A3517

Using Legumes as a Nitrogen Source

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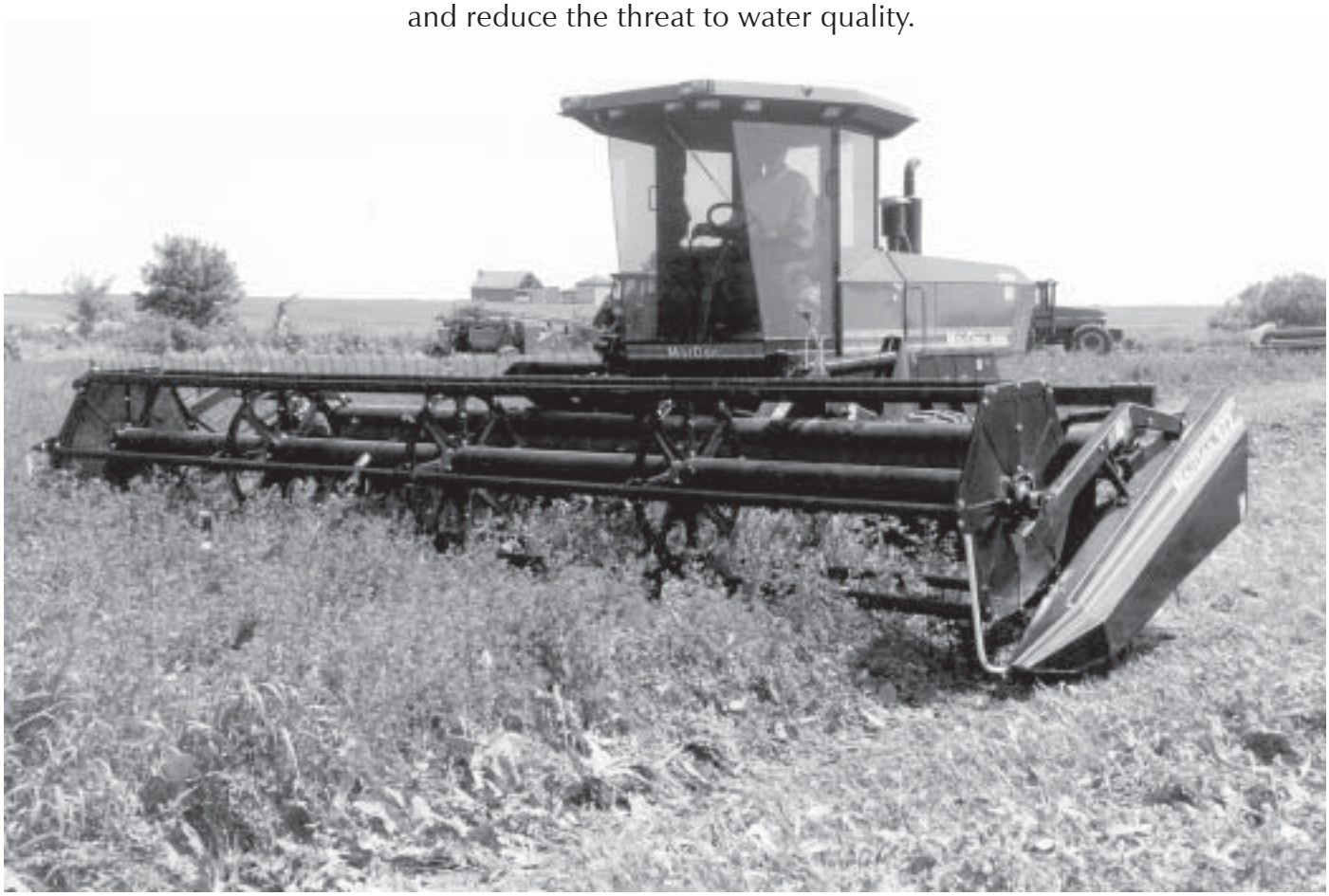
Are you taking advantage of all of your on-farm nitrogen?

By applying less fertilizer or manure N to a field following a legume crop than you do on other fields, you can save money and reduce the threat to water quality.

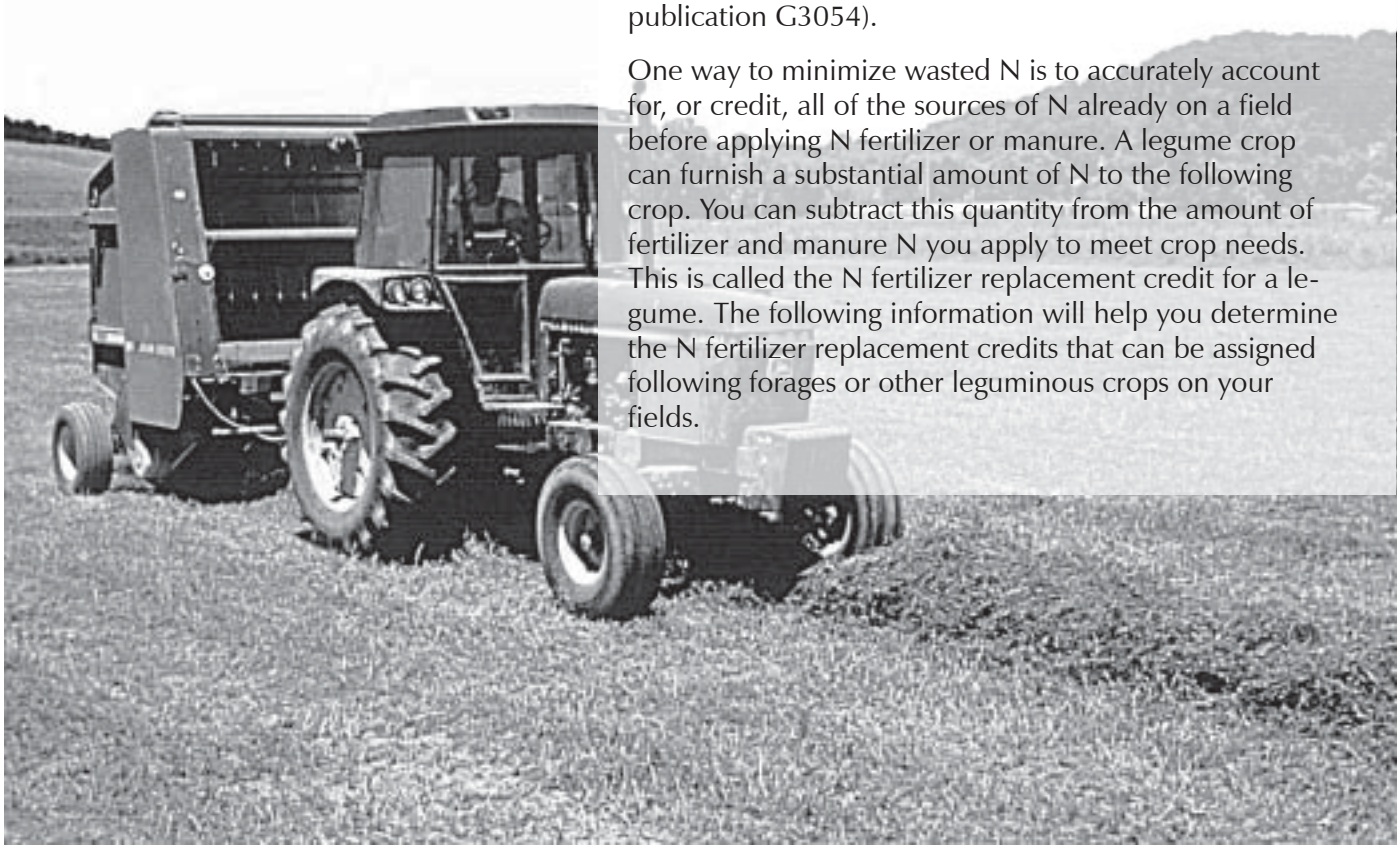


Nitrate: Plant Food and Pollutant

Nitrate (NO_3^-) is one form of nitrogen (N). It is the most commonly found pollutant in Wisconsin's groundwater and may also be a problem in surface waters. When present in sufficient concentrations, nitrate in drinking water can be toxic to infants under 6 months and may contribute to other human and livestock health problems. The Wisconsin Department of Natural Resources has estimated that the water from 10% of Wisconsin wells exceeds the state public health standard for drinking water of 10 ppm nitrate-N.

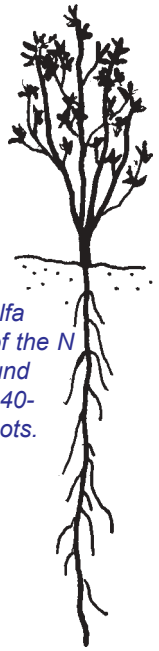
Although the nitrate-N that enters our groundwater comes from many sources, it is clear that agricultural practices are contributing a significant share. The most common agricultural sources of nitrate-N are N fertilizer, legumes, and manure. Any form of N that is applied to a field can be converted to nitrate-N by bacteria in the soil. Nitrate-N is a form of N easily taken up by plant roots, but nitrate that is not used by plants may also be carried away, or leached, by water moving through the soil.

For a given crop on a particular soil type, there is a level of N which represents an optimum supply; adding more does not increase yields and usually does not increase crop quality. It may, however, add to water quality problems. In general, the more fertilizer, manure, or legume N available in the soil above the optimal amount, the greater the amount of nitrate-N that will not be taken up by the crop and subsequently may leach to groundwater. For more information on agricultural nitrate and groundwater, refer to *Nitrates in Wisconsin Groundwater: Sources and Concerns* (University of Wisconsin-Extension publication G3054).



One way to minimize wasted N is to accurately account for, or credit, all of the sources of N already on a field before applying N fertilizer or manure. A legume crop can furnish a substantial amount of N to the following crop. You can subtract this quantity from the amount of fertilizer and manure N you apply to meet crop needs. This is called the N fertilizer replacement credit for a legume. The following information will help you determine the N fertilizer replacement credits that can be assigned following forages or other leguminous crops on your fields.

How Legumes Add N to the Soil



In a mature alfalfa plant, 40-60% of the N is in above-ground plant parts and 40-60% is in the roots.

Air is about 78% N gas. This N cannot be used directly by plants. Certain bacteria are able to convert, or "fix," N gas in the air to a form usable by plants. *Rhizobium* bacteria live in nodules on roots of leguminous plants, and some of these bacteria/plant systems are able to fix large amounts of N.

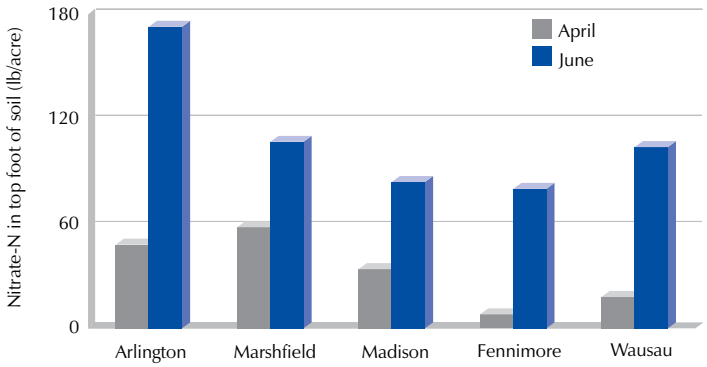
Legumes common to Wisconsin cropping systems include alfalfa, clovers, soybeans, birdsfoot trefoil, beans, and peas. Each requires association with a specific *Rhizobium* bacteria to fix N. As long as the proper bacteria are present in the soil, N-fixing nodules will form in the roots of these plants as they grow.

Substantial amounts of N can be stored in leguminous plants. For example, Minnesota studies show that alfalfa stands contain 130-230 pounds per acre of N in living plant tissues (in the fall of the seeding year after a mid-summer harvest). Nitrogen concentrations in the above-ground plant parts were similar to those in the roots.

Legumes, like all plants, need N for growth. If there is an abundance of plant-available N already in the soil (from manure or residual fertilizer, for example), a legume will use the soil-available N before expending energy for the rhizobia-fixed N. When soil N is low, however, the legume uses rhizobia-fixed N for its growth. No matter what its source, N is incorporated throughout all parts of the plant; it is not just concentrated in the root nodules.

Whenever leguminous plant residues are left in the field to decompose, the N stored in those residues is gradually released in a plant-usable form. It thus becomes available to the next crop. Nitrate-N has been measured in several Wisconsin cornfields. As is shown in Figure 1, soil nitrate levels increase markedly during the growing season after incorporation of an alfalfa stand, and much of this N is available by the time of maximum crop need by the corn.

Figure 1: Change in spring soil nitrate-N levels where no N fertilizer has been applied to corn following alfalfa, in Wisconsin.



Nitrate-N increases in the top foot of soil where corn follows alfalfa even though no N fertilizer has been applied.

Legume Rotations, N Fertilizer, and Yields

Rotation studies in the Midwest consistently show that yields for first-year corn after alfalfa without any N fertilizer are higher than yields for continuous corn that has been heavily fertilized with N. The results of a long-term rotation study at Lancaster, Wisconsin, are shown in Figure 2. They indicate that corn following alfalfa receives a significant amount of N from the preceding alfalfa. Even in the second year of corn after alfalfa, yields at lower rates of N fertilization (50-100 pounds of N per acre) are as high as in continuous corn with the highest N rate.

Field trials have shown that, on most Wisconsin soils, a fair or better alfalfa stand that has been growing for at least two years will provide all the N needed for a following corn crop (Figure 3). In more than 100 trials where alfalfa stands were fair or better, there were no increases in first-year corn yields from additions of N fertilizer except on sandy soils (as in the Waushara County trial in Figure 3) or where the stand was cut late, allowing less than 8 inches of regrowth before the alfalfa was killed.

Applied N fertilizer does not boost corn yields following alfalfa except on sandy soils or after late cuttings.

N from alfalfa and soybeans reduces or eliminates the need for N fertilizer.

Figure 2: Corn yields following four different crop rotations at Lancaster, Wisconsin (12-year average).

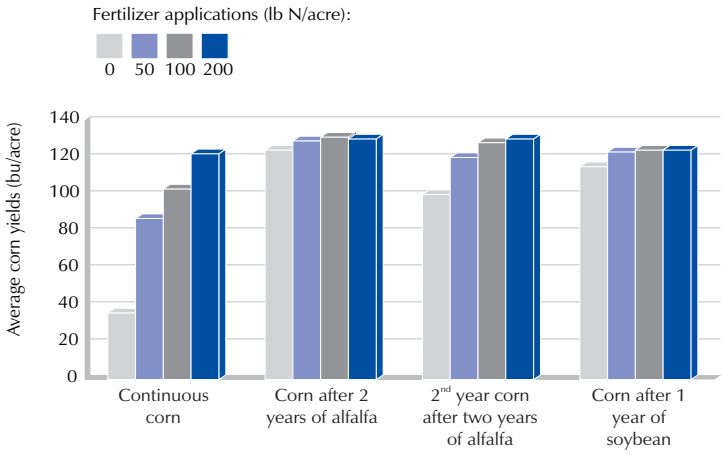
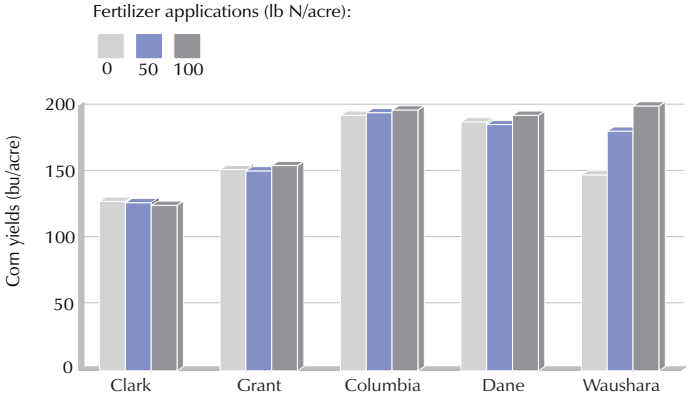


Figure 3: Effect of N fertilization on yields of first-year corn following alfalfa, in several Wisconsin counties (3-year average).



Legume N Fertilizer Replacement Value

The following recommendations for reducing N fertilizer applications after legumes have been developed from rotation studies in Wisconsin and other Midwestern states. Additional information explaining these nitrogen credits is on the following pages.

Legume Crop	Nitrogen Credit	Exceptions
Forages		
First Year Credit		
Alfalfa	**190 lb N/acre** for a **good** stand (more than 70% alfalfa or more than 4 plant/ft²) **160 lb N/acre** for a **fair** stand (30-70% alfalfa or 1.5-4 plants/ft²) **130 lb N/acre** for a **poor** stand (less than 30% alfalfa or less than 1.5 plants/ft²)	Reduce credit by 50 lb N/acre on sands and loamy sands. Reduce credit by 40 lb N/acre if less than 8 inches of regrowth after last harvest.
Red clover and birdsfoot trefoil	**80% of alfalfa credit** for similar stands	
Second Year Credit	**50 lb N/acre**, following a good or fair stand	No credit on sands and loamy sands.
Green manure crops		
Sweet clover	**80 -120 lb N/acre**	Use 40 lb N/acre credit if field has less than 6 inches of growth before tillage.
Alfalfa	**60 -100 lb N/acre**	
Red clover	**50 - 80 lb N/acre**	
Vetch	**40 - 90 lb N/acre**	Use 110-160 lb N/acre if topgrowth is more than 12 inches before tillage.
Soybean	**40 lb N/acre**	No credit on sands and loamy sands.
Leguminous vegetable crops		
Pea, snap bean, dry and lima bean	**20 lb N/acre**	

Confirming credits

Measuring the soil nitrate content with the pre-sidedress soil nitrate test (PSNT) can confirm forage legume N credits and indicate if additional N is needed on medium and fine-textured soils. Procedures for using the PSNT are given in *Soil Nitrate Tests for Wisconsin Cropping Systems* (University of Wisconsin-Extension publication A3624). If PSNT results show soil nitrate contents are at least 21 ppm N, no additional N is needed for corn. For PSNT values less than 21 ppm N, a maximum of 40 pounds N per acre can be applied to assure adequate N supplies for corn. In years with below normal spring temperatures, mineralization of N from legume residues and organic matter will be delayed, and PSNT results will be lower than in warmer years.

Explanatory Information

Forages

First Year Credit - The N credit is the amount of fertilizer N that growers can subtract from the recommended application rate for a particular crop on a given soil type. These credits are recommended following mixed alfalfa-grass pastures as well as pure alfalfa stands.

The amount of N available to first year corn is somewhat dependent on the quality of the stand. For corn following a good to fair stand, a grower using University of Wisconsin soil N recommendations need not apply N fertilizer (beyond 10 -20 pounds per acre in starter) unless the soil is sandy or a late cutting has been taken. Under those two circumstances some additional N will boost yields on some soil types. Even poor stands supply a substantial amount (130 pounds) of fertilizer equivalent N to a following crop.

Birdsfoot trefoil and red clover also supply large quantities of N to following crops. In most experiments, however, the N available to crops in the growing season following trefoil or clover was less than that from alfalfa. After these legumes, recommended N fertilizer credits are 80% of those for alfalfa, or about 150 pounds per acre for a good stand on a medium-textured soil.

Effect of Sandy Soils - Research trials on sandy soils (sands and loamy sands) have shown that less N is available to crops following a legume forage than at other sites. This is probably the result of relatively rapid residue decomposition and nitrate leaching on coarse-textured soils. Thus the recommended N credit is reduced by 50 pounds per acre.

Effect of Variety - Some varieties of alfalfa have been bred to fix more N than others. As there has not been research showing that these varieties significantly change the amount of N available to the following crop or affect yields of the following crop, forage varieties should be selected for yield performance rather than N-fixing capability. We do not have sufficient data to recommend changing N fertilizer replacement value based on variety.

Effect of Time of Harvest - Leguminous plant parts left in a field can contribute plant-available N to the soil as they decay. If a forage legume is cut late in the fall without enough time left in the growing season to allow for substantial regrowth (greater than 8 inches), less N will be provided to a following crop the next spring. In this case, the fertilizer replacement credit is reduced by 40 pounds of N per acre. Summer cuttings, however, allow for regrowth and do not affect the next year's N supply.

Effect of Tillage Method - Most research indicates that the type of tillage for corn after alfalfa (conventional tillage, conservation tillage, or no-till) and how the alfalfa is killed (herbicide or tillage) have little effect on the amount of N which should be credited. At this time, we do recommend altering the N credit due to tillage type.

Second Year Credit - Research in Wisconsin has shown that there is still a substantial amount of plant available N released in the second year following a leguminous forage crop. In some field trials, there has been a benefit even in the third year. The fertilizer replacement value suggested for the second year after a legume forage is 50 pounds of N per acre if there was at least a fair stand when the forage was plowed under and the soil is not sandy.

Forage legumes that are grown for only one growing season and then incorporated into the soil provide somewhat lower amounts of N than forage legumes grown for several seasons. The amount of N depends on the length of time that the legume has had to grow. A summer or fall-seeded legume that is incorporated into the soil in the spring will have comparatively little time to grow and will therefore provide less N than one that is seeded in the spring or early summer.

Green manure crops

The age of the green manure stand should be taken into account when determining what credit to take from the ranges shown in the table of recommendations. To use red clover as an example, a farmer planting a field where this legume had been seeded one spring and then plowed under the next spring can credit 80 pounds of N per acre. However, if the red clover is summer-seeded, the recommended N fertilizer credit is at the lower end of the range or 50 pounds per acre. If the field has less than 6 inches of growth before tillage, we suggest a 40 pounds per acre replacement credit.

Vetch grown as a green manure can accumulate substantial amounts of dry matter as N. If vetch topgrowth exceeds 12 inches, increase the N credit range to 110-160 pounds per acre.

Soybean

Corn following soybean usually needs less N to optimize yields than corn following corn. Research on the soybean effect on optimum corn N rates shows that these rates are quite variable over sites and years, but usually are at least 40 pounds N per acre less than for corn after corn. This is probably due to greater net N mineralization from organic matter where corn follows soybean. The soybean N effect does not appear to be related to soybean grain yield. Thus, a minimum adjustment of 40 pounds N per acre should be made where corn follows soybean.

Nitrogen recommendations for corn after soybean can be further improved by using the preplant soil nitrate test (PPNT) in addition to the 40 pounds N per acre reduction in N rate for corn. More information on using the PPNT is given in *Soil Nitrate Tests for Wisconsin Cropping Systems* (University of Wisconsin-Extension publication A3624). No adjustment in N rates for corn following soybean should be made on coarse textured soils (sands and loamy sands) probably because these soils tend to have low organic matter contents.

Leguminous vegetable crops

For crops following leguminous vegetables such as pea, snapbean, or dry and lima bean, we suggest a N fertilizer replacement credit of 20 pounds per acre. As with soybean, these credits should not be taken on sandy soils.

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This Nutrient and Pest Management Guide is published by University of Wisconsin-Extension Nutrient and Pest Management (NPM) program. NPM links the research base of the University of Wisconsin-Madison College of Agricultural and Life Sciences Center for Integrated Agricultural Systems with Wisconsin's agricultural community.

Partial funding provided by the Wisconsin Department of Natural Resources - Nonpoint Source Priority Watershed Program.

This publication is available from your Wisconsin county Extension office or from Cooperative Extension Publishing, Rm. 170, 630 W. Mifflin St., Madison, Wisconsin 53703. Phone 608-262-3346.

A3517 Using Legumes as a Nitrogen Source
June 1997 R-6-97-5M