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Forage Legumes and Nitrogen Production

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Recent increases in the cost of nitrogen (N) fertilizer are causing crop and pasture managers to reconsider the use of legume species for their long known ability to fix N for themselves and other crops.

This fact sheet will describe what can be expected by using legumes for N fixation, outline realistic benefits of legumes, and dispel some unfounded expectations.

Legumes can be used in pure stands (monocultures) and in mixtures with grasses. Legumes may be harvested (mechanically or by grazing animals), left on soil, or incorporated into soil. Legume cover crops, left on or tilled into soil, are used to protect soil from erosion, improve tilth, and supply N and other nutrients to subsequent crops.

Why Grow Legumes?

Legumes generally do not require N fertilizer because of their symbiotic relationship with Rhizobium bacteria. In this relationship, symbiotic N-fixing bacteria invade root hairs of host plants, where they multiply and stimulate formation of root nodules (enlargements of plant cells and bacteria in intimate association, Figures 1 and 2). Legumes and bacteria work together to extract atmospheric N (air is 78 percent N_2 but unavailable to plants) and convert it to plant-available forms within legume roots. Bacteria inside nodules convert free N to ammonia (NH_3), which the host plant utilizes to make amino acids and proteins.

It is possible to establish legumes without N-fixing bacteria, but forage yield and quality will be similar to grasses. Without Rhizobia, N fertilizer must be applied for high yield and quality, and the economic advantage of using legumes would be lost. In addition, legume forages generally have better quality than most grasses.

Figure 1. Alfalfa root with two nitrogen fixing nodules.

Figure 2. Nitrogen fixing nodules on small legume roots.

Are Legumes Easy to Grow?

Several factors influence legume yield, but foremost among these are moisture availability and soil fertility other than N. In general, legume fertility requirements are somewhat higher than those of small grains and forage grasses. Producers wishing to grow legume crops for N are strongly encouraged to have a soil test prior to legume establishment.

Legumes are generally more sensitive than forage grasses to nutrient deficiencies and low soil pH. Successful pasture legume production depends on maintaining adequate levels of phosphorus (P) and potassium (K) with a soil pH of at least 6.0. Even though N fertilization is not required, fertilizers containing P and K may be needed to maintain productive and persistent stands. Without adequate P and K or when grown in acid soils, legume stands will be unproductive and unreliable. Infertile soils can be economically improved to acceptable levels with applications of lime, P, and K. Many legumes tolerate a fairly wide range of soil pH, but they are most productive when soil pH is near neutral (7.0). Lime should be applied when soil pH values fall below 6.0.

How Much Nitrogen Can Legumes Fix?

The amount of N legumes fix varies among species due to soil conditions, amount of water available, and other

Table 1. Generalized estimates of N contribution to current or subsequent plantings as a result of plowing down a group of legume species growing in several different environments.

Growing Environment	*Legume Species*	*Size and/or Density*	*Legume Dry Matter Yield (approx. lb/acre)*	*N Contribution (lb N/acre)*
General				
September through March for fall plantings, April through May for spring plantings	Small Seeded Forage Legumes	Seedlings, 1 to 6 in. tall with few branches	10 to 100	0 to 10 [1]
Legumes interseeded with grass or small grains				
Good conditions, adequate water, P, K, and pH	Alfalfa, Clover[2], Vetch, Hop Clover, Ladino clover, Annual Lespedeza	Scattered (1 legume plant/yd^2)	100	1 to 5 [3]
	Hop Clover, Annual Lespedeza	Thick stand, 1 ft. tall	1,000	15 to 30 [3]
	Alfalfa, Clovers[2]	1 legume plant/ft^2, 12 to 15 in. tall	1,000	20 to 30 [3]
	Alfalfa, Clovers[2]	1 legume plant/ft^2, 15 to 24 in. tall,	1,500	30 to 60 [3]
	Clovers[2], Vetch	Thick stand, 3 legume plants/ft^2, 20 to 30 in. tall	2,000	40 to 60 [3]
Monoculture Legumes				
Droughty, low P, K, and/or pH	Cowpea or Australian Winter Pea with pods	Poor stand (1 legume plant/yd^2)	500 to 1,000	15 to 30[4]
	White Clover	Full stand, 3 to 4 in. tall	500 to 1,000	15 to 40 [5]
Good conditions, adequate water, P, K, and pH	Soybean (without beans), Peanut (after nuts harvested)	Full stand	1,000 to 2,000	20 to 60 [6]
	Cowpea, Australian Winter Pea with pods	Full Stand	2,000 to 3,000	50 to 95 [6]
	Alfalfa, Clovers [2]	Full stand, 24 to 36 in. tall	4,000 to 5,000	100 to 150 [6]

[1] Plow down N could be negative because seedlings required N from soil before fixation begins.
[2] Clovers include any of several upright-growing clovers including red, arrowleaf, and crimson.
[3] Additional N from roots that will eventually become available may be estimated at as little as10 lb N/acre for short-lived annuals to 90 lb N/acre for perennials with well developed root systems.
[4] Little additional N will be available from roots with a poor stand growing under poor conditions.
[5] Ladino clover plants tend to be short-lived and roots are relatively shallow, resulting in little N (10 to 20 lb/acre) from roots.
[6] Contributions from roots may be estimated in the range of 20 lb N/acre, for crimson clover, to 60 lb N/acre for 2- to 3-year-old alfalfa stands.

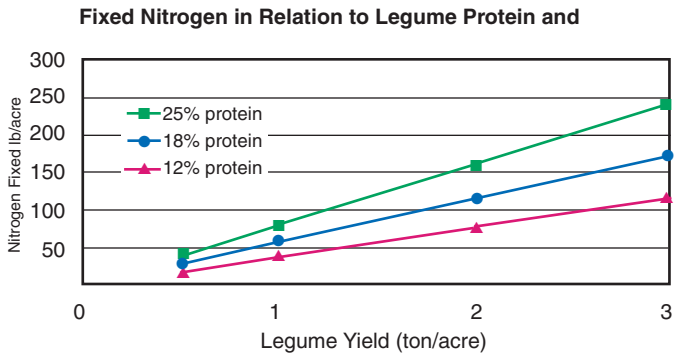

Chart 1. Simplified relation between N contribution from legumes, yield, and protein. Increasing yield and/or crude protein increases the amount of N.

Figure 3. The alfalfa variety in the middle with the thin stand has limited yield and nitrogen fixation potential compared to the adjacent plots.

seasonal factors during growth. It can range from as little as 20 lbs N/acre/year to more than 300 lbsN/acre/year. With N at 40 cents/lb, this would be equivalent to from $8 to $120/acre. Table 1 contains examples of N contribution to plants growing with legumes, and the N contribution to subsequent crops as a result of plowing down legumes. From Table 1, it becomes evident that large amounts of fixed N require high legume yield, as is also illustrated in Chart 1. Thick alfalfa stands fix more N than thin ones (Figure 3).

What Are the Main Legume Systems in Oklahoma?

Harvested Legumes

Legumes harvested for hay or silage fix large quantities of N but contribute a relatively small portion to subsequent crops. Alfalfa is the most important monoculture legume to be mechanically harvested; although pea, bean, soybean, and peanut are sometimes used as hay crops. Several clovers (red, white, rose, arrowleaf, crimson, subterranean, hop, etc.) as well as alfalfa and annual lespedeza are grown with grasses and harvested as hay. When most of the plant growth is removed, little plant-available N accumulates in soil (Chart 2).

Well-managed alfalfa may yield up to 8 tons/acre/year of dry matter and may have 20 percent crude protein (CP).

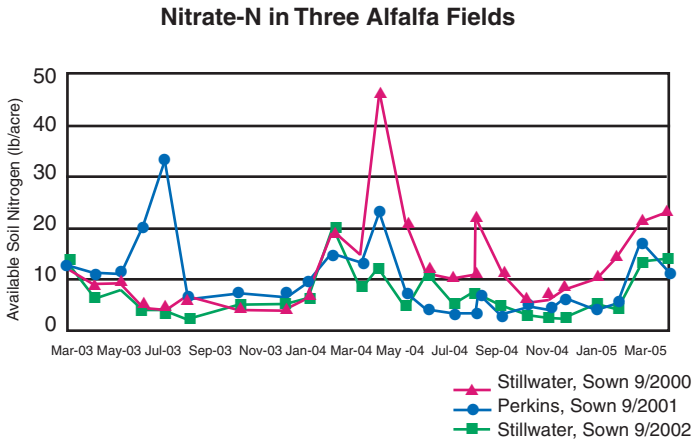

Chart 2. Plant available N remains relatively low in alfalfa fields because plants use fixed N and alfalfa also takes up mineralized N. The three high-N peaks have not been explained.

(This is equivalent to 1.6 ton of crude protein/acre, which is approximately 16 percent N). This means that 510 lbs N/acre may be harvested in a year, and the primary source of N is fixed by the legume-bacteria system rather than from commercial fertilizers. Plowing under a thick stand of alfalfa right after harvesting the top growth contributes N primarily from the root system. An estimate of 1 ton of roots/acre with 15 percent CP may be the best estimate one can make (about 50 lbs N/ac). Annual legumes, such as hop clover, crimson clover, and annual lespedeza, tend to have smaller root systems, which supply less N when plowed. If a full stand of alfalfa was incorporated into the soil rather than harvested as hay, the material incorporated would contribute to soil N. This may be approximately 1 ton/acre of forage plus 1 ton/acre of root material, containing 120 lbs N/acre.

Soybean and peanut represent single-harvest annuals that normally have much lower yields than alfalfa. For example, soybean hay harvested with most of the leaves may yield 1.5 tons/acre with 18 percent protein (2.9 percent N), resulting in harvesting of almost 86 lbs N/acre. If incorporated into soil this amount would be available for following crops, plus some credit for roots. In general, about half of the fixed N is available for the next crop, leaving some for future crops.

Pastures

Legumes in pastures (Figures 3, 4, 5, and 6) contribute N to a complex dynamic recycling system. They are important in grazed forage systems because they have the potential to extend the grazing season, increase the quantity of grazed forage, and reduce the amount of N fertilizer needed.

The amount of N fixed in a grass-legume pasture is difficult to estimate because the portion of yield that comes from legumes is highly variable and legumes grow with grasses that are highly variable in their competitiveness.

If a pasture consisting of 20 percent legume with 18 percent crude protein, and 80 percent grass with 12 percent crude protein, yields 4 tons/acre, the amount of N grazed is about 175 lbs/acre. This does not necessarily mean that legumes fixed 175 lbs N/acre. Some N was probably derived from decomposition of soil organic matter, or is recycled through

Figure 4. A pasture with a thick stand of hop clover along with tall fescue and other cool-season grasses.

Figure 5. A pasture with arrowleaf clover and white clover growing with forage grasses.

Figure 6. A thick stand of white clover and tall fescue in a pasture.

animals and used by legumes as well as grass.

In early spring while soil is cool, little N fixation takes place, and both legumes and grasses utilize N stored in the soil. Soil N comes from N-containing organic matter and N fixed in previous years. As soil N is depleted and soil warms, N fixation begins to supply needed N. If nearly all legume plants are consumed (grazed or otherwise harvested), N fixation stops until they have sufficient regrowth for fixation to proceed.

Cover Crops

Legume cover crops contribute nearly all their N to subsequent crops when plowed under or chemically "burned down." Using the same process as above we can see that yield is an important consideration when calculating the N contribution of cover crops (Chart 1). The N contribution from roots may be important when estimating possible N credits when cover crops are turned under; however, this is more difficult to estimate.

Austrian winter pea and cowpea have highly variable yields and are used as cover crops. See Table 1 for ranges of N fixed and yields. If growing conditions are relatively poor and yield is only 1 ton/acre with 15 percent protein, less than 50 lbs N/acre would be available from above ground portion and perhaps another 20 lbs N/acre from root systems. A yield of 3 ton/acre at 15 percent protein results in about 150 lbs N/acre, plus about 50 lbs N/acre from roots.

Where Is Fixed Nitrogen?

Most fixed N is found in leaves and stems. In a pasture this fixed N is primarily available as protein and is consumed by animals. Much of the N consumed as forage is recycled through urine and manure. As roots, stems, and leaves decay over time, N is released for use by other plants.

Most perennials have root systems that store nutrients, and the root mass may be almost as much as the top growth. A conservative estimate is that a perennial like alfalfa may have about one ton of roots/acre after a year's growth. Short-season annual legumes have smaller root systems, and an estimate of 0.5 ton of roots/acre for peas, annual clovers, etc., is probable. Table 1 includes some generalized estimates of the amount of N from different situations.

Do Soils Accumulate N While Legumes Are Growing?

Little N remains in soil while plants are actively growing because N is readily available and is taken up by both legumes and non-legumes. Chart 2 illustrates how the nitrate-N concentration of soil in three alfalfa stands remained almost constant during more than two years of monthly samples. No appreciable amount of nitrate-N accumulated regardless of the season or growth status of alfalfa.

Can Legumes Be Used to Decrease Fertilizer Budgets?

The answer is a **qualified yes**. Nitrogen fixation from well-managed legumes minimizes the need for N fertilizer. However, the length of time before legumes become reliable contributors of N to forage production varies from almost im-

mediately to several years. This difference is due primarily to previous management practices and their effect on legume establishment and growth.

Producers who have closely followed soil test recommendations for several years can expect significant contribution from legumes in spring following establishment. Those who have not closely adhered to soil testing recommendations can expect to see legume production increase once other soil nutrient deficiencies and growth limiting factors, including low soil pH, have been corrected.

Is Inoculation Important?

When initially establishing legumes, the proper strain of bacteria (inoculant) must be introduced into the forage system. The best way to introduce new bacteria is by planting inoculated seed. Inoculation of legume seed should occur prior to planting and can be successfully accomplished in several ways.

- Purchase preinoculated seed.
- Apply a sticking agent to seed, and then add a peat-based inoculant. Mix seed and inoculant until all seeds are well coated. The sticking agent may be a commercial preparation sold by the inoculant manufacturer. Coating seed with a 10 percent sugar solution can also be effective.
- Use inoculants that come with a clay that helps bacteria adhere to seeds when well mixed.

What Are Important Considerations in Handling Inoculants?

Inoculants contain live bacteria and should be used prior to the expiration date shown on the container. Likewise, preinoculated seed should be sown before the expiration date shown on the inoculant tag attached to the seed bag.

Inoculants and inoculated seed should NOT be stored where they will be subjected to high temperatures for a long time, and seed should NOT be mixed with fertilizer, as both practices can be lethal to bacteria.

Once a field has a successful stand of a legume species, bacteria may remain viable in the soil for two to five years, and a subsequent planting of the same legume may not require inoculation. The most consistent method, however, is to inoculate with the proper Rhizobium each time legume seed is planted, regardless of history.

Will All Inoculants Work Equally?

Rhizobium bacteria are host specific, menaing certain bacterial strains work best with certain legume species. Therefore, it is important that the strain of bacteria is appropriate for the legume to be established. Commercial packages of inoculant list legume species for which the package is effective.

How Does Nitrogen Go From Air to Grass?

N fixation. Bacteria convert atmospheric N gas to ammonia (NH_3) using energy from legume-produced carbohydrates. Legume plants provide sugars and other carbohydrates (legume yield) as energy and structure for protein synthesis. Using N in ammonium (NH_4) compounds and carbohydrates, proteins are formed which become part of legume plants.

Urinary N from grazed legumes. Animals consume legumes and excrete most of the legume N. This accounts for about 75 percent of the consumed legume N; however, much N in urine may be lost as ammonia.

Legume N in Dung. Dung contains only two percent to three percent N in organic forms (about the same concentration as forage).

Mineralization of organic matter. Organic matter containing legume proteins may be mineralized in soil, liberating N as nitrates (NO_3) and NH_4 that may be used by grass.

Decay of nodules and legume roots. Estimates of the importance of this path are highly variable (0 to 100 lbs N/acre/year).

Decomposition of leaves and stems. The N contribution from leaves and stems is highly dependent on management but may account for several pounds per acre.

Other pathways are considered to be minor and include:

- Leaching of N from living vegetation by water.
- Passing of N from legume roots and nodules directly to soil.
- Direct legume to grass transfer.

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