NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

PASTURE AND HAY PLANTING

(Ac.)

CODE 512

DEFINITION

Establishing native or introduced forage species.

PURPOSE

- Establish adapted and compatible species, varieties, or cultivars.
- Improve or maintain livestock nutrition and/or health.
- Extend the length of the grazing season.
- Balance forage supply and demand during periods of low forage production.
- Reduce soil erosion and improve water quality.
- Increase carbon sequestration.

CONDITIONS WHERE PRACTICE APPLIES

This practice may be applied on cropland, pastureland, hayland, and other agricultural land where forage production and/or conservation is needed and feasible.

CRITERIA

General Criteria Applicable to All Purposes

Plant species and their cultivars shall be selected based upon one of the following:

Appendix 1

- Use seed mixtures in *Appendix 1 – Table 1* (Seed Mixtures and Rates per Acre), FOTG Reference, Penn State Agronomy Guide - Recommended Forage Mixtures and Seeding Rates (Table 1.8 – 5). http://agguide.agronomy.psu.edu/cm/sec8/table1-8-5.cfm)
- FOTG Reference Virginia Cooperative Extension Agronomy Handbook – Part II Forage Crops http://www.ext.vt.edu/pubs/agronomy/part2.pdf), Pages 33 and 34.
- FOTG Reference WVU Extension Service Fact Sheet – Forage Species Adapted to the Northeast http://www.caf.wvu.edu/~forage/forglvst/5823.pdf
- Use Soil Treatment *Appendix 1 – Table 2.*

Specified seeding/plant material rates and date of planting shall be consistent with documented guidance in *Table 1 or an approved FOTG Reference*.

Provide a firm, weed free seedbed that ensures seed will contact soil moisture uniformly, facilitate seedling emergence, and provide a medium that does not restrict or allow roots to become dry.

Livestock shall be excluded until the plants are well established.

Cool Season Grasses and Methods of Seeding

Frost Seeding

Frost seeding to establish legumes in pastureland or hayland will follow the procedure

in *Appendix 2 – West Virginia University Extension Service Fact Sheet – Frost and Walk-in Clover Seedings.* (http://www.caf.wvu.edu/~forage/5312.htm)

Conventional Tillage

Plowing and disking should be done deep enough to kill all existing vegetation and to incorporate lime and fertilizer into the top 4 – 6 inches of soil. Any existing rills and gullies should be eliminated and a firm seedbed prepared. The surface should be reasonably smooth, free of ridges, rocks, and other obstructions.

The seeding may be done with a drill, cultipacker-seeder, cyclone seeder, hydro-seeder, or other suitable equipment. The seed should be covered a depth of ¼ to ½ inches in a firm seed bed. A roller or cultipacker will ensure a good seed to soil contact.

No – Till

When stands are to be established by no-till seeding methods, the following requirements must be met:

Eliminate competitive vegetation by heavy grazing, mowing and/or herbicides.* When pure stands of alfalfa are planted, competitive growth must be well controlled.

Undesirable species should be controlled by applying a suitable herbicide at least two weeks before the seeding date.

Insecticides* should be applied to control potential insect infestations. This is especially needed when pure stands of alfalfa are seeded.

Seed must be placed in firm contact with the mineral soil at a depth of ¼ to ½ inches. Depth control bands or other controls should be used to ensure proper placement of seed. ***Packer wheels are essential.***

* *Consult the West Virginia University Extension Service to determine the best pesticide combination and application time.*

Time of Seeding

Cool Season Species

March 15 – April 15

August 15 – September 15

Seed Requirements

All seed and materials shall be labeled and meet state seed quality law standards. *(WV Code – Chapter 19, Article 16)*

Legume seed shall be inoculated with the proper, viable rhizobia before planting. FOTG Reference – Penn State Agronomy Fact Sheet 11 - Inoculation of Forage and Grain Legumes http://cropsoil.psu.edu/extension/facts/agfact11.pdf

Warm Season Grasses and Methods of Seeding

Warn season grass seed requires a cool, moist period prior to germination. This process is known as a stratification period. Most seed may be purchased already stratified. Check with the supplier to determine if any seed will require stratification or specific storage methods prior to planting.

Unstratified seed may be planted in the fall (November 15 – March 1). However, this method is not recommended due to the low success rates, low germination and additional length of time required to establish the stand.

Warm season grasses are measured and usually sold in lbs/acre of Pure Live Seed (PLS). Warm season grasses usually have a lower germination rate than cool season species; therefore, it is essential when purchasing and planting warm season grasses that the quantities of seed will be based on PLS.

Warm season grass establishment in pastureland or hayland will follow the procedure in *Appendix 3 – Penn State University Extension Service Agronomy Fact Sheet – Warm Season Grasses.* http://cropsoil.psu.edu/extension/facts/agfact29.pdf

Conventional Tillage

If using conventional methods, the seedbed should be prepared by disking and/or plowing to a depth of 3 inches. After disking, make at least one pass over the field using a cultipacker to firm the seedbed. Make sure that the seedbed is dry and firm to ensure proper planting depth. Saturated soils should not be cultipacked or planted to avoid getting seed too deep.

Seed may be broadcast if accomplished in a uniform manner. No more than ? of the seed should be visible on the soil surface. Seeding depth should never exceed ¼ inch. A roller or cultipacker should be used to ensure good seed to soil contact.

No – Till

When stands are to be established by no-till seeding methods, the following requirements must be met:

Eliminate competitive vegetation by heavy grazing, mowing and/or herbicides.* When pure stands of warm season grasses are planted, competitive growth must be well controlled.

Undesirable species should be controlled by applying a suitable herbicide* in the fall after the area is grazed or mowed to a very low height. A second herbicide application should be planned where dense fescue or orchard grass stands exist. This application should occur just prior to planting and after any regrowth of surviving vegetation to a height of 4 to 6 inches. All herbicide applications should be performed when vegetation is actively growing.

Smooth seeded species like switchgrass may be planted using a conventional drill.

Species such as little bluestem, big bluestem and Indiangrass require a specialized no-till drill or a modified conventional drill that contains a fluff box. Specialized drills have seed boxes with dividers, agitators and oversized drop tubes and may be adjusted for shallow planting depths.

Regardless of the planting method used, seeding depth should never exceed ¼ inch.

* *Consult the West Virginia University Extension Service to determine the best pesticide combination and application time.*

Time of Seeding

Warm Season

April 1 – May 15

Seed Requirements

All seed and materials shall be labeled and meet state seed quality law standards. *(WV Code – Chapter 19, Article 16)*

Additional criteria for improving or maintaining livestock nutrition and/or health

Establish forage species that are most capable of meeting the desired level of nutrition (quantity and quality) for the kind and class of the livestock to be fed.

Additional criteria for reducing erosion and improving water quality.

Plants shall provide adequate ground cover, canopy cover, and root mass to protect soil against wind and water erosion.

Additional criteria to increase carbon sequestration

For optimal carbon storage, select species that increase site biomass.

Additional Criteria for extending the grazing

Forage species selected for establishment shall fulfill a recognized dietary deficiency within the year long forage management program.

CONSIDERATIONS

In areas frequented by high density of animals, establish persistent species that can tolerate close grazing and trampling.

Where wildlife management is an objective, the food and cover value of the planting can be enhanced by using an approved habitat evaluation procedure to aid in selecting plant species and providing for other habitat requirements necessary to achieve the objective.

PLANS AND SPECIFICATIONS

Specifications for the establishment of pastureland and hayland planting shall be prepared for each site or management unit according to the Criteria, Considerations, and Operations and Maintenance described in this standard, and shall be recorded on specification sheets, job sheets, in narrative statements in the conservation plan, or other acceptable documentation.

The following specifications will be documented in the Conservation Plan and/or the Contract narrative:

- Seed mixture
- Seeding rate
- Lime and Fertilizer requirements
- Method of weed control
- Planting method
- Planting date
- Location and Acres
- O & M

OPERATION AND MAINTENANCE

The operator will inspect and calibrate all planting, spraying, and spreading equipment prior to use to insure proper rates, distribution and depth of planting materials.

Growth of seedlings or sprigs shall be monitored for water stress. Water stress may require reducing weeds, early harvest of any companion crops, irrigating when possible, or replanting failed stands, depending on the severity of drought.

Invasion by undesirable plants shall be controlled by cutting, using a selective herbicide, or by grazing management by manipulating livestock type, stocking rates, density, and duration of stay.

Insects and diseases shall be controlled when an infestation threatens stand survival.

Evaluate forage stands each season or as needed to determine management inputs needed to achieve the desired purpose(s).

Additional O&M for Warm Season Grasses

Control competition and prevent weed seed formation by clipping, or the application of a post-emergent herbicide to control competition during the establishment period.

Do not apply nitrogen during the planting year. This encourages cool season grass and weed competition. Lime may be applied at recommended levels.

REFERENCES

Penn State Agronomy Guide, 2005 - 2006
http://agguide.agronomy.psu.edu/

Virginia Cooperative Extension 2000 Agronomy Handbook
http://www.ext.vt.edu/pubs/agronomy/

WV State Code – Chapter 19 (Agriculture)
http://www.legis.state.wv.us/WVCODE/19/masterfrmFrm.htm

West Virginia University Extension Service Fact Sheet – Frost and Walk-in Clover Seedings
http://www.caf.wvu.edu/~Forage/5312.htm

PASTURELAND AND HAY PLANTING

APPENDIX 1

NHCP, NRCS
June 2002

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TABLE 1

SEED MIXTURES AND RATES PER ACRE

1 Year Hay or Pasture

1.	Red Clover	8 lbs.
	Timothy	4 lbs.
2.	Alsike Clover	4 lbs.
	Timothy	4 lbs.

2 Year Hay or Pasture

3.	Red Clover	6 lbs.
	Alsike Clover	2 lbs.
	Orchardgrass	4 lbs.
4.	Alfalfa	10 lbs.
	Orchardgrass	4 lbs.
5.	Alfalfa	10 lbs.
	Timothy	4 lbs.
6.	Orchard Grass	10 lbs.
7.	Alfalfa	16 lbs.

3 or More Years Hay or Pasture

8.	Alfalfa	10 lbs.
9.	Birdsfoot trefoil	8 lbs.
	Timothy	4 lbs.
10.	Reed Canarygrass	12 lbs.
11.	Birdsfoot Trefoil	8 lbs.
	Orchardgrass	6 lbs.
12.	Birdsfoot Trefoil	8 lbs.*
	Tall Fescue	8 lbs.
13.	Ladino Clover	2 lbs.*
	Tall Fescue	10 lbs.
14.	Tall Fescue	15 lbs.*
15.	Ladino Clover	2 lbs.
	Orchardgrass	8 lbs.
16.	Ladino Clover	2 lbs.

Permanent Pasture

Mixture 9, 10, 11, 12, 13, 14, 15, 16, plus:

17.	Birdsfoot Trefoil	8 lbs.
	or	
	White Clover	2 lbs.
	and	
	Orchardgrass	5 lbs.
	Kentucky Bluegrass	5lbs.
18.	Crownvetch	10 lbs.
19.	Switchgrass	8 lbs.**
20.	Big Bluestem	8 lbs.
21.	Caucasian Bluestem	6 lbs.
22.	Bermudagrass	20 bushel/ac
23.	Frost Seeding	
	Red Clover	4 lbs.
	Ladino Clover	1 lb.
24.	Frost Seeding	
	Birdsfoot Trefoil	6 lbs.

*** Use only endophyte free seed.**

** PLS – Pure live seed.

FROST SEEDING PASTURE AND HAY LAND

APPENDIX 2

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TABLE 2

SOIL TREATMENT

Lime

Lime requirements should be based on a soil test. Lime will be applied to correct pH within the range for each species as follows:

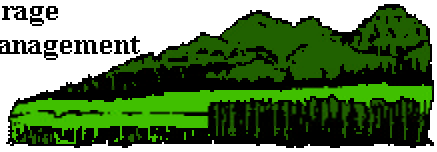
Alfalfa and Birdsfoot trefoil	6.5 – 7.0
All other legumes, smooth bromegrass, bermudagrass, reed canarygrass, orchardgrass, switchgrass, big bluestem, and Caucasian bluestem	6.0 – 7.0

Fertilizer

Apply fertilizer based on results of soil tests made by West Virginia University, other land grant institutions, or competent private laboratories. For general recommendations in the absence of a soil test, use information contained in current Field Office Technical Guide Reference – "The Agronomy Guide, Pennsylvania" or the NRCS Plants Data Base (http://plants.usda.gov) Fact Sheets.

West Virginia University Extension Service

Forage Management



FROST AND WALK-IN CLOVER SEEDINGS

Edward B. Rayburn, Extension Specialist
October 1995

Maintaining legumes in pastures and hay fields is necessary for low cost forage production and to improve forage quality. The key management used to maintain legumes are: soil fertility and pH maintenance, proper harvest management, and occasional reseeding. Reseeding can be by conventional tillage, no-till or low cost frost or walk-in seedings. Frost seedings have been used for decades, are inexpensive and when done at the correct time and managed properly very successful. Frost seedings should be made between late January and late February when there is little snow and frost action is honey-combing the soil surface.

Frost seedings are a good means of establishing clovers in pastures and hay meadows. The preferred management is to start preparing the site the summer before. Take soil tests and apply lime, phosphorus, and potassium as needed. A good liming and fertilizer program should keep your soil test in the top two inches of the soil at a pH above 6.0, P above 50, and K above 120, based on the WVU soil test. If your soil test is lower than these values, make sure to apply the recommended fertilizer and lime.

In most cases good rotational grazing will control most weeds and minimize the need for herbicides for weed control. In the fall, graze the pasture or hay field to remove excess forage growth. Spread the seed during the winter when freezing and thawing of the ground is producing frost action with ice crystals coming out of the ground. This is usually between late January and late February when the snow is off the ground.

If you plan to over-seed every year apply 2 lb. red clover seed/a/yr. Some producers like to double this to 4 lb./ac. on meadows. Since red clover is a biannual, meaning it lives for two years, you can seed every other year. In such a case you may want to increase the seeding rate up to 4 lb./ac. on pasture and 8 lb./ac. on meadows. Consider adding 1 lb. of ladino clover seed/a when seeding pastures or hayfield. Ladino clover is a perennial and longer lived than red clover when managed under proper rotational grazing. Annual lespedeza (10-15 lb/a) and birdsfoot trefoil (4-8 lb/a) can also be seeded using a frost seeding.

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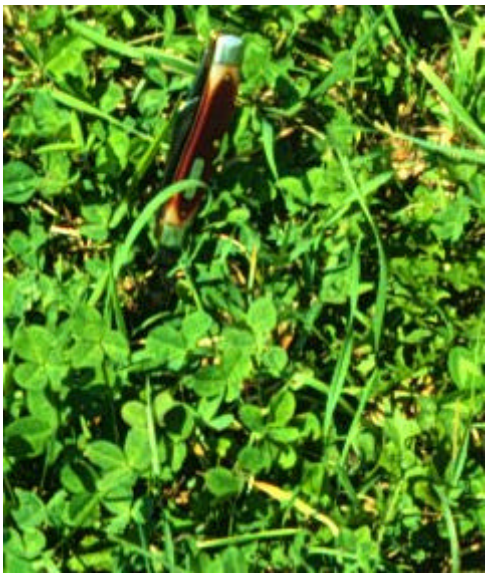
As with any seeding the important points are: test and adjust soil fertility and pH, identify and control competing vegetation, prepare a good seed bed, use high quality seed of a known variety, seed at an adequate seeding rate, cover seed to a proper planting depth, and ensure good seed to soil contact. In frost seedings we are using livestock and frost action to control the competing vegetation, prepare the seed bed, cover the seeds, and provide seed to soil contact. If there is not sufficient frost action after applying the seed, allow your cattle to walk the pastures to tread the seed into the soil surface. Only do this when the soil is firm so that the cattle will not punch the soil and push the seed too deep into the soil.

To maintain the legume in the stand continue to properly manage soil fertility and harvest timing and intensity. The management needed to maintain legumes in your pastures and hay fields will pay off. Legumes will supply nitrogen to the grass to maintain yields. This reduces the cost per ton of forage produced. Legumes improve the quality of forage by allowing cattle to eat more forage. They then need less high priced protein and energy supplements. The net return is an increase in the dollars available per cow after paying for feeding the cow.

Clover Seedlings emerging after germination of a frost seeding.

Red clover established in a pasture by frost seeding.



Clover plants a year after being established by a spring walk-in seeding.

A grass clover pasture where clovers were established by a spring walk-in seeding.

Second cutting clover-grass hay the year after an August walk-in red clover seeding.

WARM SEASON GRASS ESTABLISHMENT AND MANAGEMENT

APPENDIX 3

http://cropsoil.psu.edu/extension/facts/agfact29.pdf

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APPENDIX 4

INNOCULATION

AGRONOMY FACTS 11

Inoculation of Forage and Grain Legumes

Department of Crop and Soil Sciences - Cooperative Extension

Legumes have the ability to form a mutually beneficial (symbiotic) relationship with certain soil bacteria of th type or "genus" *Rhizobia*. The benefit to the plant, and thus to the grower, is that these bacteria can take (fix) nitrogen from the air (in soil spaces) and make it available to the plant (see Symbiotic Nitrogen Fixation, page 3). The amount of nitrogen fixed can meet the needs of the plant and leave nitrogen in the soil for following crops.

Species specific inoculation

The genus *Rhizobia* is divided into various species and subdivided into multiple strains. *Rhizobia* bacteria are fairly specific as to which legumes they will infect, form nodules on the roots of, and for which they will fix nitrogen. Legumes effectively nodulated by the same *Rhizobia* species are termed cross-inoculation groups. (Table 1). The specific bacteria to nodulate the legume you are planting may be present in the soil, espcially if that legume has been previously grown in the same field. However, to ensure the availability of the correct species and an effective strain of that species, inoculation - adding the bacteria - is practiced. Inoculation is recommended when the legume being planted has not been grown in that field in the past three years or with every planting of a high value crop. Because inoculant is inexpensive and easy to apply, it is good insurance of proper nodulation and nitrogen availability. But be sure to buy an inoculant specific for the legume you are planting.

Table 1. Cross-inoculation groups of legumes and *Rhizobia*.

Legume group	**Inoculant group***	***Rhizobia* species**
Alfalfa and sweetclover	A	*R. meliloti*
True clovers	B	*R. trifolii*
Peas and vetch (true)	C	*R. leguminosarum*
Soybean	S	*R. japonicum*
Birdsfoot trefoil	K	*R. loti*
Crownvetch	M	*R. spp.*

*Letters indicate manufacturer's reference to cross-inoculation groups.

Inoculum is not magic dust - it contains bacteria that must be kept alive. All packages of inoculum have an expiration date. After this date, the bacteria may not be alive and the inoculum should not be bought or used. Heat and direct sunlight kill bacteria in stored inoculum, even while packaged. Since a short period of heat can reduce the number of live *Rhizobia*, the package should be kept in a cool place and out of direct sunlight - even when taking it home from the store (keep it off the dashboard). The preferred storage place for inoculum is the refrigerator (do not freeze).

Live bacteria may be added to the soil (direct-soil application) or to the seed (seed-applied inoculant).

Direct-soil application

Granular forms of inoculum may be placed in the seed row via the insecticide box of a planter or through the fertilizer or grass seed box of a drill. (Clean the box before inoculum is placed in it.) The granules flow freely through field planting equipment, and their flow should be calibrated and metered.

Frozen concentrated liquid cultures of inoculant may be diluted to a slurry, then added to a water-filled tank for spray application into the seed row.

Inoculant should not be mixed with either pesticide or fertilizer if applied to the seed row. When seeding forage legumes, it is recommended that fertilizer be applied seperately.

Application of inoculant directly to the soil has been quite effective. However, the greater surface area being covered by the inoculant requires more of the material. This is especially the case when narrow-row soybean planting is practiced. Therefore, the method is more expensive than seed inoculation.

Seed-applied inoculant

Inoculum to be mixed with seed before planting is available on a variety of carriers; the most common carrier is peat. Peat has proven to be better than most other carriers in preserving live bacteria under unfavorable conditions (high temperatures, late planting).

Inoculating seed. When inoculating seed, two conditions must be satisfied to get good nodulation: (1) the roots must be in contact with the *Rhizobia* bacteria, and (2) the *Rhizobia* must be alive and able to infect the plant root.

For the bacteria to be in contact with the roots of every plant, inoculum should cover each seed. To achieve the best distribution, the inoculum should be mixed with seed in a large space rather than in a planter seedbox - on a tarp-covered floor, in a tub, in a cement mixer (paddles removed), or in the bed of a pickup.

Using an adhesive (a "sticker") helps the inoculant to adhere to each seed. This is especially important with small-seeded forage legumes, which need more inoculant per unit of seed-surface area. Table 2 shows the advantage, in number of nodules formed, of using a sticker during inoculation. Both commercial and homemade stickers are effective. A homemade sticker can be prepared as a 1-in-10 dilution of syrup or molasses, diluted cola or milk can be used.

Table 2. Effect of inoculant and use of sticker on soybean root nodulation.

Treatment	Nodules per plant
Source: University of Kentucky.	
No inoculant	0
Inoculant, no sticker	0.8
Inoculant, plus commercial sticker	2.7
Inoculant, plus sugar sticker	2.7

Mix seed with enough sticker to just moisten all seeds. Too much liquid may cause premature germination of the seed. To the moistened seed add inoculant and mix to coat the seeds. Air dry by spreading the coated seed in the shade. Drying may be speeded by adding additional peat-based inoculant or finely ground limestone. The seed must be dry to flow properly through the planter. Calibrate the seeder with inoculated seed when setting desired seeding rate. Seed should be planted as soon as possible after inoculation because bacteria begin to die in the drying process. If not planted within 24 hours, reinoculate.

The rate of inoculant to use depends on the amount of time elapsed since the legume was last grown in that field and on the conditions for bacteria survival at the time of and on the conditions for bacteria survival at the time of planting. Start with the manufacturers recommendations. If the soil is dry and germination of the seed is expected to be delayed, then a higher rate of inoculant is required to make up for loss of some *Rhizobia*. For soybeans being planted into a new field, three times the normal rate of inoculant is recommended. A good way to achieve this is to moisten the seed with liquid inoculant applied at the normal rate, then mix seed with twice the normal rate of peat-based inoculant.

Preinoculated seed. Forage seed may be purchased already inoculated. One of two methods of preinoculation is generally used: (1) impregnation of *Rhizobia* by a vacuum process or (2) pelleting with fine limestone. The pelleted type of preinoculated seed is generally preferred on the basis of research that shows that bacteria live longer on the pelleted seed and that this type of preinoculated seed results in formation of a greater number of root nodules.

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Preinoculated seed should be handled in the same way as packaged inoculum. Several precautions can ensure better results. Check for an expiration date on the seedbag tag, store and transport the seed out of direct sunlight and heat, and plant the seed as soon as possible. If you believe that bacteria may have died, then reinoculate the seed. Since water or the sticking solution causes the lime content of pelleted seed to gum up, use mineral oil (0.5 to 1.0 of oil per lb. of seed) to adhere new inoculum to seed. Plant immediately.

Other factors affecting nitrogen fixation

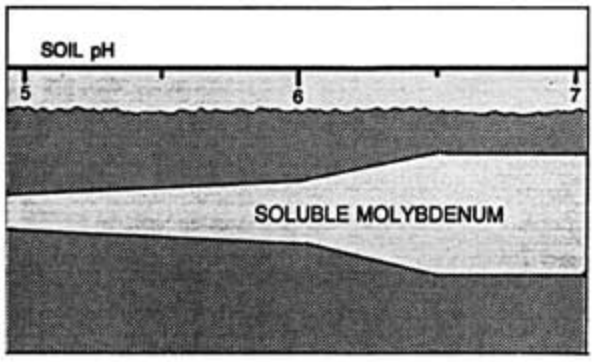

Figure 1. The relationship of soil pH and molybdenum availability. (The width of the band indicates the relative amounts of soluable molybdenum in the soil solution as influenced by pH).

Rhizobia bacteria require the availability of molybdenum (Mo), a soil element. In Pennsylvania, Mo is generally present in soils in sufficient quantity, but its availability is affected greatly by the soil pH (Figure 1). Soil into which a legume is being planted should be limed to raise the pH to between 6.5 and 7.0.

Some inoculants or preinoculated seed may be soil with combinations of Mo and or a fungicide. These additional treatments tend to reduce the number of live *Rhizobia* and generally are not recommended.

When establishing forage legumes, 20 pounds of nitrogen per acre is often recommended as a starter application. However, if conditions at planting are favorable for quick seed germination and seed has been inoculated, this starter nitrogen fertilizer is often unnecessary.

Do not apply nitrogen fertilizer to established legumes. Legumes can fix all the nitrogen they need for growth. Research has shown that nitrogen fertilizer does not increase yield of established legumes if the plants are effectively nodulated. In fact, fetilizer nitrogen discourages nodulation and inhibits nitrogen fixation.

SYMBIOTIC NITROGEN FIXATION

Air is almost 80 percent nitrogen (N). Although air-supplied nitrogen is the primary source of N for the fertilizer industry, as well as the source used by legumes, it does not come free. Nitrogen in air exists as two N atoms that are triple-bonded together; in effect, the atoms are glued, stapled, and taped together, not to be undone without a great expenditure of energy.

In the industrial (Haber) process, petroleum energy is used to break the triple bond, and three hydrogen ions from natural gas or another petroleum product are added to each N atom. Therefore, N fertilizer prices increase as energy prices rise.

In symbiotic N fixation, as is the case with legumes, these same steps are required of the *Rhizobia* bacteria. Sugars or carbohydrates of a legume infected with *Rhizobia* are the energy and hydrogen source used by the bacteria to fix N from the air at high energy costs to the plant. If the plant can avoid these costs by taking up N from the soill, it will. Therefore, N fertilization inhibits nodule formation and N fixation.

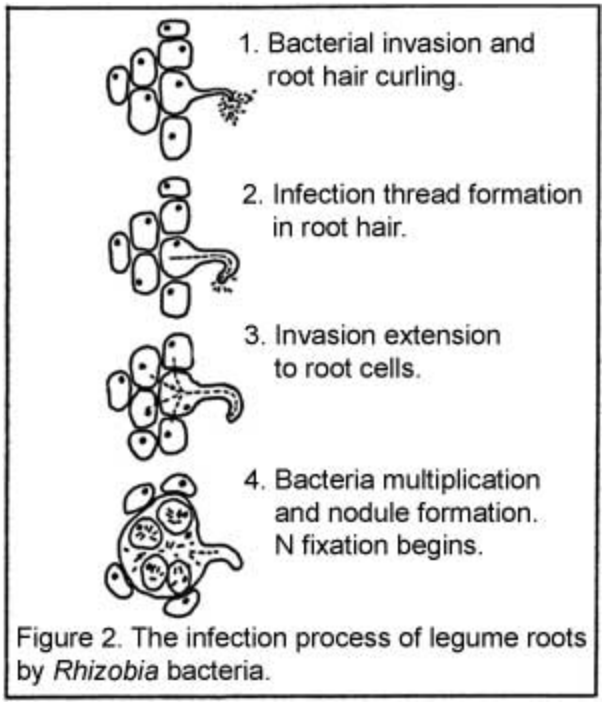

Figure 2. The infection process of legume roots by *Rhizobia* bacteria.

Infection by the *Rhizobia* bacteria is somewhat similar to an infection in the body. The bacteria enter through a susceptible location, travel inward, establish themselves, and multiply (Figure 2). In the case of legumes, the bacteria are welcome as long as they are of a certain species that the plant somehow recognizes. Infection enters through a root hair, then grows back to the base of the root hair. Multiplication of the bacteria and enlargement of the root cells form a nodule.

Inside the nodule, an enzyme called nitrogenase drives the N fixation reaction. Similar to the catalyst used in the industrial process, the enzyme also contains molybdenum (Mo). Therefore, availability of this element in the soil is important to the legume. Nitrogenase is peculiar in that contact with oxygen ruins the enzyme. The bacteria and the plant are faced with an engineering problem: how to get the nitrogen out of air that also contains oxygen. A sophisticated system to accomplish this involves a protein called leghemoglobin that is capable of binding to oxygen and removing it from the presence of nitrogenase. Leghemoglobin, like the protein hemoglobin in our blood, binds to and transports oxygen. The combination with oxygen makes both blood and the inside of an oxygen-free nodule red or pink, which is why these colors indicate an active N-fixing nodule.

Fixed N is used in the plant to make amino acids, the building blocks of proteins. The amount of N that is fixed depends on many factors that include the specific legume and the health of the plant. Because the *Rhizobia* rely on the plant to supply carbohydrate, maintaining a healthy stand fosters N fixation. The majority of the N fixed is removed with the crop; however, residual N is often available to the next crop. That residual N reduces the requirement for applied N. Table 3 lists the amounts of N that may be available to the crop that follows various legumes.

Table 3. Residual nitrogen contributions from legumes.

Source: 1985-86 Penn State Agronomy Guide.

Alfalfa	
First year after alfalfa	
50% - 75% stand	110 lb/A
25% - 49% stand	80 lb/A
<25% stand	40 lb/A
Second year after alfalfa	
50% - 75% stand	50 lb/A
Red clover and trefoil	
First year after clover or trefoil	
25% - 75% stand<	40 lb/A
Soybeans	
First year after soybeans harvested for grain	40 lb/A

Figure 3. Distribution of nodules on seedling and and established legume roots.

Checking roots for effective nodulation

To check for effective nodulation two to four weeks after germination, carefully dig around and remove several plants. Then wash the roots in a bucket of water. Look for nodules and examine their distribution. Effective nodules generally are clustered around the taproot (Figure 3). Slice and observe the interior of several nodules. Nodules that have been actively fixing nitrogen have a red or pink interior. Nodules with white or pale-green interiors are ineffective.

Emergency inoculation

If the lack of effective nodulation on a newly seeded crop is known or feared, then inoculant can be applied to the crop in the field. Nodulation deficiencies can be corrected, although not entirely overcome, by salvage (emergency) inoculation up to four weeks after seedling emergence. The grower may use one of several techniques and expect equal results. Rate of application of actual inoculant should be in the range of 1 1/4 to 1 3/4 pounds per acre regardless of the application method. The methods are:

1. Drilled application of a granular peat-based inoculant 1 inch deep.

2. Drilled application of inoculated sand. In this case, you need to inoculate sand just as you would seed, and to use a sticker. Inoculate an amount of sand for an application rate of between 60 and 90 pounds per acre and drill 1-inch deep.

3. Sprayed application of a water-inoculum suspension. Prepare the treatment by combining powdered peat-base inoculant with about a quart of water and shaking to ensure adequate saturation. After seiving to remove large peat particles, add this suspension to a water-filled sprayer tank. Remove nozzle screens and spray uniformly over soil surface. Application by this method should be made only on cloudy day just before rain is expected or irrigation is scheduled.

If the crop was fall-seeded and if cold weather has set in, then salvage inoculation should be delayed until early spring when the soil is warmer.

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Issued in furtherance of Cooperative Extension Work, Acts of Congress May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture and the Pennsylvania Legislature. L.F. Hood, Director of Cooperative Extension, The Pennsylvania State University.

This publication is available in alternative media on request.

File No. IVC2 R2M495ps U.Ed. 86-476

NHCP, NRCS
June 2002

NRCS, WV
January 2006