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Legumes and Nitrogen
Frequently Asked Questions:

The What, When, Where, and How of Nitrogen Fixation

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"Plant some legumes!" This is one of the most common recommendations made to persons who are seeking to improve pasture forage quality, decrease fertilizer needs, and reduce the effects of fescue toxicosis. Often this recommendation is followed by a series of questions in relation to "just how those legumes work."

The following are common questions received, and answers to help explain just what is going on in the field.

Q. What are the benefits of planting legumes?

Legumes provide many benefits to forage producers. The addition of compatible legumes to grasses increase forage quality and pasture diversity, and decrease the likelihood of certain animal related disorders. An important example of combatting an animal disorder is that planting white clover into toxic endophyte-infected tall fescue dilutes the high amount of alkaloids that would be ingested by animals grazing a pure toxic tall fescue stand.* Moreover, legumes have the unique and extremely valuable trait of having the ability to capture and fix nitrogen that can be utilized by non-legumes in forage production.

*Some legumes have the potential of causing bloat, but it is unlikely to occur if legumes make up less than **50%** of the ground cover. If bloat potential exists, animals need to be managed to avoid this problem.

Legumes provide high quality forage for grazing animals and biologically fixed nitrogen for the grass!

Q. Why plant legumes for Nitrogen?

The price of commercial nitrogen fertilizers has increased over the past three decades. In a time when cheap inputs are no longer an option, producers need to consider alternative methods to help sustain good soil fertility. Realizing that the cost of natural gas-based nitrogen fertilizers will almost certainly continue to increase; biological nitrogen fixation will become an essential aspect of all agricultural systems.

Historically legumes have been used in mixed pastures and crop rotations, one of the major reasons being their nitrogen fixing abilities.

Q. How does "Biological Nitrogen Fixation" work?

Legumes, such as clovers, have formed a mutually beneficial relationship with soil bacteria, *Rhizobium.* These bacteria infect legume root hairs forming small nodules near the point of root elongation (often called "root nodes"). These bacteria pull nitrogen gas (N_2) from the atmosphere and convert it to ammonium (NH_3), a plant usable form of nitrogen. This process is commonly referred to as nitrogen fixation. The legume host receives nitrogen in exchange for sugars and other compounds that the bacteria need to survive and fix nitrogen.

Q. Why do legume seed need to be inoculated?

Seed inoculation ensures good nitrogen fixation by legumes. Inoculation is the process of applying *Rhizobium* bacteria to the seed before planting to favor nitrogen fixation. If a legume to be planted has been grown in a field in recent years, the proper *Rhizobium* bacteria should already be present, but this should not discourage seed inoculation at planting. Nitrogen fixation is highly dependent on the right match of legume species and bacteria present, so providing the correct inoculant is very important in this regard. Some legume seeds come pretreated with the appropriate species of *Rhizobium* inoculum and thus do not need additional inoculation. Commercial inoculants, that are relatively inexpensive, are available and should be used to inoculate seed that has not been pre-inoculated regardless of whether legumes have been grown there before. The higher the amount of the suitable type of bacteria provided through inoculation present, the more root hairs that will be infected. Both Rhizobium inoculum as well as pre-inoculated seed should be kept in a cool, dry area. Otherwise the bacteria are likely to die.

Each legume species requires a specific species of Rhizobium bacteria to form nodules and effectively fix nitrogen.

For a list of specific inoculant group by species please visit:
http://www.aces.edu/anr/forages/Management/Establishment.php .

Q. When does the "infection of roots by bacteria" occur and how?

Once established from properly inoculated seed, seedling legume roots will quickly become infected with *Rhizobium* bacteria, and nodules will begin to appear (typically 21 to 28 days from plant emergence). As the plant gets older, the number and size of nodules will indicate the extent of nitrogen fixation. Nitrogen fixation is highly dependent on soil condition. *Rhizobium* bacteria will fix nitrogen if conditions are adequate (proper soil moisture, temperature, pH, fertility). Soil fertility and pH are directly correlated to number of *Rhizobium* present, making sure the pH is between 5 and 8 and that calcium, phosphorus, and potassium levels aren't limited will help encourage healthy *Rhizobium* populations. If soil conditions are suitable for growth of the legume, they are typically suitable for bacterial infection and nitrogen fixation.

Rhizobium populations can be reduced by extreme weather conditions (i.e. drought, flooding, etc.).

Nitrogen fixation is:

Higher	Lower
During the Day	During the Night
Sunny Weather	Cloudy Weather
Lots of Leaves Present	Few Leaves Present

Q. How can I tell if Nitrogen is being fixed?

An easy way to tell if the root nodules are actively fixing nitrogen is to cut one open. Dig up a seemingly strong, healthy plant making sure to carefully brush away the soil in order to obtain a good sample of the root and root hairs. First examine the number and size of nodules present (are there many or only a few?). Remember root nodules vary in size, number, and shape between species and often times among species between different varieties. The presence of nodules does not ensure that nitrogen fixation is occurring. Take a small knife or sharp instrument and simply cut a node in half.

If the nodule is:

pink to dark red inside = nitrogen fixation is occurring

green to white = no nitrogen is being fixed.

Q. When is the nitrogen available?

Biologically fixed nitrogen is available to the legume once the roots have been infected and nodulated. Grain legumes such as soybean and peanut use most of their fixed nitrogen for themselves. Forage legumes, such as alfalfa and clovers, are the best crops for companion planting as they can fix substantial amounts of surplus nitrogen under the right conditions. Some of this excess nitrogen is released through the roots of the legume and is available in the soil for plant uptake through nitrogen transfer. Nitrogen transfer is simply the movement of nitrogen from one plant to another. The amount of nitrogen transferred depends on species of the plants involved, plant productivity, and duration of the growing season. Planting mixed pastures of grasses and legumes is a feasible, low input management practice.

Keep in mind these are plants benefiting from growing simultaneously in close proximity to one another; legumes do not have to be dead to transfer nitrogen to other plants.

Q. Do I have to wait until the legume dies to get the nitrogen benefit?

No! Most producers utilize forage legumes through harvesting by grazing cattle or cutting hay. These processes are collectively referred to as defoliation and they have an effect on the legume's ability to fix atmospheric nitrogen. Defoliation through harvesting, results in root die back as the plant adjusts to meet the needs of the above ground material. When nitrogen fixing legumes are defoliated, this encourages root die back and thus release of nitrogen fixing nodules into the soil. Removal of the above ground material (i.e. leaves) through harvest results in the removal of the "sources of energy" for the legume plant and root nodules. When these nodules are "cut off" from the legume root they will degrade and release nitrogen into the soil that is then available for plant uptake. Once the plant recovers and regrows leaves, the formation of new nodules will occur and biological nitrogen fixation will continue. Grazing pastures with a legume component is a common practice and can be very beneficial to both the growing animal and the pasture. Not only is nitrogen released in the soil through defoliation by grazing, but some of the nitrogen is also returned to the land through the excrement of the animal in the form of urea. When a grazing animal consumes legume forage it is taking in nitrogen fixed by the legume, much of which is recycled in the form of dung and urine. With proper grazing management, much of this recycled nitrogen will eventually again be available for uptake by pasture plants. In addition, legume leaves that shatter eventually decompose and provide some nitrogen and other nutrients to the soil.

Q. How much Nitrogen is "fixed"?

The amount of nitrogen fixed by legumes fluctuates considerably depending on legume species, soil conditions, proper inoculation, amount of bacteria available, etc. expectations are listed in the following table to use as a guideline:

Crop	Nitrogen Fixed (lb/A/year)
Alfalfa	150-250
Red Clover	75-200
White Clover	75-150
Annual Clovers, Vetches, Lespedeza	50-150
Source: Southern Forages, 4th Edition (Ball et. al)	

Q. How much nitrogen do I need to apply if I have legumes present in my field?

It is typically recommended that if legumes make up at least **30%** of the ground cover in a field, no nitrogen should be applied. Nodulation and nitrogen fixation is highest in soils that contain minimal amounts of nitrogen. In order to realize the full benefits of biological nitrogen fixation, application of nitrogen to fields containing substantial amounts of legumes should be avoided or minimized.

Remember:

it is easier for the legume to take up commercial fertilizer from the soil than to fix nitrogen from the atmosphere. As more commercial Nitrogen is applied less bacterial infection occurs, fewer nodules are formed, and lower amounts of biologically nitrogen will be fixed.