent, decomposing organic matter, soil organic matter, and N fertilizer. High NO_3 levels in drinking water can cause methemoglobinemia or "blue baby syndrome"; a condition primarily seen in very young infants and farm animals. Although reports of methemoglobinemia are extremely rare, the U.S. EPA has established a safe drinking water standard of 10 ppm NO_3-N for community drinking water supplies.

To fully understand the transformation and movement of N in the environment, some knowledge of the N cycle is needed. Nitrogen in the soil is commonly found in the form of organic N in the soil humus, ammonium (NH_4), nitrate (NO_3), or in a gaseous form (NH_3, N_2O, N_2). Nitrogen in soil organic matter may be converted to the NH_4 form by a biological process called mineralization. The NH_4 form is converted to NO_3 by another biological process called nitrification. Fertilizer N, whether organic or inorganic, is biologically transformed to NO_3, which is highly leachable. The speed of this transformation is determined by soil temperature and moisture, but will eventually occur in any well-drained agricultural soil. Plants will absorb and utilize both NH_4 and NO_3. Therefore, producers need to match N applications to crop uptake patterns to minimize NO_3 leaching and maximize efficiency.

Nitrogen Fertilizer Best Management Practices

BMP 1. Base N fertilizer rates on results from soil analysis, as well as irrigation water and plant analysis when appropriate, using environmentally and economically sound guidelines.

While soil, climatic, and geologic characteristics of the site strongly influence leaching potential, management practices finally determine the amount and extent of N leaching. Proper nutrient management includes:

- Accounting for crop N needs

- Applying appropriate inputs as determined by N budget.

- Applying N when and where it can be used most efficiently by the crop.

This will assure that the residual soil NO_3 available for leaching is minimized. The following management practices also will help producers and fertilizer applicators maximize economic returns from fertilizer dollars while protecting water quality. For more information on crop N requirements, refer to CSU Cooperative Extension bulletin XCM-34, "Guide to Fertilizer Recommendations in Colorado".

BMP 2. Develop a nutrient management plan for each field and crop.

The plan should include:

a. The previous crop, variety, and yield.
b. The current crop, variety, and expected yield.
c. Current soil test analysis data showing the amount of available N in the soil.
d. An estimate of the amount of N available from soil organic matter, manures, and from previous legume crops expected to become available during the crop growth period.
e. The amount of supplemental N necessary to meet expected crop yield. This includes N from chemical fertilizers, manures, organic wastes, irrigation water and other sources.
f. Special management practices needed to reduce N leaching including: timing of application, multiple applications, sidedressing, banding, foliar feeding, fertigation, stable forms of N, nitrification inhibitors or needed changes in crops or crop sequence.

These records should be maintained for several years to help producers refine their management. (See "N Management Record Sheet" in Appendix 1 for suggested format)

BMP 3. Sample soil from each field for analysis of plant available nutrients. As a guideline, sample depth should be at least 2 to 3 feet, preferably to the depth of the effective root zone.

Soil testing is a very important BMP for determining plant nutrient needs. Yearly sampling of each field is necessary to make accurate N fertilizer recommendations. The key to good soil test results is proper sampling protocol. Each sample should contain 15-20 cores of soil from a reasonably uniform area of approximately 40 acres. Large fields should be broken into sampling units based upon crop, yield, and fertilizer histories. Deep soil sampling for residual NO_3 is requisite to precise fertilizer recommendations and provides producers season-end information regarding crop N use and N remaining for next year's crop. Keep the surface soil sample separate from subsoil so that it can be analyzed for P, K, and micronutrients. Sampling to a minimum depth of 2 to 3 feet is recommended for all soil types. For more detailed information on soil sampling, see CSU Cooperative Extension SIA .500, "Soil Sampling".

BMP 4. Establish realistic crop yield expectations for each crop and field based upon soil properties, available moisture, yield history, and management level. Yield expectations should be based upon established crop yields for each field, plus a reasonable increase (5% suggested) for good management and growing conditions.

Setting realistic yield goals is a very important BMP. Fertilizer N recommendations should be based upon a yield goal submitted by producers with their soil samples. While farmers tend to be optimistic, overestimating yield goals results in excess N applications, leading to loss of farm income and potential groundwater contamination.

Applying enough fertilizer for a 200 bu/acre corn crop when other conditions such as limited irrigation water will only allow a 150 bu/acre yield, can result in 60-70 lbs/acre of excess N being applied. Rather than project a **yield goal**, it is recommended that producers establish a **yield expectation** based upon historical yield averages.

Yield expectations must be established on a field-by-field basis. The five most recent yield averages for each field should represent an obtainable yield. If a recent crop has been lost to hail or other disaster, that year's yield should be omitted from the average.

Colorado State University suggests that a producer add 5% to their five year yield average and use this value as their yield expectation. If the crop season and growing conditions appear to be above average, producers can adjust N rates upwards at sidedressing or by applying N through irrigation water. In-season soil or plant tissue analysis may be utilized to determine whether additional N is required. The key to setting realistic yield expectations is to base them on actual field averages plus a modest increase for improved management and good growing conditions.

BMP 5. Credit all sources of plant available N to crop fertilizer requirements.

Soil organic matter, irrigation water, manure, and previous legume crops all contribute N to the growing crop. The N contribution from these sources must be credited in order to make accurate fertilizer recommendations. Table 1 suggests average credits from various sources of N.

Legume crops can be a very significant source of plant available N due to bacterial N_2 fixation in root nodules. Plowing down a full stand of alfalfa may release as much as 100 lbs of N per acre in the first year after plowdown. The amount of N credit given for legumes depends upon the crop, stand, and degree of nodulation. A minimum of 30 lbs N/acre should be credited in the first year after any legume crop.

Sewage sludge is another valuable source of plant nutrients that must be properly used to avoid environmental problems. Each ton of dry sludge contains approximately 50-100 pounds of total N, 120 pounds P_2O_5, and 10 pounds K_2O at a fertilizer value of $30 to $60 per ton. In Colorado, the land application of municipal sludges is regulated by the Colorado Department of Health (5CCR 1003-7) and restrictions are in place to prevent surface or ground water contamination. While application rates may be limited by heavy metal content of the sludge or P content of the soil, crop N requirements typically set the appropriate sludge rate. However, sludge application rates can exceed actual crop N uptake when crop yields are significantly lower than anticipated. Sludge acts as a slow release N source and can cause a buildup of soil NO_3 levels over time if N uptake is lower than estimated. For this reason, producers using sludge should utilize deep soil testing and sludge analysis to adjust application rates over time. Crop N uptake should be calculated using conservative yield estimates, crediting all available N sources, and assuming a 30% annual N mineralization rate for anaerobically digested sludge and a 50% annual N mineralization rate for aerobically digested sludge.

Table 1. Nitrogen Credits for Crop Requirements

N Source	N Credit
Soil organic matter	30 lbs N/% OM
Residual soil nitrate	3.6 lbs N/ppm NO_3-N
Manure	10.0 lbs N/ton manure
Irrigation water	2.7 lbs N/AF x ppm NO_3-N
Previous alfalfa/sweet clover	50 lbs N/acre
Other previous legume crop	30 lbs N/acre

BMP 6. Analyze irrigation water quality periodically, and credit NO_3-N in water to crop requirements.

Irrigation water containing nitrate can supply N to the crop since it is applied and taken up as the crop is actively growing. Water tests for NO_3-N should be taken periodically during the irrigation season to accurately calculate this credit. Multiply ppm NO_3-N by 2.7 lbs/acre ft. times the amount of water applied to the crop (in AF) to determine lbs N/acre applied in the irrigation water. Inexpensive quick tests are available for on-farm water testing. If a water sample is taken for laboratory analysis, it should be kept refrigerated, but not frozen, until it gets to the lab.

Example Calculation: Irrigation water N credit

20 inches of effective irrigation containing 7 ppm NO_3-N = ? lb N/A

$$\frac{\text{20 inches applied/A}}{\text{12 inches/AF}} \times (\text{2.7 lbs N/AF}) \times (\text{7 ppm } NO_3\text{-N}) = \text{31.5 lb N/A}$$

Table 2. N credit from irrigation water

NO_3-N conc. in water (ppm or mg/L)	Effective Irrigation -------- Acre inches ----------- 6	12	18	24	30	36
	-------- lb N/A ----------					
2	3	5	8	11	14	16
4	5	11	16	22	27	33
6	8	16	24	32	41	49
8	11	22	32	43	54	65
10	13	27	40	54	67	81
12	15	32	48	65	81	97
14	18	37	56	76	95	113
16	21	42	64	87	109	129
18	24	47	72	98	123	145

BMP 7. Apply N fertilizers where they can be most efficiently taken up by the crop.

Optimal fertilizer placement can greatly enhance plant uptake of N. Subsurface applied or incorporated fertilizer is much less subject to surface losses than surface broadcast fertilizer. Band applied fertilizer can be placed in closer proximity to plant roots. All surface applied fertilizers should be incorporated to reduce runoff and volatilization.

BMP 8. Time application of N fertilizer to coincide as closely as possible to the period of maximum crop uptake.

Fertilizer applications should be timed to coincide as closely as possible to the period of maximum crop uptake. Partial application of N in the spring, followed by sidedress application improves crop N uptake efficiency and reduces N available for leaching. Waiting until the crop is well established before applying large amounts of N reduces the chance of early season losses and allows producers to more accurately determine the crop yield potential. Poor stands and below average precipitation are good reasons to adjust N rates downward at sidedress time. Conversely, exceptional conditions warrant increased N at sidedress. This type of managerial flexibility offers producers economic benefits and helps maintain water quality.

BMP 9. Avoid fall application of nitrogen fertilizer for spring planted crops.

Fall applied N fertilizer has been shown to cause groundwater degradation in areas of high fall and winter precipitation. It should be avoided on spring planted crops in situations with moderate to severe leaching potential (Table 5). There may be economic and management benefits to applying N in the fall, but the environmental risks make this a poor choice on coarse textured soils or in situations where preplant irrigation is necessary.

BMP 10. Use nitrification inhibitors in combination with ammoniacal fertilizers, where feasible.

Nitrate forms of N fertilizer are readily available to crops, but are subject to leaching losses. Nitrate forms should not be applied in large amounts when the leaching hazard is moderate to severe. Ammonium N forms, such as urea or anhydrous ammonia, are preferred in these situations because they are not subject to immediate leaching. However, under warm, moist soil conditions, transformation of NH_4 to NO_3 occurs rapidly. Other more slowly available N sources such as IBDU or the coated ureas are commercially available and should be utilized where they are economically feasible.

Nitrification inhibitors can be used to delay the conversion of NH_4 to NO_3 under certain conditions. Farmers should consider using nitrification inhibitors when it is not feasible to use split applications or other management techniques on leachable soils. Nitrification inhibitors seldom produce a direct economic return to farmers and should not be used as a substitute for following other BMPs, but they can reduce leaching under certain situations.

BMP 11. Use plant tissue analysis where appropriate to guide in-season nitrogen fertilizer application.

Plant analysis during the growing season is another practice to help assess nutrient sufficiency in the growing plant. While nutrient deficiencies are many times visibly apparent, excess nutrient levels can only be determined by plant tissue analysis. This technology offers producers the ability to apply lower rates of N preplant, and to monitor and adjust plant nutrient status throughout the growing season. Plant analysis, when properly used, offers producers insurance that careful N management will not negatively affect the bottom line.

Other N Management Tools

Although proper N rates and good irrigation management are the most critical components of N management, there are other tools which should also be considered. Proper calibration and maintenance of fertilizer equipment is essential to get uniform distribution of fertilizer at the correct rate. Crop rotation can be beneficial by minimizing total fertilizer and pesticide needs. Often, yield improvement and economic benefits are achieved through a good rotation plan due to better pest control, soil tilth, and N fixation by legumes. Deep rooted crops can be used to scavenge N left in the subsoil by shallow rooted crops. Cover crops are beneficial in preventing wind and water erosion, and can utilize residual N in the soil profile. Finally, computer assisted decision aides such as the Nitrate Leaching and Economic Analysis Package (NLEAP) model can help producers make wise choices and avoid unnecessary water quality degradation.