Nitrogen Management Strategies for Potato Producers
Michigan State University Extension Service
Maurice L. Vitosh, Crop and Soil Sciences
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NITROGEN MANAGEMENT STRATEGIES FOR POTATO PRODUCERS

by Maurice L. Vitosh
Extension Specialist, Crop and Soil Sciences Department

Much attention has recently been focused on agricultural nonpoint sources of pollution. National studies suggest that agricultural pollution adversely affects more than two-thirds of the nation's river basins. A nonpoint source is most frequently described as "a diffuse source of water pollution that does not discharge through a pipe." Runoff or drainage from agricultural land which contains pollutants such as soil, nutrients or pesticides, is considered a nonpoint source of pollutants. Nitrogen (N) fertilizers are considered a major nonpoint source of nitrate contamination of streams, lakes and groundwater. It is not surprising that agricultural activities constitute the most widespread cause of water-quality problems from nonpoint pollution sources because approximately 63 percent of nonfederal land in the United States is used for agriculture, including crop and livestock production.

A 1984 survey of 178 wells in Montcalm county in central Michigan found that 7 percent of the water samples exceeded the standard of 10 ppm (parts per million) of nitrate nitrogen in drinking water. Although the percentage is not large by any standard, there is cause for concern. The area represents an intensive agricultural area having a high concentration of irrigated potatoes grown on sandy soils where relatively high rates of nitrogen fertilizer are required to produce economic yields.

While it is probably impossible to achieve 100 percent recovery of the applied nitrogen fertilizer, increasing the nitrogen efficiency and uptake of the potato crop is an important goal to strive for. However, one should not assume that nitrogen not taken up by plants but left in the soil is lost to groundwater. Nitrate movement through the soil, the geological strata above the aquifer and the movement in groundwater itself is highly unpredictable, which makes it extremely difficult to determine the fate of applied sources of nitrogen. In addition, biological processes in the soil such as decomposition, immobilization and denitrification constantly change the amount of nitrate-nitrogen that is available for leaching. This is true for fertilized soils and for nonfertilized areas where normal ecological processes are active. Nevertheless, there is great concern for the preservation of high-quality drinking water and the need to improve nitrogen fertilizer efficiency.

This bulletin deals with management strategies for efficient use of nitrogen fertilizers and other management practices for helping minimize nonpoint source pollution. *Efficient use of nitrogen fertilizer is an important key to minimizing nitrate contamination of surface water and groundwater.*

Present Situation

Nitrogen fertilizer practices used by Michigan potato growers are the result of several historical factors. University recommendations based on field-plot research have played an important role in guiding farmers toward the optimum and most efficient nitrogen rate, particularly during the early days of fertilizer use. Today, the experience and preference of growers, as well as economics and yield expectations, play an equally important role in determining the present fertilizer usage. Research continues to provide guidance for growers with information on nitrogen rates, sources, time of application and placement for the best efficiency.

With today's technology, an increasing number of Michigan potato growers have developed the skills and management systems necessary to grow 500 hundred-weight (cwt) of potatoes per acre, more than double the state average. High land values and high production costs have caused many growers to seek higher yields. Because higher potato yields are closely associated with higher nitrogen fertilizer rates, more and more growers are using higher rates of nitrogen fertilizer. As a result, some low-yielding fields are receiving excessive amounts of nitrogen. Other cultural and management practices are limiting yields in these fields. Relatively cheap nitrogen fertilizer prices and the prospect of a high-value cash crop have also encouraged growers to overfertilize with nitrogen to insure that nitrogen is not limiting yield.

Overfertilization with nitrogen generally results in some residual nitrogen left in the soil at the end of the growing season. In semi-arid regions, the residual nitrogen may be available for next year's crop. In more humid regions such as Michigan, very little residual nitrogen remains available, particularly in sandy soils. Most of the nitrogen remaining at the end of the growing season is lost, either by leaching beyond the root zone or to the atmosphere by the process of denitrification.

Denitrification is thought to be the dominant process in fine-textured soils (clays, clay loams and loams). Although these soils are usually poorly drained, artificial tile drainage may allow some of the residual nitrogen to be leached to surface water. In course-textured soils (sands, loamy sands and sandy loams) where most potatoes are grown, leaching is the dominant process of nitrate loss during the season, and particularly when the crop is not actively growing. Any nitrate nitrogen leached below the crop rooting zone is lost to the crop and is generally believed to eventually reach groundwater.

Choosing the Optimum Nitrogen Rate

Choosing the optimum nitrogen rate for potatoes is an important key to minimizing the potential for nitrate contamination of groundwater. Determining that optimum rate, however, is not easy. The grower must consider all sources of available nitrogen and supplement any remaining requirement with fertilizer nitrogen. The available sources include residual nitrogen remaining from the previous crop, mineralized nitrogen from organic matter or manure and decomposing crop residues. Routine soil test procedures for measuring residual nitrogen and easily mineralized nitrogen have not been adopted in Michigan because of the unpredictability of nitrogen losses from the rooting zone.

Present nitrogen recommendations for potatoes grown in Michigan are based strictly on the expected yield and previous cultural practices. Soil types and management greatly influence the expected yield. The key to this approach is selecting the appropriate yield goal: one that is realistic and achievable. The grower should achieve the goal at least two out of five years, or nearly 50 percent of the time. If the goal is seldom achieved, one must conclude that overfertilization with nitrogen has occurred, and factors other than nitrogen are limiting yield and reducing nitrogen efficiency.

Michigan State University nitrogen recommendations for potatoes are shown in Table 1. They are based on an expected yield goal and adjusted for nitrogen supplied by a previous alfalfa crop. The formula at the bottom of the table can be used to calculate the optimum nitrogen rate for any specific yield goal. The formula assumes that the soil has an organic matter content of 2-4 percent, and that the nitrogen fertilizer will be applied as efficiently as possible.

Table 2 includes additional suggestions for adjusting the basic nitrogen rate obtained from Table 1 or the formula. Soils with a high level of organic matter will supply more mineralized nitrogen than those with a low level. Legumes other than alfalfa may contribute to the available nitrogen supply, but the amount is usually less.

Table 1. Nitrogen fertilizer recommendations for potatoes grown on mineral soils.

Yield Goal	N Recommendation[1]
cwt/A	lb/A
300	150
350	170
400	180
450	200
500	210

[1]For Russet Burbank, add an additional 40 lbs. of nitrogen to obtain the same yield goal as other full season varieties.

Recommendations are calculated from the following formula and rounded to the nearest 10 lbs:

$$XN = 60 + .3 * YG$$

where XN = lb N/acre and YG = yield goal (cwt/acre).

Table 2. Suggested nitrogen credit or deficit for various management practices, soil types, climatic and environmental situations.

Situation	Nitrogen Credit or Deficit*
	lbs/A
Soil organic matter content	
0-2%	(−) 20-40
2-4%	0
4-8%	(+) 20-40
>8%	(+) 40-80
Previous crop	
Alfalfa	
60-100% stand	(+ 80-100
30-60% stand	(+) 60-80
0-30% stand	(+) 40-60
Red clover and other clovers	(+) 40-60
Soybeans, dry edible beans	0
Small grains, corn grain, sugarbeets	0
Corn silage	(−) 30-50

*(+) indicates a credit and should be subtracted from the recommended rate.

(−) indicates a N deficit and should be added to the recommended rate.

Data from the Montcalm Research Farm in Table 3 show the typical nitrogen response of potatoes in a potato-corn-dry edible bean rotation. The optimum nitrogen rate for this study was 240 lbs per acre where 60 lbs was applied at planting and 180 lbs per acre sidedressed at hilling time. The highest rate of nitrogen produced lower yields for both varieties.

Table 4 shows the benefits of a previous alfalfa crop to supply nitrogen to potatoes. The previous alfalfa crop was equivalent to approximately 150 lbs of nitrogen, since there was no response to nitrogen beyond the 75 lbs of nitrogen applied at planting time. Higher levels of nitrate nitrogen were present in the plant tissue on July 13 following the alfalfa crop as compared with the corn, even at the low rate of nitrogen. Alfalfa may also have improved soil physical conditions because of its deep tap root system resulting in improved nitrogen uptake.

Plant analysis for nitrate nitrogen can also be a very effective tool for determining the optimum nitrogen rate. Petiole samples taken periodically throughout the growing season can be used to determine the nitrogen status of the plant. Guidelines for interpreting the nitrate levels are given in Table 5. If nitrate levels fall below the adequate level, additional nitrogen may be needed to produce the optimum yield. Excessive levels of nitrate indicate that overfertilization with nitrogen has occurred, and it would be advisable to reduce the total amount of nitrogen fertilizer used or improve the timing of nitrogen application.

Efficient Use of Nitrogen

Nitrogen efficiency can be maximized by supplying the needed nitrogen just prior to the crop's greatest demand. For potatoes, this occurs during rapid growth and dry matter accumulation (figure 1). In Michigan, this period usually starts shortly after emergence and continues throughout July and August. Fertlizing to achieve maximum efficiency usually means applying some of the nitrogen at or before hilling or applying it through the irrigation system.

Table 3. **Effect of nitrogen sidedress rate on yield of irrigated Russet, Burbank and Sebago potatoes (Montcalm Research Farm 1970-72).**

Nitrogen placement: Banded at planting	Sidedress at hilling	Total nitrogen	Total yield: Russet Burbank	Sebago
lb/A			cwt/A	
0	0	0	146	189
60	120	180	360	439
60	180	240	377	458
60	240	300	359	431

Table 4. **Effect of nitrogen rate and previous crop on yield and petiole nitrate content of irrigated Atlantic potatoes (Montcalm Research Farm 1983).**

Nitrogen placement: Banded at planting	Sidedress at hilling	Total nitrogen	Previous crop	Tuber yield	Petiole[1] nitrate
l/A				cwt/A	ppm
75	0	75	Corn	342	9,130
75	150	225	Corn	440	12,420
75	0	75	Alfalfa	450	16,320
75	150	225	Alfalfa	437	16,060

[1]Sampled July 13.

Table 5. **Guidelines for interpreting nitrate-nitrogen levels of potato petioles.**

Interpretation	Stage of growth[1]: Early tuber set	Mid-season	Late season
	ppm Nitrate-nitrogen		
Deficient	<6,000	<5,000	<4,000
Inadequate	6,000 to 17,000	5,000 to 11,000	4,000 to 5,000
Adequate	18,000 to 22,000	12,000 to 15,000	6,000 to 8,000
Excess	>22,000	>15,000	>8,000

[1]Approximate dates corresponding to the growth stages of Russet Burbank are:

Early tuber set - June 15-June 30
Mid-season - July 1-July 15
Late season - July 15-August 15

Nitrogen management practices will be different for each grower and may be slightly different for each field, depending on the soil type, variety grown, length of maturity and previous cultural practices. Each grower must evaluate his own management in terms of tillage practices, fertilizer source, available equipment, time constraints and what is economically feasible. Table 6 illustrates the benefits of sidedressing nitrogen at hilling time as compared with broadcasting before planting. Both varieties responded favorably to the sidedress treatment.

Applying nitrogen through the irrigation system offers the greatest opportunity to supply nitrogen when the crop's demands are greatest. The method requires little additional energy for application and is well suited to sandy soils where leaching is a problem. The most common fertilizer applied is a 28 percent nitrogen solution because it is readily available and causes little or no problem during injection to the water supply. Anhydrous ammonia cannot be used in sprinkler irrigation systems because it can cause precipitation of calcium in the water and loss of free ammonia to the atmosphere.

Approximately one-third to one-half of the total nitrogen requirements may be supplied through the irrigation system. A good practice is to apply approximately one-third of the nitrogen at planting, one-third as a sidedress application and the remainder through the irrigation system. Applying too much of the nitrogen through the irrigation system has its disadvantages. For example, when rainfall is adequate during the early growing season and irrigation water is not needed, a nitrogen shortage may occur. It is very important that nitrogen be readily available during tuber initiation and bulking. Applying a small amount of nitrogen through the irrigation system during each irrigation in July and early August should provide the best possible utilization of nitrogen with a minimum of loss of nitrate to groundwater.

Irrigation Scheduling

Nitrogen management alone will not effectively reduce nitrogen leaching on irrigated sandy soils. Excess water from either irrigation or precipitation can cause nitrates to move below the root zone. Proper irrigation scheduling during the growing season is necessary to minimize percolation losses.

There are several methods of accurately scheduling irrigation water for potatoes. All methods require knowing the soil's water-holding capacity and being able to determine or estimate the available soil mositure at any time during the growing season. Soil tensiometers, which measure the tension with which water is held, are excellent tools on sandy soils for determining when to irrigate. The water-balance approach to irrigation scheduling is also a very good method. This method requires the estimation of crop water use (evapotranspiration). Computerized programs using the water-balance approach to irrigation scheduling are available from the Cooperative Extension Service.

Figure 1. Nitrogen uptake of potatoes in relation to dry weight accumulation. (Adapted from Saltanpour, *American Potato Journal* 46:111-119, 1969.)

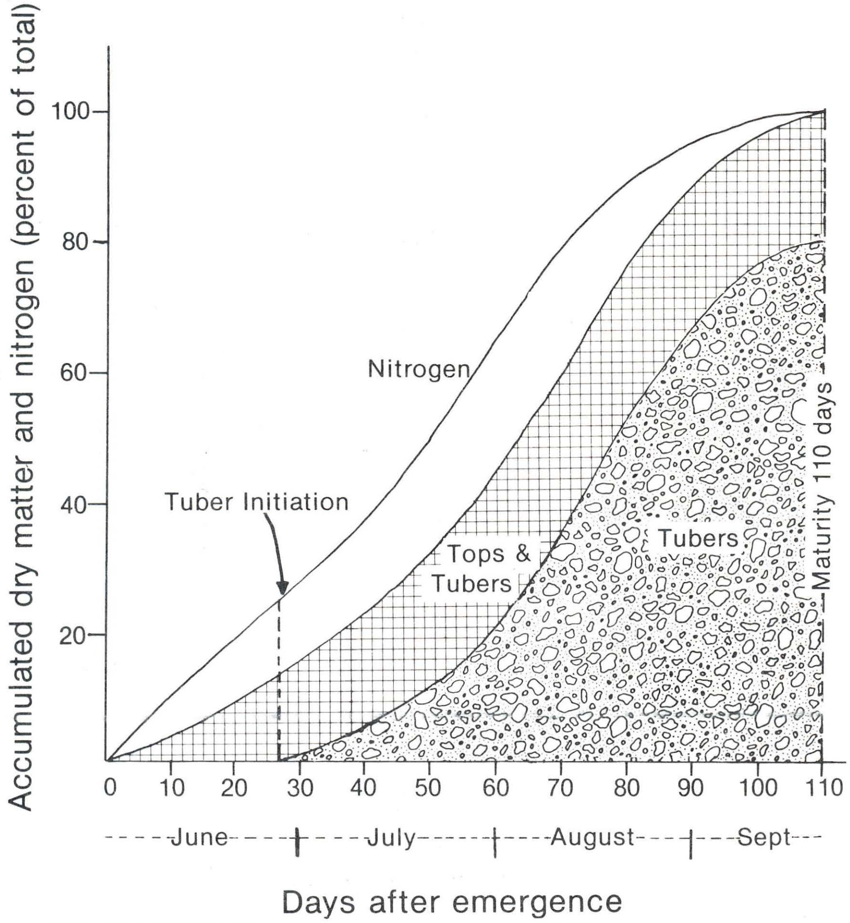

Table 6. **Effect of rate, placement and time of nitrogen application on yield of irrigated Russet Burbank and Sebago potatoes (Montcalm Research Farm 1967-69).**

Nitrogen placement				Total yield	
Broadcast preplant	Banded at planting	Sidedress at hilling	Total nitrogen	Russet Burbank	Sebago
lb/A				cwt/A	
0	0	0	0	176	201
0	60	0	60	240	277
60	60		120	279	323
	60	60	120	307	355
120	60	0	180	311	353
	60	120	180	321	368

Although good irrigation management can minimize or reduce nitrogen losses from the root zone during the growing season, precipitation after the growing season can result in the removal of nearly all of the residual nitrogen left. Therefore, it is essential that irrigators manage the amount of nitrogen in the root zone at all times. Applying nitrogen through the irrigation system offers an excellent opportunity for improving nitrogen efficiency.

Summary

There are many management strategies for achieving effective and efficient nitrogen use without unnecessary risk of reducing potato yield and contaminating groundwater with nitrate nitrogen. The following outline describes a few of the recommended management strategies.

1. Choose the optimum nitrogen rate.
   a. Consider all sources of available nitrogen.
   b. Follow recommendations based on unbiased research.
   c. Choose a realistic yield goal.
   d. Make adjustments for soil organic matter, previous legume crops and manure.
   e. Use plant analysis to adjust nitrogen usage.
2. Apply nitrogen efficiently.
   a. Consider the soil and its physical properties.
   b. Consider the plant and its nitrogen uptake pattern.
   c. Irrigators should consider applying nitrogen through the irrigation system.
3. Use modern irrigation scheduling techniques.
   a. Know the water-holding capacity of the soil.
   b. Use tensiometers on sandy soils.
   c. Know the water requirements of the crop.

Related Publications

Extension Bulletin E-550, *Fertilizer Recommendations for Vegetable and Field Crops.*

Extension Bulletin E-1411, *Testing for Nitrates in Well Water.*

Extension Bulletin WQ06, *Nitrogen Fertilizer Management for Efficient Crop Production and Preservation of Water Quality.*

Extension Bulletin WQ07. *Nitrogen Management Strategies for Corn Producers.*