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# PRINCIPLES OF FORAGE LEGUME MANAGEMENT

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# LEGUME NITROGEN FIXATION AND TRANSFER

## Nitrogen Fixation Process

Nitrogen is the most limiting nutrient for plant growth. A legume plant's ability to use nitrogen from the air is the best known benefit of growing legumes but the least understood. Approximately 79% of the air is nitrogen gas. However, it is not in a form that plants can use. In reality it is not the plant that removes nitrogen from the air but *Rhizobium* bacteria which live in small tumor like structures on the legume plant roots called nodules. These bacteria can take nitrogen gas from the air in the soil and transform it into ammonium ($NH_4$) which can be used by the plant. This ammonium is the same form as in ammonium nitrate (34-0-0) and ammonium sulfate (21-0-0) fertilizer.

The nitrogen fixation ($N_2$-fixation) process between the legume plant and rhizobia bacteria is referred to as a symbiotic (mutually beneficial) relationship. Each organism receives something from the other and gives back something in return. Rhizobia bacteria provide the legume plant with nitrogen in the form of ammonium and the legume plant provides the bacteria with carbohydrates as an energy source. Rate of $N_2$-fixation is directly related to legume plant growth rate. Anything that reduces plant growth such as drought, low temperature, limited plant nutrients, or disease will also reduce $N_2$-fixation. Maintaining sufficient leaf area in a legume stand to intercept most of the sunlight is also critical to maintaining a high growth rate to support $N_2$-fixation.

The quantity of nitrogen fixed by legumes can range from almost none to over 200 lb/acre. Factors that influence the quantity of nitrogen fixed are the level of soil nitrogen, the rhizobia strain infecting the legume, amount of legume plant growth, how the legume is managed, and length of growing season. If given a choice, a legume plant will remove nitrogen from the soil before obtaining nitrogen from the air through $N_2$-fixation. A legume growing on a sandy soil very low in nitrogen will get most of its nitrogen from the air while a legume growing on a fertile riverbottom soil will get most of its nitrogen from the soil. General estimates of the amount of nitrogen fixed in the eastern half of Texas range from 50 to 100 lb N/acre for annuals and about 200 lb N/acre for alfalfa.

## Seed Inoculation

Most legume species have a specific rhizobia strain that maximizes $N_2$-fixation. Arrowleaf clover, white clover, alfalfa, vetch, annual medics, cowpea, and lespedeza all require different strains of *Rhizobium* bacteria. There are some instances where an effective rhizobia strain will work on several legume species. White and red clover use the same strain and alfalfa and sweetclover use the same strain. There are numerous strains of native *Rhizobium* bacteria that occur naturally in different soils. Some of these rhizobia strains are capable of infecting a given legume species but will vary in their efficiency to fix nitrogen. Ineffective strains will form many small nodules on the legume root but fix little or no nitrogen. Effective rhizobia strains that fix high rates of nitrogen form fewer but larger nodules that have dark pink or red centers. Rhizobia bacteria enter the legume plant through infection sites on new root hairs. Research with arrowleaf clover indicates that these infection sites are receptive to rhizobia bacteria for about 24 hours. Large numbers of effective bacteria in the area of new root growth are essential for good nodulation. To ensure that an effective rhizobia strain is present when planting a legume species, the seed are inoculated (*Rhizobium* bacteria applied on the seed) before planting.

The inoculant should be purchased when buying the legume seed several weeks in advance of the estimated planting date. This allows time for the retailer to order the seed and/or inoculant if not kept in stock. Ground peat moss is used as a carrier for the bacteria by inoculant companies. When purchasing inoculant be sure the legume species you want to plant is listed on the package and that the expiration date has not passed. There are several brands of inoculant. The most effective ones are those which have a large number of rhizobia per gram of inoculant and contain a sticker that helps hold the inoculant to the seed such as HiStick and Pelinoc-Pelgel. Rhizobia bacteria are very susceptible to high temperatures. Be sure the inoculant is kept in a cool dry location away from direct sunlight. Most inoculant companies recommend their products be kept in a refrigerator until used except for HiStick, which can be kept at room temperature. It is desirable to drill the inoculated seed in the soil to help protect the bacteria from the sun and high temperatures.

Poor nodulation may occur even if good seed inoculation practices were used. Rhizobia bacteria begin dying as soon as the inoculated seed are planted. The longer the seed lies in the soil before germination, the fewer viable rhizobia are present. If regular inoculant is just applied to the seed with water, buttermilk, or Coke as a sticker, the bacteria may only survive in the soil for about a week. Inoculant containing a sticker or that is coated on the seed provides more protection for the bacteria which improves its survival to about 3 weeks.

It is difficult to introduce a new legume species into a pasture that has had a native, naturalized, or different legume species growing on it for several years. The rhizobia strain infecting the previously grown legume species will have built up a large soil population over the years. Just because of greater numbers, the resident rhizobia strain may occupy most of the infection sites on the new seeded legume and prevent infection by the introduced rhizobia strain.

An example would be trying to plant white or subterranean clover in a pasture where burr clover had grown for several years. In some instances the native rhizobia in the soil can fix adequate amounts of nitrogen in some legume species. White clover on poorly drained clay soils on the Upper Gulf Coast and berseem clover on the blacklands do not always show a response to seed inoculation. But inoculating the seed is always recommended when planting a different legume species on a pasture for the first time.

When the legume plant matures and dies, nodules on the root system decompose and release the rhizobia into the soil. If the same legume species is planted again the following year or volunteers from seed produced the previous year, sufficient numbers of rhizobia are usually present to provide good nodulation.

## Nitrogen Transfer

Forage legumes contain from 3 to 4% nitrogen that can come from both the soil and air. Legumes are generally grown with grasses in the hope that the legume will provide nitrogen for the grass and thereby eliminate or reduce the need for applied commercial nitrogen fertilizer. A common misconception is that the nitrogen is released into the soil from the legume roots. Research has shown there is a release of some soluble nitrogen compounds such as amino acids and ammonium from intact legume roots and nodules, but it is an insignificant amount. The primary pathways for nitrogen transfer from the legume to the soil are through grazing livestock and decomposition of dead legume plant material.

When legume forage is consumed by grazing livestock most of the nitrogen in that forage passes through the animal and is excreted in the urine and feces. Unfortunately about 50% of the nitrogen in the urine is lost through volatilization. Another problem is the distribution of feces and urine on the pasture. With continuous grazing at low stocking rates, much of the animal excreta is concentrated around the water source and under shade trees. Animal excreta distribution is improved with moderate to high stocking rates and with rotational grazing systems where stock density is higher.

The root system and unused leaves and stems of annual legumes die at plant maturity and are decomposed by soil microbes over time. Nitrogen contained in this plant material is released over time and is available to other plants. However, because this nitrogen is not available until after the legume dies only grasses that follow the legume growing season can use it. This is a major nitrogen transfer pathway for cool-season annual legumes overseeded on warm-season perennial grasses because the clover-growing period precedes the warm-season grass-growing season.