A3634

Nitrogen management on sandy soils

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Nitrogen (N) requires careful management when used for crop production on sandy soils because of the high potential for leaching losses of nitrate through these soils. Selecting the appropriate nitrogen rate is the primary management consideration on medium- and fine-textured soils. However, on sandy soils, other decisions such as nitrogen source, and method and time of application are of equal concern to ensure that nitrogen is not lost by nitrate leaching during the growing season. This publication outlines management considerations for nitrogen use on sandy soils.

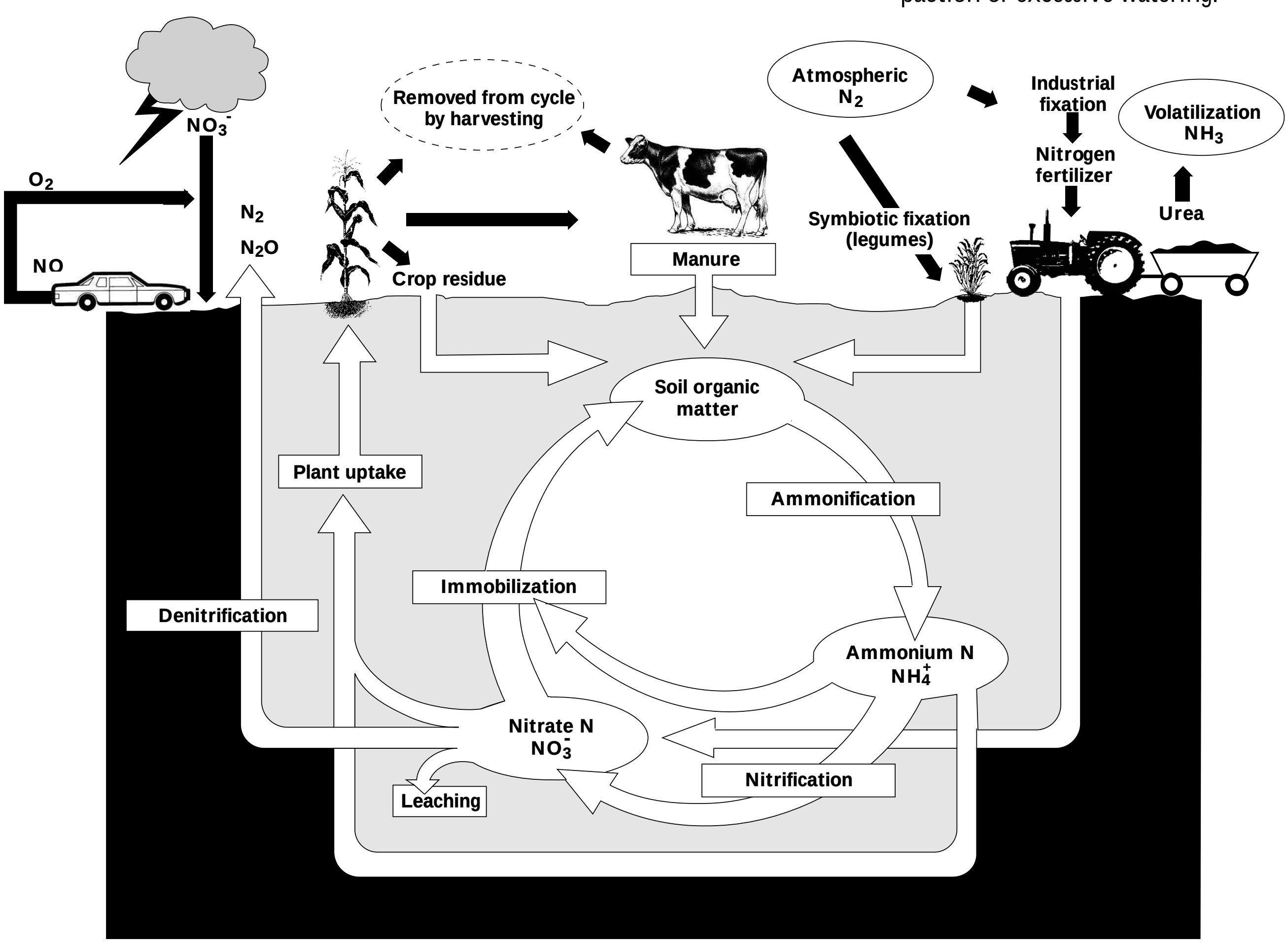
Nitrogen and sandy soils

Nitrogen is constantly changing forms in the environment (figure 1). The most important of these changes that influences nitrogen management in sandy soils is the process known as nitrification.

Nitrification occurs when ammonium nitrogen is added to warm, moist soil. Soil bacteria convert ammonia to nitrate. Because nitrate (NO_3^-) is a negatively charged ion, which is not held by soil particles, it is readily leached as water flows through the soil. Nitrates leach more rapidly from sandy soils than from finer-textured soils because sandy soils have a lower water-holding capacity. This means that the same amount of water from rainfall or irrigation will leach ions deeper in sandy soils than fine-textured soils. Recent research has shown that water moves through sandy soils faster than once thought, flowing through channels created by roots and burrowing animals and insects, and along soil textural boundaries. This study highlights the need to carefully manage nitrogen inputs to minimize groundwater contamination.

Denitrification, the conversion of nitrogen from nitrate to a gas, occurs in waterlogged soils. On sandy soils, denitrification is a concern only on localized wet areas where standing water accumulates due to soil compaction or excessive watering.

Figure 1. *The nitrogen cycle.*



The organic matter content of sandy soils is usually lower than those of finer-textured soils. Soil organic matter acts as a slowly available source of nitrogen. Crop residues decompose faster on sandy soils. Accelerated decomposition means that the nitrogen released from crop residues after harvest may be leached before they can be used by the next crop.

A nitrogen fertilization program for sandy soils should be developed with thought toward the conversions shown in the nitrogen cycle. Fertilization practices should optimize yield and recover as much of the applied nitrogen as possible in the harvested portion of the crop.

Factors affecting nitrogen management decisions

Many factors enter into nitrogen management decisions for sandy soils. This section examines the role each factor plays in selecting a nitrogen fertilizer and in deciding when and how to apply it.

Rate

University of Wisconsin nitrogen rate recommendations are based on research that identifies the amount of nitrogen needed to optimize yield from agronomic, economic, and environmental considerations. Applying less than the recommended nitrogen rate can substantially reduce profits, while over-application increases the risk of nitrate contamination of the groundwater.

Nitrogen rate recommendations are affected by (1) the crop to be grown, (2) soil texture, (3) soil organic matter, (4) soil yield potential, (5) use of irrigation, and 6) yield goal for potato. Be sure to credit nitrogen inputs from legumes and organic by-products, such as manure. Nitrogen fertilizer recommendations assume that nitrogen losses such as leaching, denitrification, and loss of ammonia from urea-containing materials (volatilization) are minimized.

Table 1 shows the recommended nitrogen rates for corn and potato. Recommendations for other crops are given in Extension publication *Soil Test Recommendations for Field, Vegetable, and Fruit Crops* (A2809). The use of nitrogen availability tests, such as the preplant profile nitrate test or the presidedress nitrate test, are *not* recommended on sandy soils because the soil nitrate content changes rapidly on these soils.

Timing

The goal of a nitrogen fertilization program is to provide adequate amounts of available nitrogen when plants are actively growing and using nitrogen rapidly. This period lasts from mid-June through July for most annual crops. Losses of applied nitrogen on sandy soils can often be reduced by delaying application until after the crop has emerged (sidedressing). The best time to sidedress nitrogen to corn is between 5 and 8 weeks after planting.

There is little nitrogen carryover from one year to the next in sandy soils, making it important for plants to use, or recover, as much applied nitrogen as possible to minimize nitrate leaching and maximize crop yield. Even under ideal conditions, most crops recover no more than 60% of the applied nitrogen. Do not fall-apply nitrogen fertilizers, manure, or biosolids (sludge and other organic wastes) on sandy soils because much of the nitrogen will be lost from the crop root zone before the next growing season.

Some growers believe that there is a benefit to splitting nitrogen additions into several applications to "spoon feed" the crop. This is usually done by applying some of the nitrogen with the irrigation water. This practice allows fertilization of crops that are too tall for ground equipment and often increases recovery of applied nitrogen. The disadvantage of split applications using ground equipment include the added cost and availability of equipment, weather delays, root pruning or damage by injected applications, and the need for additional field operations. Table 2 shows the results of a study where 210 lb/a nitrogen was applied to corn as a single application and as two, three, and four applications. Even though yield was affected in just one year, the four-way split substantially increased recovery of applied nitrogen by the crop in both years.

Table 1. *Nitrogen recommendations for corn and potato grown on sandy soils*

Organic matter	Corn		Potato (yield goal, cwt/a)		
	Irrigated	Non-irrigated	250–350	351–450	451–600
%	amount to apply, lb/a nitrogen				
<2	200	120	115	150	200
2.0–4.9	160	110	90	125	150
5.0–10.0	120	100	70	100	125
>10	80	80	50	75	100

Source: K.A. Kelling et al., Extension publication Soil Test Recommendations for Field, Vegetable, and Fruit Crops *(A2809).*

Considerable research has compared the timing of nitrogen applications in potato production. These studies have found that applying one-third to one-half of the nitrogen at emergence improves yield and/or quality. Table 3 shows that splitting nitrogen applications generally provides an advantage over a single application. While splitting the treatments further can help in years with very high precipitation (as in year 3), during years with average precipitation other treatments gave better results. Other studies have found a higher percentage of cull potatoes in treatments with multiple applications. Given the unpredictability of weather and the cost of applications, excessive splitting of potato nitrogen applications is generally not recommended.

Fertilizer source

Many nitrogen fertilizer materials are available for use on sandy soils. Price, availability of the fertilizer material and application equipment, and crop to be grown will influence selection of fertilizer source.

Anhydrous ammonia is usually the least expensive nitrogen source, although this material has handling and application requirements that must be followed for safe and effective use. Anhydrous ammonia should be knifed into 6 to 8 inches of moist soil using attachments to cover the knife openings. Anhydrous ammonia readily combines with water in the soil to form ammonium ions which tend to remain as ammonium for a longer time than other sources of ammonium (e.g., urea). Anhydrous ammonia may not be well suited for some crops, such as potato, because the hills make side-dress application difficult. Because anhydrous ammonia slows the conversion of ammonium to nitrate by creating an environment hostile to nitrifying bacteria, it performs better on

Table 2. *Effect of timing of UAN application on corn grain yield and nitrogen recovery (Hancock, Wis.)*

Timing				Year 1		Year 2	
PP	SD	SD+4	SD+8	Yield	Recovery	Yield	Recovery
— % nitrogen applied —				bu/a	%	bu/a	%
100	0	0	0	140	44	129	26
0	100	0	0	139	56	143	30
50	50	0	0	—	—	149	41
0	50	25	25	140	49	138	35
17	50	17	17	143	65	141	56

All plots received 210 lb/a nitrogen, UAN = Urea-ammonium nitrate solution.
Abbreviations: PP=preplant, SD=sidedress,SD+4=sidedress plus 4 weeks, SD+8=sidedress plus 8 weeks.

Table 3. *Effect of timing of nitrogen application on potato yield (Hancock, Wis.)*

Timing					Yield				
E	H	H+10	H+20	H+30	1	2	3	4	Avg.
— % nitrogen applied —					cwt/a				
100	0	0	0	0	495	345	319	380	385
0	100	0	0	0	549	311	342	367	393
0	0	100	0	0	516	270	299	359	361
50	50	0	0	0	514	351	342	401	402
33	67	0	0	0	543	371	335	391	410
33	33	33	0	0	526	312	338	359	384
33	17	17	17	17	555	323	372	338	397

All plots received 120 lb/a nitrogen.
Abbreviations: E=emergence, H=hilling; H+10=hilling plus 10 days; H+20=hilling plus 20 days; H+30=hilling plus 30 days.

sandy soils than other nitrogen sources. Table 4 shows that corn yield and recovery of applied nitrogen were higher with anhydrous ammonia than with incorporated urea on a sandy soil. This response was greatest when the nitrogen fertilizers were applied preplant. Even though yield was not affected by nitrogen source at sidedress, recovery was still higher where anhydrous ammonia was used. These data show that preplant applied urea on irrigated sandy soils is not an effective nitrogen management alternative.

Urea and urea-containing materials, such as UAN solution, should be incorporated after application to prevent the loss of nitrogen through ammonia volatilization. Ammonia losses following surface application of urea-containing fertilizers can be controlled by incorporation or by at least 0.20 inches of precipitation or irrigation within 48 to 72 hours of application. Injection below the soil surface is also a satisfactory method of reducing nitrogen loss from ammonia volatilization. Ammonia volatilization losses are maximized by warm weather, high levels of crop residue, and high soil pH. Research in southern Wisconsin shows that about 20% of the surface-applied, urea-nitrogen can be lost as ammonia when conditions are favorable.

Other sources of nitrogen, such as ammonium nitrate, calcium nitrate, and ammonium sulfate are often used on specialty crops and potatoes. These materials are usually more expensive than anhydrous ammonia or urea on a cost per pound of nitrogen basis, but they are easier to apply and they supply other plant nutrients. Specialty fertilizers such as calcium nitrate and potassium nitrate are sometimes used to supply calcium or potassium during the growing season. Avoid using these products as the sole nitrogen source. Instead, include materials that contain ammonium forms of nitrogen, especially for early-season applications. A five-year study examining the effects of nitrogen sources on potato yield, quality, and nitrogen recovery (table 5) found that fertilizers containing ammonium produced higher yields and allowed greater recovery of applied nitrogen than an all-nitrate program.

Placement

Nitrogen fertilizers can be applied by several methods depending on the nitrogen source, equipment availability, and time of application. Application methods include sidedressing, knifing, banding, broadcasting, incorporating by hilling, and applying with irrigation water.

Sidedress applications of nitrogen fertilizers are often made by surface banding followed by cultivation or incorporation by irrigation. This practice prevents nitrogen loss by volatilization from urea-containing materials. Care should be taken to avoid root pruning where anhydrous ammonia or other fertilizers are injected. Crops with restricted root systems, such as snapbeans, should have nitrogen placed near roots.

Another form of sidedressing is used for crops grown in hills. Usually the fertilizer is applied near the row and is incorporated into the soil when the hill is formed. Fertilizer nitrogen that is applied between rows is more likely to be lost from the root zone. This occurs because the crop canopy acts like an umbrella and directs water into the furrow. Research shows that about three times as much water flows through the soil in the furrows than through the hills.

Knifed applications place a concentrated band of fertilizer in the root zone. The high concentration of ammonia or salt slows the conversion of ammonium to nitrate. Delayed conversion is most likely with anhydrous ammonia.

Table 4. *Comparison of anhydrous ammonia and urea applied preplant and sidedress, 4-year average (Hancock, Wis.)*

Source	Timing	Yield	Recovery
		bu/a	%
Anhydrous ammonia	PP	144	47
	SD	142	54
Urea	PP	110	27
	SD	140	48

All treatments received 210 lb/a N.
Abbreviations: PP=preplant, SD=sidedress.

Table 5. *Yield and quality of Russet Burbank potato when fertilized by several nitrogen sources, 5-year average (Hancock, Wis.)*

Source	Total yield	Grade A	N recovered in tubers
	cwt/a	%	lb/a
Ammonium nitrate	504	72	56
Ammonium sulfate	528	70	64
Calcium nitrate	490	74	47
Urea	502	71	57

All treatments received 200 lb/a nitrogen split 50:50 at emergence and hilling.

Broadcast applications uniformly distribute nitrogen and are often applied preplant. Preplant applications on sandy soils are often less effective than those made after crop emergence. Broadcast applications of dry materials at high rates over growing crops present the risk of foliar salt burn. Leaf burn can be severe when crops catch fertilizer pellets, such as in the whorl of corn, or when leaves are wet at the time of application. Application of nitrogen-containing solutions can also cause foliar injury. These applications should be limited to less than 40 lb/a of nitrogen and should be made in the evening when the relative humidity is higher and the dew will dilute salts.

Irrigation systems can be fitted with equipment to apply nitrogen solutions with the water in a process known as fertigation. This method has the advantage of avoiding a separate field operation to apply nitrogen and allows for applications throughout the season to "spoon feed" the crop. Fertigation has the disadvantage that timely rains may reduce or eliminate the need for irrigation. Watering solely to supply nitrogen is inefficient and may leach nitrate and other chemicals.

Nitrification inhibitors

Nitrification inhibitors are chemicals that can be added to ammonium-containing nitrogen fertilizers to delay the conversion of ammonium to nitrate. The benefit of nitrification inhibitors is limited by the relatively short-term effectiveness (3 to 6 weeks) of currently available materials on most Wisconsin sandy soils. Nitrification inhibitors will only effectively conserve nitrogen if there is a moderate to high risk of nitrogen loss such as would be found with a preplant applications. A four-year study found that while a nitrification inhibitor (e.g., nitripyrin) increased nitrogen recovery when added to preplant applications, plants recovered more nitrogen when the fertilizer was sidedressed—with or without the inhibitor (table 6).

Table 6. *Effect of nitrification inhibitors on corn yield and recovery, 4-year average (Hancock, Wis.)*

Inhibitor	Timing	Yield	Recovery
		bu/a	%
No	PP	116	37
	SD	134	63
Yes	PP	121	51
	SD	134	65

All treatments received 140 lb/a nitrogen.
Abbreviations: PP=preplant, SD=sidedress.

Legume credits

Legume crops fix nitrogen from the atmosphere into forms usable by the plant. This nitrogen becomes available to succeeding crops when the legume residues decompose. Crops recover less nitrogen from legumes grown on sandy soils than on fine-textured soils because the residue decomposes faster on sandy soils due to warmer soil temperatures, the relatively low storage potential of mineralized nitrogen from organic matter, and the increased potential for nitrate leaching. Legume credits for sandy soils are listed in table 7. Research shows that these credits are applicable to corn, potato, and other crops commonly grown on sandy soils. A nitrogen credit is not given for soybean and vegetable legumes (e.g., peas and snapbeans) on sandy soils because of their low nitrogen fixing capacity, limited dry matter production, and high potential of legume nitrogen loss before it can be used by the next crop.

Table 7. *Legume credits for sandy soils in Wisconsin*

Legume crop	Special conditions	Nitrogen credit (lb/a)
Alfalfa[a]	Good stand (>70%) >4 plants/sq. ft.	140
	Fair stand (30–70%) 1.5–4 plants/sq. ft.	110
	Poor stand (<30%) <1.5 plants/sq. ft.	80
Red clover		80% of alfalfa credit
Soybean		0
Peas/snapbeans		0

[a] *If harvested after September 10 (<10 inches of regrowth at the time of stand destruction) reduce nitrogen credit by 40 lb/a in each stand category.*

Irrigation scheduling and nitrate contribution

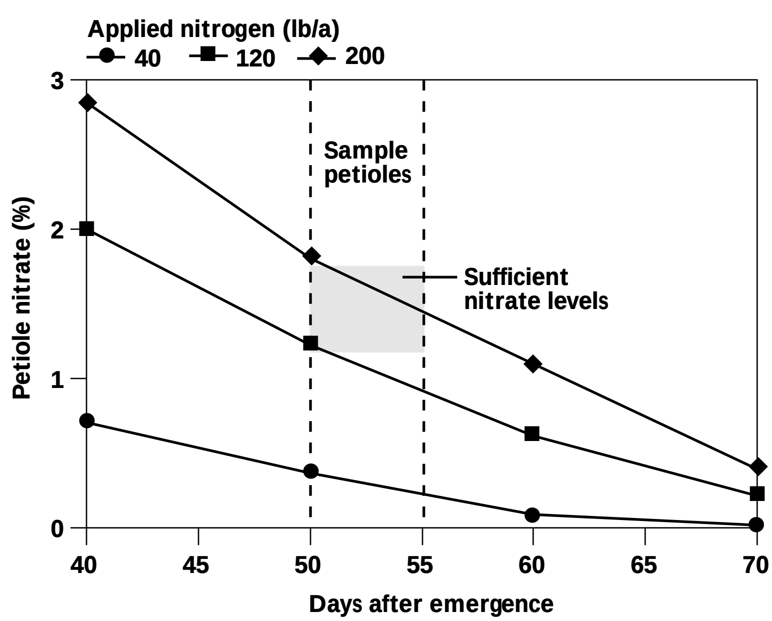
Irrigation is necessary to optimize productivity on sandy soils. The goal of an irrigation program is to supply enough water to optimize yield while avoiding excess irrigation which increase pumping costs and can leach soluble materials from the root zone. Growers should develop an irrigation schedule for each field. Irrigation scheduling requires a knowledge of soil water holding capacity, crop water use, and accurate weather measurements. The Wisconsin Irrigation Scheduling Program (WISP) has been developed to provide irrigation scheduling based on these factors. Consult Extension publication *Irrigation Management in Wisconsin—The Wisconsin Irrigation Scheduling Program (WISP)* (A3600) for additional information.

Growers often ask whether the nitrate present in their irrigation water should be credited. Substantial amounts of nitrogen may be applied through irrigation, especially when either the rate of application or nitrate content of the water is high. For example, 1 inch of irrigation water at 10 parts per million (ppm) nitrate-nitrogen provides 2.3 lb/a nitrogen. Depending upon the year, many growers apply 12 to 15 inches of water or 28 to 35 lb/a nitrogen to a crop. However, most nitrogen response research on irrigated crops has not taken the nitrate content of the irrigation water into consideration when developing nitrogen rates and management practice recommendations. Therefore, the nitrate content of irrigation water is part of the background nitrogen supply across all rates and is included in the nitrogen recommendation. Because nitrogen applications must be made before it is known how much water will be applied in a growing season, do not take an irrigation water nitrogen credit.

Monitoring nitrogen nutrition

Nitrogen deficiencies sometime occur on sandy soils where appropriate nitrogen management practices have been used. This situation can arise when heavy rains early in the season leach applied nitrogen. By the time visual symptoms appear on a crop, nutrient deficiency may be so severe that significant yield losses have already occurred. A better approach is to use plant analysis to confirm a suspected nitrogen deficiency and then make a remedial nitrogen application in time to supply crop needs. Plant analysis measures the concentration of essential elements to identify nutrient deficiencies. For information on when and how to sample, see Extension publication *Sampling for Plant Analysis: A Diagnostic Tool* (A2289).

Figure 2. *Relationship between nitrogen rate and date of sampling on the petiole nitrate concentration of Russet Burbank potatoes (Hancock, Wis.).*



For potatoes, the petiole nitrate test gives the best evaluation of the crop nitrogen status. Figure 2 shows the relationship between the time of petiole sampling and nitrate content of Russet Burbank petioles where several rates of nitrogen were applied. A rate of 200 lb/a nitrogen is recommended to optimize potato yield on the sandy soils of central Wisconsin. Calibration studies have shown that petiole nitrate levels of 1.2 to 1.6% at 50 to 55 days after emergence are needed to optimize yield. Growers who routinely monitor petiole nitrate levels should consider reducing initial nitrogen application rates, with the anticipation of applying additional nitrogen if indicated by the petiole test.

Keys to managing nitrogen on sandy soils

1. **Apply the recommended rate.** Select the correct rate for your soil based on soil test recommendations. Remember to select a starter fertilizer program that will provide at least 10 lb/a nitrogen (20 lb/a nitrogen for potato). Don't subtract this nitrogen from the nitrogen rate unless it exceeds 20 lb/a for corn or 40 lb/a for potato. Calibrate application equipment to be certain that the proper rate is being applied. Too little nitrogen cuts profits through yield reductions; too much nitrogen hurts profits through unnecessary fertilizer use and increases the potential for nitrate contamination of the groundwater.
2. **Apply just before peak crop demand.** On sandy soils wait until the crop has emerged. There may be an advantage to splitting nitrogen applications, but consider the additional costs. *Avoid fall and preplant applications of fertilizers, manure, and biosolids (sewage sludge and other organic wastes).*
3. **Select an ammonium-containing fertilizer.** Ammonium-containing fertilizers will provide greater nitrogen recovery and higher yield than sources which contain only nitrate. For corn, anhydrous ammonia is superior in early season applications, but is similar to urea when applied sidedress. Preplant urea is not a satisfactory nitrogen source on sandy soils.
4. **Incorporate materials as soon as possible after application.** Soil incorporation is particularly important when using urea-containing fertilizers.
5. **Use nitrification inhibitors where needed.** Use nitrification inhibitors when preplant-applying ammonium sources of nitrogen, if sidedressing is not an option. Sidedress applications without nitrification inhibitors are superior to preplant applications with nitrification inhibitors.
6. **Take credit for organic sources of nitrogen.** Legume and manure nitrogen credits are significant on sandy soils and must be taken to manage nitrogen efficiently. Take no nitrogen credit for a previous crop of soybeans, snapbeans, or peas.
7. **Irrigate wisely.** Irrigation is necessary to maximize the yield potential of sandy soils. Use an irrigation scheduling program to provide the water the crop needs without over application.
8. **Monitor crop nitrogen.** Scout fields to evaluate nitrogen status by appearance and monitor nitrogen fertilization programs by sampling fields for plant analysis. Use the petiole nitrate test to determine supplemental nitrogen needs for potato.

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