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Inoculation of Legumes in Idaho

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The purpose of this publication is to provide basic inoculation information for growers, fieldmen, county agents and other personnel associated with production agriculture in Idaho.

Legumes

Legumes are plants that have the capability to obtain nitrogen (N) required for plant growth from the atmosphere. Roots of legume plants work in association with certain bacteria (rhizobia) to "fix" N from the air. In this process, they convert N_2 gas to usable ammonia nitrogen. Legumes are usually grown for either human or animal consumption. In addition to their use to produce seed and forage, legumes can be used as green manure crops that provide N for the crop following in rotation and as cover crops to decrease soil erosion.

Non-legumes require the application of large amounts of a commercial N fertilizer for optimum plant growth. Legumes provide a large portion of their N requirement by N_2 fixation.

Legumes are commercially important in Idaho since they are raised on over 2,500,000 acres of cropland in the state. Large acreages of alfalfa, beans, peas and lentils are grown in various parts of the state. In addition, legumes such as birdsfoot trefoil, red and white clover and chickpeas, although not widely grown at present, may become more important in the future. Research has indicated that legumes such as faba beans and lupines may also be important in Idaho some day. Legumes are also important on millions of acres of grass/legume pastures and rangeland found throughout the state.

Symbiotic Nitrogen Fixation

Nitrogen-fixing bacteria are present in many soils, but are usually introduced either directly to the soil or by applying them to the seed. When the legume seed germinates, the rhizobia invade the seedling root hairs and begin to multiply. Nodules formed on the plant roots house the rhizobia and are the sites where N_2 fixation occurs (Fig. 1).

The relationship between the rhizobia and the legume plant is called symbiotic, that is, beneficial for both parties. The plant provides food and a structure for the rhizobia to live in while the rhizobia provide N for the growing plant.

The legume is able to translocate the usable N through its vascular system to its fruit and leafy tissue. The plant supplies the rhizobia with an anaerobic environment and

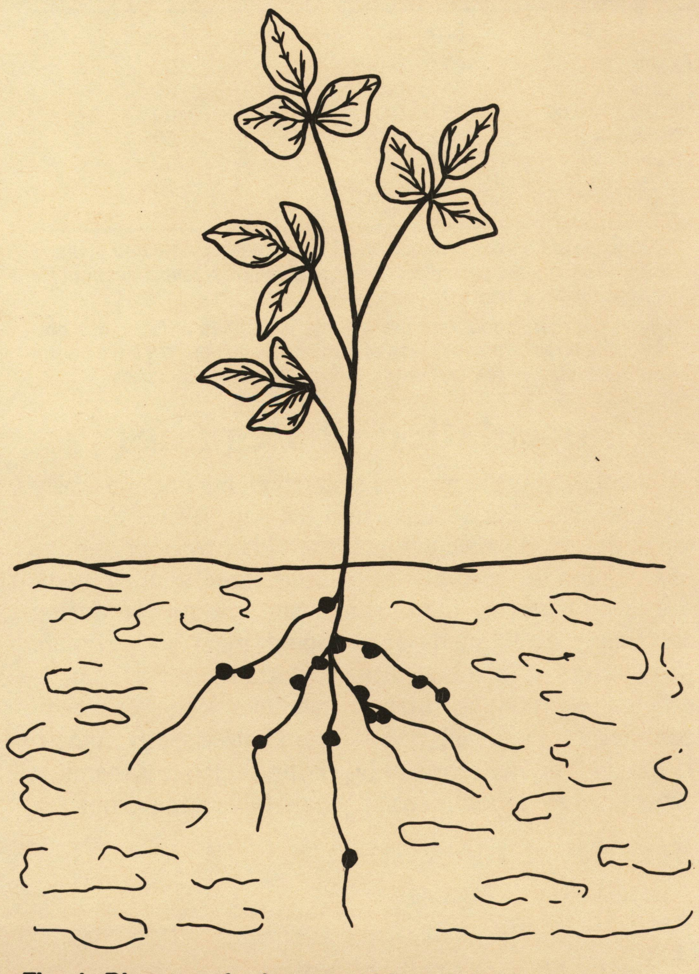

Fig. 1. Diagram of a legume with nodules on roots.

photosynthate, a food base the rhizobia use as an energy source. When cut open, healthy nodules that are actively fixing atmospheric N are pink in color. Conversely, inactive nodules are usually green, yellow or brown.

Relevance of N_2 Fixation

Nitrogen fixation is important because it reduces the N fertilizer requirements for the legume crop. The N fixed by the legume and plowed into the soil as residue is often available for the next crop in rotation (usually a nonlegume), thus reducing N fertilizer costs for the next crop. In addition, N_2 that is fixed by legumes is added directly to the plant system in a usable form and thus is not in the soil posing a potential environmental pollution hazard.

Amounts of N Fixed By Idaho Crops

The legumes grown in Idaho range from very poor to excellent N fixers. The N_2 fixation potential of each legume is shown in Table 1. Nitrogen fixation can supply virtually all the N needed to grow alfalfa, birdsfoot trefoil and most types of clovers when properly inoculated and nodulated. Peas, beans, lentils and chickpeas are intermediate, usually obtaining about half of their N requirement by N_2 fixation.

Table 1. Typical amounts amounts of N_2 fixed by legumes grown in Idaho.

Legume	Range of N_2 fixed*	Potential N_2 requirement**
	(lb/acre)	(%)
Alfalfa	150 to 340	100
Beans	50 to 125	80
Birdsfoot trefoil	75 to 200	100
Chickpeas	10 to 80	50
Clovers	100 to 250	100
Lentils	10 to 50	60
Peas	20 to 80	60

*The range of N_2 fixed is based on all crops being inoculated at planting. Differing yield potentials and available soil N levels account for ranges within a crop.

**Under optimum conditions the legume is capable of fixing this portion of its N requirement. Lack of proper inoculation, dry soils and/or high available N soil levels will reduce these percentages.

Inoculation of Legumes

Inoculation is the process of introducing commercially prepared rhizobia bacteria into the soil. These rhizobia are supplied in sufficient quantity either by applying the inoculant to the seed before planting (seed-applied method) or by metering the inoculant into the furrow during planting (indirect method). Although many soils contain populations of rhizobia, these bacteria usually are not as efficient N_2 fixers as rhizobia that have been selected by commercial inoculant companies. Consequently, inoculation with highly efficient N_2 fixing rhizobia is the most efficient way to attain good yields of legume crops.

Benefits of Inoculation

Inoculation of legumes will:

1. Improve crop yields.
2. Assure plants a supply of N when needed, provided other nutrients are present in sufficient quantities.
3. Often improve the protein content of forage legumes.
4. Increase the N content of legume residue incorporated into the soil, thus providing additional N for the following crop in rotation.

Rhizobia Bacteria

Rhizobium is the genus or type of bacteria that will enter into a symbiotic relationship with legume plants. Within the genus there are different species. The rhizobia species that produces nodules on peas will not produce nodules on alfalfa. Currently seven different rhizobia species are recognized. These species are often referred to as cross-inoculation groups (Table 2). Each species has many different strains. Even though all strains will nodulate a legume in a certain cross-inoculation group, the efficiency by which N_2 is fixed is variable. Commercially effective inoculants contain only strains that will effectively nodulate and efficiently fix N_2 for a given legume.

Table 2. Cross-inoculation groups of legumes.

Group	Rhizobium species	Legumes inoculated
Alfalfa	meliloti	alfalfa sweet clover
Bean	phaseoli	dry beans string beans
Clover	trifolii	red clovers white clovers sub. clovers
Cowpea	unspecified	chickpeas peanuts lima beans
Lupine	lupini	birdsfoot trefoil lupine
Pea	leguminosarum	peas vetch lentils sweet peas
Soybean	japonicum	soybeans

Effective Nodulation

Field observations can be used to determine the effectiveness of nodulation. Plants can be dug for examination 30 to 40 days after germination. The plant should be carefully dug so as not to destroy the nodules and roots. After collection the plants should be carefully washed. Two major questions should be asked to determine the effectiveness of rhizobia:

1. Are the nodules clustered around the plant tap root (Fig. 2)?
2. When slicing open a nodule, is it pink in color?

If the answer is "yes" to both questions, the legume in question is probably efficiently fixing N_2.

When Is Inoculation Necessary?

Inoculation should be considered under the following conditions:

1. The legume chosen has not been grown on the particular field in the last 4 years.
2. The legume has not produced satisfactory yields on the field in the recent past.

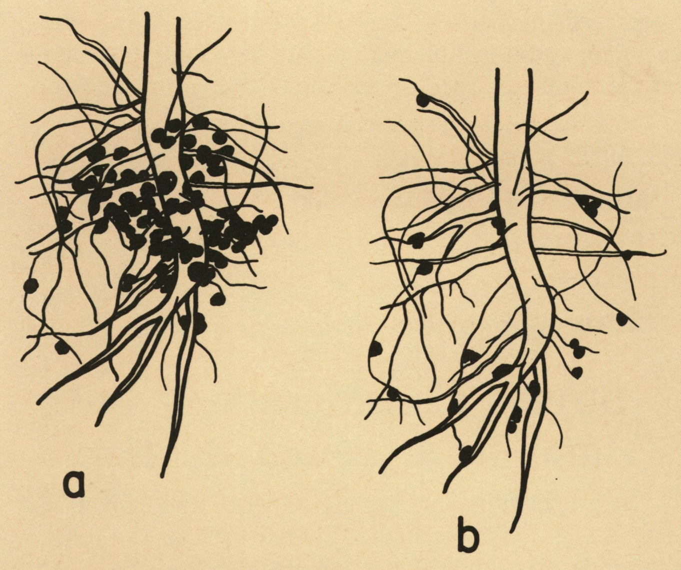

Fig. 2. The plant on the left (a) is well nodulated; note the number and proximity of the nodules to the tap root. Conversely, the plant on the right (b) has fewer nodules which are located on lateral rather than the tap root.

3. The texture of the field is sandy loam, loamy sand or sand.
4. A forage legume will be seeded.

Selecting the Right Inoculant

Carriers and Forms Available

Commercial legume inoculants are available in three basic forms: (1) solid (peat-based), (2) liquid and (3) freeze-dried. The solid peat-based inoculum is the type most widely used in the United States. Liquid inoculants have been available for many years. This type of inoculant has storage problems, however. The liquid must be kept cool to prevent the rhizobia from dying. In addition, the storage life of this type of inoculant is much shorter than a peat-based inoculant. Freeze-dried inocula is not readily available in the Pacific Northwest.

Methods of Application

Although significant advances have been made in the application (delivery systems) of legume inoculants over the years, two primary categories of application can be defined: (1) indirect delivery systems and (2) seed-applied delivery systems.

Indirect Delivery Systems — The two types of indirect delivery systems are granular and liquid applications. With the granular method, an operator can apply massive amounts of rhizobia to a soil as a granular peat carrier. This system eliminates the concern of mixing inoculants with fungicide-treated seed since the rhizobia do not come in direct contact with the seed. The granular inoculant is metered into the seed row at planting. The large quantity of rhizobia in the inoculant ensures nodulation of the legume. This system is most commonly used in Idaho with chickpeas.

With liquid applications, the liquid inoculum is mixed with water and applied with conventional spray equipment into the seed furrow. The liquid indirect delivery system is not currently used in Idaho.

Seed-applied Delivery Systems — Most seed-applied delivery systems use peat-based inoculants. The four most common types of seed-delivery systems used are: (1) planter box, (2) preinoculated seed, (3) custom inoculation and (4) pelletization.

Planter box application is the most commonly used seed-applied system. The inoculant is mixed with the seed in the hopper. For best seed adherence, the inoculant should be applied as a slurry. When time and labor will not allow the use of a slurry, the peat-based inoculant should be layered within the hopper to achieve the best contact with the seed.

Preinoculation of legume seed is the process of applying inoculum (peat-based) to the seed before it is sold to the grower. This approach is most often used for small-seeded legumes. Typically, a processor of small-seeded legumes will preinoculate a quantity of seed to the customer's specified order. The seed must then pass through the commercial distribution system to the grower. The main problem with this type of operation is that the grower must be certain that the preinoculated seed has been kept in a cool environment to maintain the viability of the rhizobia. High temperature is the major cause of rhizobia death and consequent failure of inoculation and nodulation.

Custom inoculation is similar to preinoculation of legume seed except that the inoculation process is generally done at the farm or by a nearby dealer or grain elevator, reducing the potential hazards involved in the commercial distribution system. In Idaho, most custom inoculation is done on large-seeded legumes such as peas and lentils. The dealer usually uses a sticking agent to adhere the inoculum to the seed.

The newest system is called pelletization. Pelletization involves a two-part mixture of: (1) an inoculant package containing rhizobia in a fine mesh peat with calcium carbonate and (2) a nutrient-rich adhesive formulation. When mixed together and applied to small-seeded legumes, this mixture yields excellent inoculation results.

Inoculation Recommendations

The following procedures are recommended for inoculating legumes in Idaho:

Large-seeded Legumes

Peas/Lentils — Since peas and lentils are members of the pea cross-inoculation group, they should be inoculated with *Rhizobium leguminosarum.* Peas and lentils are most commonly inoculated with a peat-based carrier using the custom inoculation seed-applied system. Follow the manufacturer's recommendation for the exact rate of inoculum per bushel of seed. If custom inoculation is not available, a peat-based inoculum can be used with the planter box seed-applied system.

In addition to the inoculum, molybdenum (Mo) is also commonly applied as a seed treatment when the soil pH is less than 5.7. As long as the Mo application rate does not exceeed ½ ounce per acre of seed planted, it should not harm the viability of the rhizobia. Mo can be applied to the seed as part of the custom inoculation operation. For more information on molybdenum, refer to University of Idaho CIS 589, *Molybdenum in Idaho*, and CIS 448, *Northern Idaho Fertilizer Guide for Peas and Lentils.*

Chickpeas — Chickpeas are a member of the cowpea cross-inoculation group, so a special inocula, called *Cicer* inocula in the trade, should be used. Since chickpea seed is usually treated with a fungicide that is toxic to rhizobia, *Cicer* inoculum is often applied in the granular form via an indirect delivery system. The application rate of granular inocula should be between 5 and 10 pounds per acre depending on the frequency of chickpeas cultivation in the field. If the last chickpea crop was less than 4 years previous, use 5 pounds; if more than 8 years, use 10 pounds. If granular inoculum is too expensive, two alternatives exist:

1. Add a peat-based inoculum at twice the manufacturer's recommended rate to the drill box (slurry method) just before planting, or
2. In areas where water mold fungi (*Pythium*, etc.) are major pathogens, use metalaxyl as the fungicide instead of captan and then use a peat-based inoculum as a seed coat.

Beans — *Rhizobium phaseoli* should be used as inoculum since beans are members of the bean cross-inoculation group. Rhizobia inoculations are generally unnecessary for most bean crops in the current bean-growing areas of Idaho. A peat-based inoculum may be used on beans that are grown on new or uncropped soils. After the initial inoculum application, however, no further inoculations are required. Indigenous *Rhizobium phaseoli* in the soil and irrigation water can provide adequate inoculum for both dry beans and string beans.

A bean crop may require 150 to 200 pounds of N per acre. Most of this N requirement can be supplied by the rhizobia bacteria with the remaining amounts coming from soil mineralization or organic matter breakdown. Nitrogen fertilizer is generally unnecessary for beans in Idaho. If the pre-plant soil test for nitrate (NO_3) is below 10 ppm, 30 pounds of N per acre will act as a starter fertilizer. For further information, see University of Idaho Experment Station Bulletin 282, *Bean Production in Idaho.*

Small-seeded Legumes

Seed processors frequently preinoculate small seeded legume seeds with the proper rhizobia species during seed processing. This saves time at planting, ensures proper matching of rhizobia to the legume species and adds only 1 to 2 percent to the total cost of the seed. Thus preinoculation of small-seeded legumes is relatively inexpensive insurance against ineffective inoculation. Preinoculated seeds may not be available, however. If this is the case, the traditional planter box mixing of appropriate inoculum with the seed is recommended.

Rhizobia species used with specific small-seeded forage legumes are:

Alfalfa — *Rhizobium meliloti.*

Birdsfoot trefoil — *Rhizobium lupini* (since trefoil is a member of the lupine cross-inoculation group).

Clover — *Rhizobium trifolii.*

Buying Considerations and Handling Recommendations

The proper selection, storage and use of inoculants can have a significant impact on legume yields. The following guidelines should be considered for achieving maximum performance of legumes:

Expiration Dates — All legume inoculants are perishable in time. Responsible manufacturers put expiration dates on their product packages. If an expiration date is missing or outdated, do not purchase the material.

Carrier Type — Peat has consistently been superior to other carriers in maintaining the viability of rhizobia bacteria.

Package Size — Check inoculant packages to see how much material is provided per bushel of seed. Bargain-priced products may provide too little inoculant to properly treat the stated quantity of seed.

Combination Products — Many fungicides and other seed protectants are toxic to inoculant rhizobia bacteria when they are mixed and packaged together. Avoid purchasing premixed products.

Extension Recommendation — Check with your county Extension agricultural agent or state crop specialist for recommendations regarding the type and brand of inoculant best suited to your needs.

On-farm Storage — Store inoculants out of the sun and in the coolest area available. Do not leave inoculants in planting equipment overnight. Follow any special storage intructions provided by the manufacturer.

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