Legume Inoculation (MT 9619)

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Each year, more Montana producers are including legumes in their cropping programs. Alfalfa acreage in Montana is about 1.5 million acres and the production of other legumes such as peas, lentils and beans is over 100,000 acres. In the case of alfalfa, this means devoting certain acreage exclusively to legume production for long periods. In other cases, annual legumes are incorporated into rotation schemes, or are grown as companion crops.

Legumes are unique in that in order for good productivity without high nitrogen fertilizer inputs, they must be grown with rhizobia bacteria. These rhizobia bacteria enter into a close association with legumes by forming specialized structures—referred to as "nodules"—on the legume roots.

Inside these nodules, the legume plant and the bacteria exchange nutrients that are vitally important for both organisms. The plant uses solar energy to convert carbon dioxide into sugars that it feeds to the rhizobia bacteria. The bacteria use these sugars as energy to convert nitrogen gas in the air into ammonia, which it then releases to the plant. In summary, this agriculturally important plant-microbe interaction involves the exchange of carbon for nitrogen, and both elements are derived from the air.

The ability to acquire nitrogen from the air allows legumes to be grown without the addition of nitrogen fertilizer. Furthermore, the use of legumes in crop rotations typically adds nitrogen to the soil for subsequent crops. In order to take advantage of this special rhizobia association, the appropriate rhizobia must be present in the soil.

Soils contain millions of bacteria, but rhizobia proliferate best in soils that are planted with their correct host legume. If a legume is planted to a particular soil for the first time, there is a very good chance that the correct rhizobia will not be present. Under such conditions, successful nodulation requires inoculation of the legume seed at the time of planting.

Inoculation can be accomplished by a variety of methods, but it is essential that the correct rhizobia be paired with the legume being planted. For example, the rhizobia that nodulate alfalfa do not nodulate navy beans. Likewise, the rhizobia that form nodules on navy beans do not form nodules on peas, lentils, etc. Therefore, it is crucial that the correct rhizobia inoculant be used. Table 1 provides information regarding the correct rhizobia for legumes currently grown in Montana.

Here are some other points to keep in mind about inoculating legumes:

- When purchasing your inoculant, check the inoculant expiration date. The viability of bacteria in the inoculant is not indefinite and inoculant should never be used if it is out of date. Using last year's inoculant is an excellent way to obtain poor nodulation.
- Store the inoculant in a cool dark place until use. Do not transport the inoculant exposed to direct sunlight (e.g. in the back of the pickup) and ask the supplier how the inoculant was stored before you purchase it. It is important that the inoculant be stored under cool refrigerated conditions. If not, you could be wasting your time and money as you will see little benefit from inoculation
- Plant seed within 48 hours after inoculation or re-inoculate.
- Check label of other seed treatments for compatibility with inoculants. Never mix the inoculant with any kind of pesticide or fertilizer—these are almost always lethal to the rhizobia bacteria.
- Monitor development of nodules on the roots of the planted legume. Nitrogen stress symptoms or uneven green coloration are indications of poor nodulation.

Inoculants for all legumes grown in Montana can be purchased from most seed retailers. Alfalfa seed is usually supplied pre-inoculated and can be used as such without inoculation, provided seed storage conditions are conducive to rhizobia survival. If seed storage conditions are suspect, then alfalfa seeds should be inoculated just prior to planting as with other legumes.

Typically, the highest quality inoculants are peat-based. Other carriers such as clay, oil, or water (frozen concentrate) are also available, but our recommendation is to use a peat-based inoculant produced by reputable companies. While inoculant quality is monitored in Canada, as of yet no formal mechanism of quality control is in place in the United States.

Inoculate the seed in a shady area. Seed and inoculant can be mixed in a tub or bucket. For best results, moisten the seed with a binder or sticking agent to help the inoculant adhere to the seed. Several continuous flow seed treaters are now marketed which can be used effectively for applying inoculants. Sticking agents that can be used include 10 percent (in water) solutions of: powdered milk, corn syrup, or sugar. Do not use calf milk replacer as it contains antibiotics that will kill the rhizobia, nor should any compounds that are strongly acidic or basic be used. Commercial stickers are also available. For best results, follow instructions provided on the package.

Approximately two to three weeks after emergence, pull up or dig up a few plants and look at the roots for nodule formation. Nodules will have different shapes depending on the legume species being planted. Alfalfa and clover nodules tend to be fairly small, so look closely and perhaps gently wash the roots to remove clinging soil.

If nodulation failure is observed in crops such as alfalfa, you can reinoculate by watering with a solution containing inoculant made up of powdered peat, followed by additional irrigation to help the bacteria percolate into the soil. This is not as efficient as coated-seed inoculation and should only be used if initial inoculation fails.

With annual legumes such as navy beans, lentils, and peas, if the initial inoculation fails, plants at this stage may be delayed and stunted due to poor nitrogen availability and likely will not sufficiently recover for optimum yields—even if a second inoculation is successful. For perennials such as alfalfa, delayed nodulation will probably reduce first year yields, but there should be little differences in following years provided the second inoculation results in good nodulation.

Other Considerations

Poor nodulation may result from factors not related to inoculation. Factors most commonly associated with poor nodulation include soil moisture and temperature, soil pH and nutrient levels. Each are briefly considered below.

Soil Moisture

Soil moisture is critical for successful inoculation and nodulation. Survival of the rhizobia bacteria in dry soil is very poor. In addition, temperatures at the soil surface can exceed the tolerance limits of the inoculant bacteria. For example, alfalfa is typically planted shallow to maximize emergence. The alfalfa seeds can be planted in dry soil and wait for adequate moisture for germination, but the rhizobia provided as an inoculant will rapidly die under such conditions. Therefore, planting into moist soil is important. This can be a problem for dryland alfalfa and so it is helpful to monitor the weather forecast and try to plant inoculated seed just prior to a predicted rain. Usually, seeding as early as possible will help insure maximum soil moisture content.

Soil pH and Nutrients

Legumes such as alfalfa are very sensitive to pH and do poorly when the soil pH is below 5.5 - 6.0. Optimum pH for alfalfa is in the 6.6 to 7.5 range, although about 80-90 percent of maximum yield can be expected to as low as pH 6.0. Most Montana soils do not have acidity problems, but if soil pH drops below 6.0, significant problems develop and lime must be added. Alfalfa rhizobia are particularly affected at low pH. Hydroponic experiments have shown alfalfa can grow reasonably well down to pH 4.0 if adequate calcium is supplied, but the rhizobia simply stop growing at pH 5.5.

Some researchers believe the real issue is soil solution aluminum levels that are associated with low pH and not pH *per se.* Alfalfa yields are depressed when aluminum exceeds 12 - 20 percent of cation exchange capacity of the soil. Actual aluminum level depends on the soil and must be determined by soil tests.

Liming is effective for raising the pH of acidic soils, however, over liming or high soil pH can bring on problems with phosphorus and boron availability if these nutrients are already borderline. For most Montana producers, lime amendment is not cost effective; therefore, some acidic soils are not best suited for legumes such as alfalfa. In short, the producer needs to be aware of the nutritional requirements of the different legumes being considered. Optimum production of legumes requires adequate levels of phosphorus (P), potassium (K), boron, manganese and iron. Over fertilization with nitrogen will lead to reduced nodulation. Producers are encouraged to obtain proper soil analysis prior to legume establishment. Typically, soils should be tested for pH, EC, P and K (see MontGuides 8602 and 8704 for sampling procedures and interpretations) For more information, contact the authors or your county Extension agent.

Table 1. Appropriate rhizobia bacteria used to inoculate legumes grown in Montana.

Legume	**Rhizobia**
Alfalfa	*Rhizobium meliloti*
Chickpea (garbanzo bean)	*Rhizobium* spp.
Field Bean (Great Northern, kidney, navy, pink, pinto)	*Rhizobium leguminosarum* bv *phaseoli*
Garden Bean (snap, string, wax)	*Rhizobium leguminosarum* bv *phaseoli*
Lima Bean (cowpea)	*Bradyrhizobium* spp.
Sweet clover (white or yellow)	*Rhizobium meliloti*
Other clovers (alsike, Berseem, red, strawberry, white)	*Rhizobium leguminosarum* bv *trifolii*
Lentil	*Rhizobium leguminosarum* bv *viceae*
Black Medic	*Rhizobium meliloti*
Peas Field peas (Austrian Winter, Dry, Feed)	*Rhizobium leguminosarum* bv *viceae*
Garden peas (Green, Snow, Sugar)	*Rhizobium leguminosarum* bv *viceae*
Sainfoin	*Rhizobium* spp.
Birdsfoot Trefoil	*Bradyrhizobium* spp.