Kansas State University

Using Legumes in Crop Rotations

Department of Agronomy L-778 Crop Rotations

For centuries, the use of legumes in crop rotations has been a principal means of supplying nitrogen to non-legume plants. Rotating legumes with non-legumes has the double advantage of growing the legume with little or no additional nitrogen fertilizer, plus a nitrogen credit for the subsequent non-legume crop.

Legumes that enter into a symbiotic relationship with specific *Rhizobia* bacteria make an important contribution to plant nutrition. An estimated 10 to 20 percent of the annual nitrogen input to soils in the United States comes from symbiotic nitrogen fixation. In developing countries where nitrogen is not readily available, this benefit is even more important.

The process of nitrogen fixation

Rhizobia bacteria interact with legume host plants to change atmospheric dinitrogen (N_2) gas into a form usable by the host plant and subsequent crops. This process is called symbiotic nitrogen fixation. The *Rhizobia* bacteria inhabit nodules on the roots of host legume plants. The host plant provides energy for the reactions through which the bacteria convert atmospheric dinitogen (N_2) gas into usable nitrogen. The atmospheric nitrogen used in this process is inexhaustible, as the earth's atmosphere is 78 percent N_2 gas.

> **Q** What about plowing down alfalfa or clover as a green manure crop? Should an additional nitrogen credit be given when this is done?
>
> **A** The practice of plowing down a legume green manure crop has little effect on nitrogen credit, but can significantly improve soil physical properties such as structure, aggregation, and water infiltration rate.

Factors affecting nitrogen fixation

The amount of nitrogen fixed in this process varies with the strain of bacteria, condition of the host plant, and various soil and climatic conditions. Nitrogen fixation has been estimated to be as high as 450 pounds of nitrogen per acre by a crop of clover in New Zealand. However, this occurs only under optimum conditions; amounts are normally much less—and largely depend on the nitrogen requirement of the legume and the residual soil nitrogen available.

Rhizobia species	**Legume crop**
Rhizobium meliloti	Alfalfa, sweet clover
Rhizobium trifoli	Red clover, white clover
Rhizobium leguminosarium	Pea, sweet pea
Rhizobium phaseoli	Dry bean
Rhizobium japonicum	Soybean

Type of bacteria: *Rhizobia* bacteria are host plant specific—that is, the inoculum for soybeans is not the same strain that would be used for inoculating alfalfa. The chart below lists the *Rhizobia* species required for commonly grown legume crops.

Inoculum labels indicate the legume plants for which the bacteria are effective. Remember, the bacteria in the inoculum are living organisms and should be treated accordingly. Inoculum should be stored in a cool, dry place away from direct sunlight, and should be used according to label directions before the expiration date. Legume seed preinoculated with viable inoculum more than 30 days prior to seeding should be reinoculated before seedling.

Once a population of *Rhizobia* is established in the soil, it probably is not necessary to reinoculate provided the host plant is grown every 2 to 3 years. It is essential, however, to inoculate on new ground where the legume is being grown for the first time and is advisable if there is any question of the bacteria's presence in the soil due to flooding.

Host plant and environmental conditions: Because the *Rhizobia* depend on the host plant for the energy required in nitrogen fixation, anything that limits normal plant growth and development will affect nitrogen fixation. Symbiotic nitrogen fixation requires oxygen, so well-aerated soils with good host plant growth provide the optimum environment. Poorly drained, water-logged soils are detrimental to host plant root growth and to the *Rhizobia* bacteria. *Rhizobia* are adversely affected by very acid soils, and soil pH should be properly monitored and maintained for optimum legume production.

Nutrients other than nitrogen need to be at levels adequate for normal growth and development. Phosphorus is especially critical, as legumes are heavy users of phosphorus. Steps should be taken to be sure the phosphorus supply is adequate.

Small amounts of residual nitrogen in the soil or small amounts of nitrogen added before or at seedling are not detrimental to the bacteria. In fact, 10 to 30 pounds of nitrogen is recommended on ground being seeded to a legume for the first time. This small amount of nitrogen gets the host plants off to a vigorous start, allowing rapid development of nodules and subsequent nitrogen fixation. However, research has shown that large amount of residual nitrogen in the soil, either from carry-over or added nitrogen, reduce nitrogen fixation. Apparently, the host plant expends less energy by utilizing residual soil nitrogen than by fixing nitrogen through the *Rhizobia*. In a study in southeast Kansas, a plot of soybeans receiving no nitrogen fertilizer averaged 445 nodules per five plants, while a plot receiving 150 pounds per acre of preplant nitrogen had only 140 nodules per five plants.

Other conditions that favor nitrogen fixation include a relatively high soil pH (6.0 to 8.0), adequate soil moisture and aeration, and an adequate supply of available calcium. *Rhizobia* bacteria have a high calcium requirement, and this is one reason for the positive correlation of high soil pH and available calcium to their activity. The bacteria are sensitive to acid soil, and do not function well when soil pH drops below 5.5. Since *Rhizobia* are adversely affected by very acid soils, soil pH should be routinely monitored and properly maintained with a sound liming program. Cool soil temperatures also limit nitrogen fixation.

Q What is the nitrogen credit for wheat planted in the fall after soybeans are harvested?

A None, in this case. Nitrogen fixed by soybeans is largely in an organic form contained in the nodules and soybean residue. This fixed nitrogen must be converted to a form available for plant uptake. These processes do not occur in cool soil temperatures, as is the case when the wheat is growing. Thus, no nitrogen credit for wheat following beans.

Nitrogen credits from legumes

Nitrogen fertilizer rates should be adjusted when legumes are used in crop rotations with corn, grain sorghum, and other summer annual crops. Research consistently shows that nitrogen credits can be applied, in amounts that vary with the legume crop and its condition. The use of credits for legumes in crop rotation could result in significant cost savings for nitrogen fertilizer. Table 1 summarizes the nitrogen credit allowed for legumes in crop rotations.

Alfalfa: The nitrogen credit derived from alfalfa can vary significantly depending on the condition of the stand when rotated out of alfalfa. If the alfalfa stand is good, with few grasses or weeds, a very good corn or grain sorghum crop can be grown without additional nitrogen fertilizer. However, if the alfalfa stand has deteriorated and weeds are present, nitrogen credits should be reduced significantly. For a crop grown the second year after rotation from alfalfa, the nitrogen credit is half that of the first year.

Clovers: Red and sweet clovers, both yellow and white, also make excellent rotation crops providing significant nitrogen credits. The clovers may be especially well suited to short-terms rotations. For example, clovers used as cover crops on set-aside acres provide a double benefit: They are excellent cover crops that effectively control erosion on set-aside acres while fixing nitrogen that can be used by a subsequent non-legume crop.

Soybeans: This is the most widely used legume rotation crop in Kansas. For corn, sorghum, sunflowers, and other summer crops, credit about 40 pounds of nitrogen per acre from the preceding soybean crop. Most nitrogen fixation is completed in soybeans by the time pod fill is initiated.

Research findings

Studies evaluating the use of legume crops in rotation with corn or grain sorghum in Kansas have been continuing for more than 50 years. Results from this work, which include data from most of the state's experiment fields and stations, are consistent in showing the benefits of

Table 1. Nitrogen credits from legumes in summer row crop rotations.

Legume crop	Nitrogen credit
Alfalfa*	
Excellent (>5 plants/ft^2)	120 lbs/a
Good (2- 5 plants/ft^2)	80 lbs/a
Fair (1 - 2 plants/ft^2)	40 lbs/a
Poor (<1 plant/ft^2)	0 lbs/a
Sweet clover*	60 - 120 lbs/a
Red Clover*	40-80 lbs/a
Soybeans**	40 lbs/a

** Values are for summer row crops such as corn, grain sorghum, or sunflowers. For wheat, credit one half of indicated values.*

*** No nitrogen credit is given for wheat immediately following soybeans.*

the legume rotation and the value of the nitrogen fixed by the legumes. The data reported in tables 2, 3, and 4 are a small but representative sample of research results from Kansas and from similar studies in surrounding states. The data are especially meaningful as the yields shown are mostly long-term averages. These research results clearly support the nitrogen credits for the various legumes given in Table 1.

Table 2. Effect of nitrogen rate on dryland no-till corn following alfalfa.

Cornbelt Experiment Field, Brown County				
N Rate	First year after alfalfa		Second year after alfalfa	
lb/A	Yield, bu/A	Leaf N, %	Yield, bu/A	Leaf N, %
0	136	3.79	140	3.42
30	140	3.79	157	3.75
60	139	3.79	159	3.73
90	136	3.71	165	3.67

Source: M.M. Claassen, Kansas Fertilizer Research Report of Progress 389, 1980, p. 139-140

Other benefits

The positive results of using legumes in rotation are not entirely due to nitrogen credits. The use of legumes in rotation may break insect and disease cycles that are problems in monocultures. For example, rootworms have been a major pest in corn production since the mid 1800s. Early records indicate that even in a rotation of corn and oats, rootworms were damaging. However, rootworms prefer to lay eggs in soils that have corn residue, and developing larvae do not survive on host roots other than corn. Thus, a system of continuous corn favors the development of the rootworm. The standard recommendation in most states in the Corn Belt is to manage rootworms. Under a rotation system, particularly a corn-soybean rotation, the life cycle of the rootworm is broken and the potential for yield loss due to rootworms is reduced.

Many other insects and some diseases are indirectly affected by crop rotations. In general, if a management practice provides a deterrent to the life cycle of a pest or a benefit to the life cycle of a predator, it will decrease that pest's effects on the economic return of the practice.

Legume rotation systems also help in managing such problem weeds as shattercane, johnsongrass, and perennial broad-leaved weeds. A corn-soybean

Table 3. Crop sequence and nitrogen rate on grain sorghum.

Cornbelt Experiment Field, Brown County			North Central Experiment Field, Republic County		
N rate	Continuous Sorghum	Sorghum after soybeans	N rate	Continuous Sorghum	Sorghum after soybeans
lbs/A	Yield, bu/a	(5 yr. avg.)	lbs/a	Yield, bu/a	(4 yr. avg.)
0	41	79	0	32	51
40	57	90	50	40	52
80	79	88	100	46	58
120	85	89	200	51	59
200	88	89			

Source: M.M. Claassen, R.J.Raney, Kansas Fertilizer Research Report of Progress 488, 1985, p.77-78 and p. 149-150

Table 4. Crop sequence and nitrogen rate on irrigated corn.

Kansas River Valley Experiment Field, Shawnee County			Northwest Research Center, Thomas County		
N rate	Continuous Sorghum	Sorghum after soybeans	N rate	Continuous Sorghum	Sorghum after soybeans
lbs/A	Yield, bu/a	(5 yr. avg.)	lbs/a	Yield, bu/a	(2 yr. avg.)
0	61	90	50	131	158
75	103	120	100	158	174
150	123	116	150	166	174
225	113	115	200	167	177

Source: L.D. Maddux, H.D. Sunderman and J.R. Lawless, Kansas Fertilizer Research Report of Progress 462, 1984, p.85-86 and p. 145-147 or grain sorghum—soybean rotation is an excellent management tool for shattercane control, particularly where infestation levels are low or moderate.

Alfalfa or other legumes used in crop rotations can offer similar advantages, but the rotations may be longer-term. In addition to aiding insect, disease, and weed control, there appears to be a positive effect on soil physical characteristics. Soil aggregation and water infiltration can benefit from the use of legumes in rotation. On the other hand, alfalfa does deplete subsoil moisture supplies, so in years of below-average rainfall, crops following alfalfa may show more drought effect.

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This publication is intended to provide a better understanding of the factors that affect nitrogen fixation, nitrogen credits for legumes in rotations, and other benefits of using legumes in crop rotations. An individual producer's decision on using legumes in cropping systems must be made as part of the management plan for the whole farm enterprise.

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