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Providing Proper N Credit For Legumes

by
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INTRODUCTION

Efforts to improve the profitability from corn production and preserve the quality of rural groundwater supplies require that nitrogen (N) be put to its most efficient use in all N management programs. Several management tools and options are available to help growers attain that goal. Establishing proper credit for the amount of N supplied by a legume crop that precedes corn or other non N-fixing crops is of major importance. This publication is designed to help:

- Develop an understanding of rotation effects created by legumes
- Establish importance for the influence legumes have on N fertilizer management programs
- Enable crop growers to confidently use N credits from legumes in their crop rotation

GENERAL CHARACTERISTICS OF LEGUME CROPS

Legumes have several characteristics that influence the N supply to crops following. Legumes possess the unique ability to "fix" atmospheric N_2 gas into plant usable forms through the close association they share with *Rhizobium* bacteria. Residue from legume crops is usually high in N when compared with residue from other crops and can be a major source of N for crops that follow legumes in rotation. Most of the N contained in crop residue is not available to plants until microbes decompose the plant material. Residues from legume crops have low carbon to N (C:N) ratios and are easily decomposed by soil microbes. Residues from non-legume crops have a higher C:N ratio and are slower to decompose. In addition, immobilization (tie-up) of available soil N is higher during decomposition of non-legume residue because of the high C:N ratio.

SORTING ROTATION EFFECTS FROM NITROGEN CREDITS

Farmers know that better yields can be produced when corn follows a legume instead of another corn crop. Enhanced yields are primarily due to an increased N supply because of the N fixing legume. In addition to a N contribution, researchers have identified other yield enhancing effects that legumes provide. Collectively, these are termed "rotation effects." Various factors have been proposed to explain this rotation effect. These include: 1) improved soil physical properties, 2) depression of phytotoxic substances, 3) addition of growth promoting substances, and 4) decreased disease pressure.

Long-term research at the University of Minnesota's Southern Experiment Station, Waseca, shows the effect of rotation and N supplied by soybeans (**table 1**). At the optimum N rate, corn yields in a corn-soybean rotation averaged 14% higher than yields in continuous corn. Even with higher N rates, continuous corn yields could not equal those obtained in a rotation system. Yield potential for corn is generally higher in a rotation and is an important point when making N manage-

Table 1. Effect of previous crop on corn response to N at Waseca. Yields reported are averages from 1975 through 1986.[1]

	Previous crop	
N Rate	Corn	Soybeans
lb N/A	— — bu/A — — —	
0	75	109
40	100	134
80	115	146
120	125	153
160	133	158
200	136	158

[1] *G.W. Randall, P.L. Kelly, and M.P. Russelle. University of Minnesota.*

ment decisions. Nitrogen requirements as affected by previous legume crops will be discussed here later.

Nitrogen credit is a term that can mean different things to different people. To simplify in providing N recommendation guidelines, N credit will refer to the difference between N recommended for continuous corn and N recommended for corn following a legume crop.

ACCOUNTING FOR LEGUME N CONTRIBUTION

Commonly, N credits for a good stand of alfalfa range from 100 to 150 lbN/acre and soybeans from 20-40 lb/acre. Where does this N come from? Using a checkbook balancing approach of additions and subtractions is impossible because of the complexities of N behavior in the soil system. However, recent research provides information that can help in understanding the N supplied from legume residue.

In addition to plants above-ground, the roots and crowns of forage legumes contain substantial amounts of N. Researchers in Minnesota have measured the N remaining in total plant residue (includes roots and crowns in soybeans) after harvest of soybeans and forage legumes (**table 2**).

Nitrogen credits given for soybeans and alfalfa are similar to the reported values for N remaining in plant residue (**table 2**): 40 lbN/acre for soybeans and 104 lbN/acre following three years of alfalfa. The total N credit for a legume crop, however, cannot be totally attributed to N remaining in residue. In Minnesota, Hesterman et al. found that approximately 50% of incorporated legume N was put to use by a corn crop.

If the 50% availability factor is applied to table 2 data, then surely a fair amount of the N credit is not accounted for by just the N in the crop residue. Higher yields would leave more residue and would supply more N. Also, roots in the surface soil too small to be measured, roots below sampling depth, and nodules not measured would contribute to the N supply.

Table 2. The amount of N remaining in crop residue after soybean and forage legume harvest

Crop	Crop residue	Total N in residue
	— — lbs./A — — —	
Soybean[1]/	3845	45
Alfalfa[2]/		
1 yr. stand	3600	103
2 yr. stand	3400	91
3 yr. stand	4600	104
Red clover[2]/		
3 yr. stand	2600	65

[1] *Includes stems, nodules, and roots from 34 bu/acre soybeans. From G.H. Heichel, USDA-ARS, University of Minnesota.*

[2] *Residue includes roots to 12 inches, crowns, and fall regrowth (6-8 inches tall) from a 3-cut harvest system. From M.H. Hall and C.C. Sheaffer, University of Minnesota.*

EFFECTS OF LEGUMES ON SOIL N

Soil N is a pool of organic N composed of partially decayed plant material and microbial biomass. Soil N levels can change as legumes grow. With alfalfa, for example, N can exude (transfer) from the root to the soil and is subject to various soil N transformations. In addition, during the life of a forage crop, old leaves and roots decay and add to the soil N pool. Measurements have indicated that under alfalfa, soil N can increase approximately 50 lb/acre/year. This is not all immediately available N, but does add to the mineralizable N fraction that can make a significant N contribution to the crop that follows the legume.

For soybeans, a large portion of the N taken up or fixed by a soybean plant is removed with the grain. Because small amounts of N are left in residue compared with what was taken off in grain, the total N status of the soil changes very little.

FIELD STUDIES

Although it is difficult to explain and account for the various components of the total N credit, it is possible to measure the total effect. Considerable field research from the Midwest has been conducted to provide usable, up-to-date information about the total rotation effect from legumes and how it impacts N management programs for corn. The following sections contain information from recent Midwest research for major cropping systems.

CORN-SOYBEAN ROTATION

Soybeans are grown on approximately 5 million acres of cropland in Minnesota each year. Corn commonly follows in rotation. Table 1 contains data to evaluate the N credit that soybeans provide for corn. Corn yields were substantially higher following soybeans compared with continuous corn at all N rates. In rotation analysis, corn yields were optimized at 140 lbN/acre while continuous corn yields were optimized at 175 lbN/acre. The total rotation effect is reflected by these different optimum rates. Nitrogen recommendations provided by the University of Minnesota are structured to take into account the reduced need for N (20-40 lbN/acre/yr.)in a corn-soybean rotation. Nitrogen recommendations for similar yield goals are 20-40 lbN/acre less for corn following soybeans than for continuous corn.

CORN-FORAGE LEGUME ROTATION

The presence of a forage legume in a crop rotation can have significant impact on fertilizer N needs for the corn crop that follows. The N credit for legumes is many times neglected, forgotten, or not credited to its fullest extent. If N credits from legumes are not used, application of unneeded N can contribute to contamination of groundwater in geologically sensitive areas and reduce profitability.

Iowa research over 11 years concludes that when corn followed two full production years of alfalfa, average corn yields of 150 bu/acre could be produced without the addition of fertilizer N (**table 3**). Alfalfa was harvested with standard harvest schedules. Only short term fall regrowth was plowed down. Sufficient N for 150 bushel corn was supplied from the alfalfa root system, some top growth which developed after the last harvest, and soil organic matter.

Table 3. Effect of fertilizer N on yields of corn in two crop rotations at the Clarion-Webster Research Center in Iowa, 1971-1981[1]

	Crop rotations[2]	
N Rate	Continuous corn	COMM[3]
lbs./A	— — bu/A	— — —
0	52	151
60	96	143
120	123	150
180	133	146

[1] *Voss, R.D., and W.D. Shrader. Iowa State University.*
[2] *O = Oats; M = Alfalfa dominant forage. Both sequences grown each year.*
[3] *Corn, oats, meadow, meadow rotation.*

Recent Midwest-collected data suggest that a N credit of 150 lbN/acre is appropriate in Minnesota for corn following a good stand of alfalfa (five or more plants per square foot). If stands are considerably thinner, then the N credit should be reduced to approximately 75 lb/acre. These values should be used following standard harvest management (3-4 cuts) that may include fall regrowth (up to 6 inches). If substantial regrowth is plowed down, increase N credit by 40 lb/ton/acre of legume plowed down.

SECOND-YEAR CORN

Long-term research in Wisconsin shows that N fertilizer needs for second-year corn are also reduced following a good stand of alfalfa (**table 4**). In this study, second-year corn yields appear to be optimized with 50 to 100 lbN /acre. This study indicates that a 75 lbN/acre credit can be used for second-year corn following a good stand of alfalfa. For second-year corn following a poor stand of

Table 4. The effect of N rate on corn yield of continuous corn and first and second year corn following alfalfa at Lancaster, Wisconsin, 1977-1986[1]

	N Rate applied(lb/A)			
Sequence	0	50	100	200
	— — — bu/A	— — —	— —	—
Cont. Corn	34	86	103	127
MMCCC[2]	131	131	139	132
MMCCC	89	114	129	130
MMCCC	72	112	125	126

[1] *Higgs R., W. Paulson, A. Peterson, J. Swan, J. Jackobs, and W. Wedin. 1977 - 1986 crop sequence progress report (Illinois, Iowa, Minnesota, and Wisconsin). University of Wisconsin, Platteville, WI.*
[2] *C = Corn, M = Alfalfa, direct seeded. Underlined C represents year of sequence.*

alfalfa, a N credit should not be used. Limited research conducted by the University of Minnesota supports a 75 lbN/acre credit for second-year corn following a good stand of alfalfa.

TILLAGE

Limited research suggests that the type of tillage system used will affect the N credit for a previous alfalfa or clover crop. When corn planted with a no-till system will follow a poor stand of alfalfa or clover, use the N rate suggested for corn as a previous crop (**table 5**). When no-till corn will follow a good stand of alfalfa, use the suggested N rates for the situation where a poor stand of alfalfa or clover is the preceding crop.

Under no-till systems some N will be supplied to second-year corn, but these amounts are not well defined. There are no adjustments in N credits for situations where corn follows alfalfa and the seedbed has been prepared with a chisel plow.

Table 5. Nitrogen recommendations for corn in Minnesota when the soil nitrate test is not used

Yield goal		Previous crop and organic matter level							
		Alfalfa[1] (good stand) ---- O.M. ----[3]		Soybeans, field peas ---- O.M. ----		Any crop in group 1* ---- O.M. ----		Any crop in group 2* ---- O.M. ----	
Grain	Silage	low to[2] medium	high	low to medium	high	low to medium	high	low to medium	high
bu./acre	ton/acre	N to apply (lb./acre)							
75 or less	10 or less	0	0	50	40	0	0	60	40
76 - 95	10 - 12	0	0	70	50	15	0	90	70
96 - 115	13 - 15	0	0	100	70	45	0	120	100
116 - 135	16 - 18	0	0	120	90	75	45	150	120
136 - 155	19 - 21	30	0	150	120	105	75	180	150
156 - 175	22 - 24	50	20	160	130	125	95	200	170
more than 175	more than 24	70	40	180	150	145	115	220	190

* **CROPS IN GROUP 1**
- alfalfa (poor stand)
- alsike clover
- birdsfoot trefoil
- grass-legume hay
- grass-legume pasture
- red clover

CROPS IN GROUP 2
- barley
- buckwheat
- canola
- corn
- edible beans
- flax
- grass hay
- grass pasture
- millet
- mustard
- oats
- potatoes
- rye
- sorghum-sudan
- sugarbeets
- sunflowers
- sweet corn
- triticale
- wheat
- vegetables

1 *For second-year corn after a good stand of alfalfa on fine- and medium -textured soil, apply the N rate suggested for a previous crop of clover.*

2 *The well-drained silt loam soils in Southeastern Minnesota receive the N recommendations for soils with a high organic matter content. All irrigated soils are included in the low to medium organic matter category.*

3 *Low to medium—less than 4.5%; high—more than 4.5%.*

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