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Inoculation of Forage Legumes

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Forage legumes play a critical role in forage-livestock programs in Kentucky, and they must play an important role in the future. Forage legumes are grown alone (alfalfa for hay) but are mostly grown in association with grasses in Kentucky pastures and hay fields. When grown in association with cool-season grasses, research and farmer experience has shown increased yield, quality, and summer production. In addition, properly nodulated legumes "fix" nitrogen (N); that is, they take nitrogen from the air and change it chemically so it can be used by legume plants to make protein and other nitrogen-containing compounds. Some of the fixed nitrogen becomes available to grasses growing in association with the legumes. Value and amount of nitrogen fixed depends on species, growing condition, and price of nitrogen (Table 1).

Table 1. Value and amount of nitrogen fixed by various legumes.

Crop	N fixed, lb/A/year	N value, $, @ 25¢/lb	35¢/lb	45¢/lb
Alfalfa	150-250	38-63	53-88	68-113
Red clover	70-200	19-50	26-70	34-90
White clover	75-150	19-38	26-53	34-68
Vetch, lespedeza, and other annual forage legumes	50-150	13-38	18-53	23-68

Source: Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 2002. Southern Forages. Potash & Phosphate Institute and Foundation for Agronomic Research, Norcross, Georgia.

Nodules are formed on the roots of legume plants when bacteria called Rhizobia "infect" root hairs (Figure 1). The bacteria obtain the energy for N fixation from the legume, and in turn they supply the N needed for legume growth. Many nodule-producing bacteria may be present in soils; however, all are not equally effective in fixing N. To ensure that nodules will be formed from the best bacteria, you should properly inoculate legume seed before planting. *This may be critical to the success of forage legumes, especially in fields where the legume to be seeded has not been recently grown.* Most commercial inoculants are sold as a mixture of Rhizobia and finely ground peat, which helps keep the bacteria alive for several months.

For infection and N fixation to occur, inoculant bacteria must be: (1) correct for the legume on which they are used; (2) in contact with roots of the legumes they are to nodulate; and (3) alive and capable of infection. It is also important to have adequate soil fertility. A medium to high soil test phosphorus level and pH of at least 6.2 are required for good nodulation to occur.

Figure 1. Rhizobium nodules are elongated, swollen structures attached to roots of legumes. The interior of nodules that are actively "fixing" nitrogen will be pink.

Use Correct Inoculant

Legume inoculants are divided into groups based on their capability of infection and N fixation (Table 2). Groups included Alfalfa, Clover, Cowpea, Lupine, Pea and Vetch, and Other. Some inoculant manufacturers follow the practice of mixing the alfalfa and clover groups so that one inoculant may be used on most legumes (alfalfa or clovers) seeded in Kentucky.

Check the inoculant package for species. If the legume species is not listed on the package, do not use it.

Put Bacteria in Contact with Roots

The first thing that emerges from a germinating seed is the primary or first root. In legumes, this becomes the taproot. To be certain that large numbers of bacteria contact the roots, inoculant should be "stuck" to every seed. There is little assurance of this happening if dry inoculant is applied to dry seed. Wetting seed with water may help, but it is much better to wet with something sticky. Commercial sticking agents are best, but you can make your own by diluting one part of syrup or molasses with nine parts of water.

It also helps to use large numbers of bacteria. Research from North Carolina has shown that using heavy inoculant rates and better stickers results in more nodules per plant and a greater percentage of plants nodulated than does using dry inoculant.

Table 2. Inoculation groups for commonly grown forage legumes.

Alfalfa Group (*Rhizobium meliloti*)	Alfalfa Black medic Bur clover Button clover White sweetclover Yellow sweetclover
Clover Group (*Rhizobium trifolii*)	Alsike clover Arrowleaf clover* Ball clover Berseem clover Crimson clover Hop clover Persian clover Red clover Rose clover* Subterranean clover* White clover
Cowpea Group (*Bradyrhizobium japonicum* spp.)	Alyceclover Cowpea Kudzu Peanut Lespedeza Joint vetch
Lupine Group (*Rhizobium lupini*)	Blue lupine White lupine
Pea and Vetch Group (*Rhizobium leguminosarum*)	Bigflower vetch Common vetch Hairy vetch Roughpea Winter pea
Other**	Bird's-foot trefoil (*Rhizobium loti*) Cicer milk vetch Crown vetch Sainfoin (*Rhizobium*) Soybean (*Rhizobium japonicum*) Kura clover Leucaena

* *Specially selected strains specific for this legume species are most effective.*

** *Except for legumes listed under "Other" and those that require species-specific strains, the same inoculum can be used for all the species listed within an inoculation group.*

Source: Ball, D.M., C.S. Hoveland, and G.D. Lacefield. Forage Crop Pocket Guide. Potash & Phosphate Institute and Foundation for Agronomic Research, Norcross, Georgia.

Be Sure Inoculant Bacteria Are Alive

When purchasing inoculant, pay attention to the following:

1. **Date on the package—**Each package of inoculant is marked with an expiration date. After that date, many bacteria are likely to be dead; therefore, do not use outdated inoculant.
2. **How inoculants are stored—**Even if the expiration date has not passed, many bacteria may be dead if they have been stored where the temperature is high. Leaving the package on the dashboard or in your truck or car for even a short time may kill many bacteria. Best storage is in a refrigerator. Do not expose inoculant or inoculated seeds to sunlight. Ultraviolet light will kill bacteria.
3. **Condition of the package seal**—Holes in the inoculant package may permit the peat and bacteria to dry and result in death of some bacteria.

Inoculation Recipe

1. Place 25 pounds of seed in a tub.
2. Use a commercial sticking agent or make one by diluting syrup or molasses with water, using nine parts of water to one part of syrup. Shake well.
3. Add only enough of the "sticker" solution to moisten the 25 pounds of seed and mix thoroughly, coating every seed with sticker. **Don't add too much liquid!** If you do, seed will stick together and will not flow through the seeder. Add one-half bag of inoculant and mix thoroughly.
4. Repeat the process until a sufficient quantity of seed is prepared for planting.
5. Plant seed as soon as possible after inoculation. If they can't be planted immediately, store the seed in a cool place. Repeat inoculation if seeds are not planted within 24 hours. Do not leave inoculated seed in direct sunlight. Slightly moist soil provides the best conditions for bacteria survival.

Pre-Inoculated Seeds

Pre-inoculated and/or lime-coated seeds are widely available in Kentucky. Many advances have made this process very reliable. Pre-inoculation is the process of sticking large numbers of bacteria to the seed at the processing plant prior to bagging. Often the pre-inoculated seeds are coated with finely ground limestone or other coating material. This practice offers seeds that are ready to plant. Although bacteria on pre-inoculated seed can die in storage over time, advances in seed coating research have extended the shelf life to 18 months or more, depending on storage conditions. Always check the tag and do not buy seed when the expiration date has passed.

Summary

Legumes can improve grass-based forage programs by increasing yield, improving quality, improving summer production, and converting atmospheric nitrogen into a chemical form that the legume plant can use, thus reducing the need for applied nitrogen fertilizer. In order for the legume to "fix" nitrogen, they must have active nodules on the roots. Nodules are formed when proper bacteria are in contact with the seed during the establishment period. Supplying this bacteria in sufficient quantities can be done through the addition of rhizobia bacteria prior to seeding on the farm or at the factory when seed are pre-inoculated with large quantities of rhizobium.

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