

Legume Inoculation

Legumes are a family of plants (*Fabaceae*) that have the ability to react in a symbiotic (mutually beneficial) relationship with unique strains of *Rhizobia* bacteria to convert atmospheric nitrogen (N_2) from the soil atmosphere to ammonia nitrogen (NH_3). Plant available nitrogen created by this relationship between a growing plant and soil bacteria is virtually free to the producer as there is little or no need to purchase nitrogen fertilizer products. This additional nitrogen improves soil fertility, produces higher protein, and increases forage yields in the host plant and in many cases for following crops.

The correct strain of bacteria will infect the roots of the legume to form nodules (see Figure 1). The bacteria work within the nodules to transform atmospheric nitrogen to plant available nitrogen. The interaction involves the exchange of water and nutrients for nitrogen with both the plant and bacteria benefitting. The host plant is the only plant that will benefit from the nodules growing on live roots. The roots and nodules must decay to make nitrogen available to other plants and soil biota.

The ability to acquire nitrogen from the atmosphere is a trait that allows legumes to be grown without the addition of nitrogen fertilizer. Growing legumes in a crop rotation or forage management system typically adds nitrogen to the soil for subsequent crops or production periods. In order for this symbiotic relationship to establish and develop, the appropriate *Rhizobia* bacteria must be present in the soil as the legume's roots grow and develop.

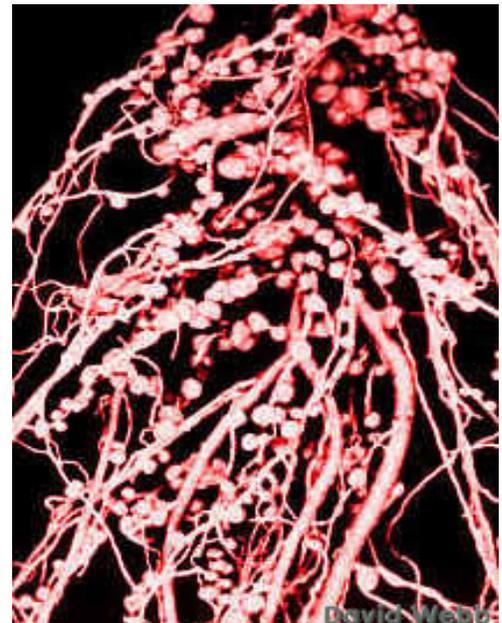


Figure 1 – Roots with bacteria nodules

Soils contain millions of bacteria, but *Rhizobia* bacteria proliferate best in soils that are planted with the correct host legume crop. When a legume is planted on a particular soil for the first time, there is a very good chance that the correct *Rhizobia* strain will not be present. Successful formation of nodules requires inoculation of the legume seed with the appropriate bacteria at planting and placing the seed in the soil in contact with the inoculant.

The producer should follow the manufacturer's recommendations regarding the strain of inoculum and the amount to be added with the legume seed. The inoculant package will list the appropriate legume species. Due to the different formulations and carriers used in developing the inoculant, each manufacturer will have a different requirement for the amount needed.

Benefits of Inoculation:

- Increased yield – yields may increase from 10 to 100% depending on specific soil conditions; soils with average fertility may have yield increases from 15 to 25%.
- Improved protein content – inoculated alfalfa has tested 3.5% higher for protein in the upper Midwest.
- Increases soil nitrogen for future crops – nitrogen fixation will vary depending on plant species, suitable bacterium population, soil nitrogen content, soil fertility level, soil pH, moisture, and temperature; average nitrogen values are shown below:

Legume Species (pure stands)	Pounds of Nitrogen Fixed per Acre per Year
Alfalfa	140 to 200
Ladino Clover	130 to 185
Alsike Clover	70 to 125
Red Clover	62 to 119
Birdsfoot Trefoil	44 to 100
Soybeans	80 to 128

Types of Inoculation Procedures:

Inoculants may be available in dry, granular, or liquid formulations. Inoculants can be mixed and applied with the seed by one of the following methods:

1. Pre-inoculated Seed – The inoculant is pre-applied to the seed prior to sale to the producer. Seed inoculated in this manner must be stored under cool conditions until immediately prior to planting to insure viability of the bacteria.
2. Slurry Method – The dry, granular, or liquid inoculant is mixed with the seed in a wash tub or barrel along with a liquid to form a slurry. Water is the most common liquid used. The slurry is transferred to the planter box for planting. Various commercial “stickers” are also available and can be used with the slurry method to aid in adhering the bacteria to the seed. This method is generally considered to be the most effective of the in-field inoculation methods. Make sure that all seed and liquid is removed from the planter boxes at the end of the day.
3. Sprinkle Method – Seed is pre-moistened with water or a “sticker” product in the planter hopper, a wash tub, or a barrel prior to mixing in the dry or granular inoculant formulations; liquid inoculant can be used without additional water or sticker products. Allow the seed to dry in a shady area before attempting to plant. This method is not considered as good as the slurry method but can be adequate under good planting conditions. Again make sure to remove all seed from the planter boxes at the end of the day.

Refer to Table 1 for a listing of manufacturers and the inoculants they produce. Refer to Table 2 for a listing of the specific *Rhizobia* bacteria that are required for a legume species or group of species.

IMPORTANT NOTE: Inoculants are perishable. They should be transported and stored in a cool, dry place and never used past the date recommended by the manufacturer.

Points to Remember:

- Inoculation of legumes with the appropriate *Rhizobia* bacteria is needed to maximize biological nitrogen fixation.
- Based on the relatively cheap cost of inoculants and the high cost of nitrogen fertilizers, the addition of inoculants to a seeding is a wise investment in fertilizer management and crop production.
- Select the *Rhizobia* inoculant or mixture of inoculants based on the legume species that will be planted. Do not use an inoculant if the legume species is not listed on the package or company literature as appropriate.
- Do not allow the inoculant to be exposed to direct sunlight or heat when transporting.
- Store the inoculant according to the manufacturer's recommendations (refrigeration may be required but do not freeze).
- Mix the seed and inoculant in a shady location out of direct sunlight.
- Plant seed within 24 hours after mixing with inoculant or re-inoculate.
- Never mix the inoculant with any kind of fertilizer or pesticide unless specifically labeled for that use. Avoid contact with agricultural lime.
- Effective sticking agents for use with inoculants include 10 percent solutions in water of powdered milk, corn syrup, molasses, or sugar along with the "commercial sticker" products that are available. Using carbonated liquids or compounds that are acidic or basic will result in poor inoculant survival.
- Soil moisture is very important for successful inoculation and nodulation. Do not plant inoculated seed into dry soil.
- Soil temperature and soil pH can also affect the survival and ultimate effectiveness of inoculants.
- Not all root nodules fix nitrogen because there are other soil bacteria that form root nodules. Slice through a few nodules and look at the color of the cut surface. Red or pink color indicates the ability to fix nitrogen. White color indicates ineffective bacteria. Green color indicates nodules that are no longer producing.
- No simple test exists to determine whether suitable *Rhizobia* are already present in the soil prior to planting.
- A relatively small investment of time and money in inoculant and sticker products will ensure that the correct bacteria species is present for a legume stand to produce nitrogen.
- Because inoculants are cultures of living organisms, contact suppliers well in advance of the planned seeding dates to make sure viable inoculants will be available.

TABLE 1 – Available Sources of Inoculants

Seed dealers will be responsible for supplying the compatible Rhizobia bacteria species for each legume listed in Table 1. The information in this table is presented merely to show various manufacturers of inoculants but may not list all manufacturers.

Legume Species	Inoculant Manufacturers					
	Novozymes	Becker Underwood, Inc.	CelPril - Bayer Crop Science	EMD Crop Bioscience	INTX Microbials, LLC	Plant Probotics
Birdsfoot trefoil		X			X	X
Alsike clover		X		X	X	X
Ladino clover		X		X	X	X
Red clover		X		X	X	X
Alflafa	X	X	X	X	X	X
Common lespedeza		X			X	X
Kura clover						X
Illinois bundleflower						X
Partridge pea		X			X	X
Roundhead bushclover						X
Showy ticktrefoil						X

Addresses and contact information for the manufacturers in Table 1

Philom Bios/Novozymes
3935 Thatcher Avenue
Saskatoon, SK Canada S7R1A3
Phone: 888.744.5662
Fax: 306.975.1215
USA Representative
Dorn Severtson
Phone: 952.361.3495
Cell: 952.913.3941

Nitragin/EMD Crop Bioscience
13100 West Lisbon Avenue
Suite 600
Brookfield, WI 53005
Phone: 262.957.2000
Fax: 262.957.2121

Becker Underwood, Inc.
801 Dayton Avenue
Ames, IA 50010
Phone: 800.232.5907
FAX: 515.232.5961

INTX Microbials, LLC
200 W. Seymour
P.O. Box 62
Kentland, IN 47951
Phone: 219.474.5510
FAX: 219.474.3700

CelPril – Bayer Crop Sciences
251 Oak Street
Manteca, CA 95337
Phone: 209.823.1738
FAX: 209.823.8855

Plant Probotics
6835 Lindel Court
Indianapolis, IN 46268
Phone: 317.329.7731

TABLE 2 - Legume Cross-Inoculation Groups

<u>Crop or Forage</u>	<u>Inoculation Species</u>
Clovers (<i>Trifolium spp.</i>) Red Clover Ladino and White Clover Alsike Clover	<i>Rhizobium leguminosarum trifolii</i>
Kura Clover	<i>Rhizobium spp.</i> for Kura Clover
Birdsfoot Trefoil	<i>Mesorhizobium loti</i>
Alfalfa	<i>Sinorhizobium meliloti</i> or <i>Rhizobium mongolense</i>
Common and Korean Lespedeza, Partridge Pea, Showy Ticktrefoil, and Roundhead Bushclover	<i>Bradyrhizobium spp.</i> for lespedeza
Illinois Bundleflower	<i>Rhizobium giardinii</i> or improved inoculant
Soybeans	<i>Bradyrhizobium japonicum</i> or <i>Bradyrhizobium elkanii</i> or <i>Bradyrhizobium liaoningense</i> or <i>Sinorhizobium fredii</i>
Peas, Field Beans, Lentils, and Hairy Vetch	<i>Rhizobium leguminosarum viciae</i>

NOTE: An attempt has been made to include all *Rhizobia* manufacturers and their current contact information in this publication. Please notify Ron Miller at ron.miller@mo.usda.gov with the necessary information on any manufacturer that was not included. Errors in this listing are not intentional.