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LEGUME INOCULATION

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GUIDE TO SUCCESSFUL INOCULATION

- When ordering bacterial culture always state name of legume to be inoculated.
- Use culture within the recommended "safe" period.
- Inoculate seed just before sowing.
- If inoculated seed must be stored it is a wise precaution to inoculate again just before sowing.
- Sow into moist soil.
- If seed has been treated with copper or mercury dusts it is best to apply the inoculum separately by means of a carrier such as sawdust or vermiculite.
- Acid soils should be treated with lime before inoculated seed is sown.
- Application of inoculum to seed treated with a weak syrup solution gives good results and is recommended especially for bird's-foot trefoil.
- When inoculating bird's-foot trefoil seed, add two to three times the amount of inoculum suggested on the container.

Cover photo:

A well-nodulated root of alfalfa.

LEGUME INOCULATION

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Legumes differ from other plants in being able to convert nitrogen from the air into a form that is available for their growth. They play a major role in helping us to conserve our supplies of soil nitrogen and are, therefore, of great importance to agriculture.

All plants must have a certain amount of nitrogen if they are to grow satisfactorily. Most agricultural plants, including grasses, cereals and root crops, can use only the nitrogen that is in the soil. If these crops are continually grown on the same soil, sooner or later they will use up all the available nitrogen and will suffer from nitrogen deficiency unless nitrogen-containing fertilizers are applied.

Plants of the legume family do not have to depend entirely on the supply of nitrogen in the soil. Crops such as red clover, white clover, sweet clover, alfalfa, bird's-foot trefoil, peas, beans, vetches, lupines and sainfoin have the special ability to use nitrogen from the air. The process by which legumes can make use of atmospheric nitrogen is called nitrogen fixation. The plants are said to "fix" nitrogen.

The nitrogen in air occurs as a gas in a pure form and is often referred to as "free" nitrogen. It is estimated that about 35,000 tons of nitrogen are contained in the air above each acre of land. This nitrogen is continually replenished as it is used up, so that the supply remains quite constant.

LEGUMES REQUIRE BACTERIA

In order to make use of the nitrogen in the air, legumes require the cooperation of certain bacteria. Without the proper bacteria they, like nonlegumes, are forced to depend on soil nitrogen.

The bacteria, known as *Rhizobium,* penetrates the root hairs of legumes where they grow and multiply and stimulate the roots to produce small tubercles or nodules. It is in these nodules that free nitrogen is "fixed" into usable form. Nodules vary in size and shape, and can be seen easily when a legume plant is carefully dug up and the soil washed from its roots (see cover picture).

Nitrogen-fixing bacteria and legumes form a partnership for their mutual benefit. The legumes depend on the bacteria to help them fix nitrogen, and the bacteria persist in large numbers only when legumes are included in the rotation. When a legume dies, the nodule bacteria return to the soil where they stay until they find another suitable crop to invade. Without a suitable host crop the bacteria decrease in numbers, particularly in acid soils. After a few years they may be so scarce that successful invasion of a crop may not be possible unless their numbers are reinforced with an artificial inoculation of bacteria. Inoculation is generally accomplished by applying commercially prepared bacterial cultures to legume seed.

DIFFERENT TYPES OF LEGUME BACTERIA

Although the bacteria associated with the various kinds of legumes are closely related, different types have become so adapted to certain species that they are unable to produce nodules on other species. Therefore, when a certain legume crop is to be inoculated it is very important to use the right type of bacterial culture. The alfalfa bacteria, for instance, are able to produce nodules on sweet clover as well as on alfalfa, but cannot do so on the common clovers, peas or beans. Pea bacteria are useless for alfalfa, clovers or beans, but are adaptable to most vetches.

For practical purposes the legumes common to agriculture are classified in groups, which are often referred to as "cross-inoculation" groups. Each group is made up of those legumes that are nodulated by the same type of bacteria.

The legume crops found under cultivation in Canada can be grouped as follows.

- Alfalfa, white and yellow sweet clover
- Common clovers: red, white, alsike and zigzag
- Field and garden peas, sweet peas and most vetches, including common and hairy vetch
- Field and garden beans
- Soybeans
- Lupines
- Bird's foot trefoil
- Sainfoin
- Crown vetch

The bacteria that are able to nodulate legumes in any one "cross-inoculation" group vary considerably in the benefit they bring to the plants. Some strains are very efficient in fixing nitrogen for their host plants, whereas others are of little or no value. The presence of nodules, therefore, is in itself no guarantee of nitrogen fixation, as it is important that the strain of bacteria living in the roots be of high nitrogen-fixing capacity. In general, good-sized nodules located on or near a taproot indicate more effective nitrogen fixation than small nodules scattered over a whole root system.

NEED FOR INOCULATION

It is apparent that legumes can make use of the free nitrogen in the air only when the soil contains efficient strains of nodule bacteria, suited to the cross-inoculation group to which the particular legume belongs. Where the soil cannot meet these requirements it is advisable to add the bacteria or, in other words, to inoculate.

Unfortunately, there are no simple soil tests that detect the presence or absence of the proper bacteria. However, there are a number of general rules that can be used as a good guide as to whether or not to inoculate. For instance, when legumes are seeded under one or more of the following five conditions, inoculation can be considered essential.

(1) Where soil acidity is a problem. (See also "Precautions" at the end).

(2) Where lack of good drainage is a problem. Poorly drained soils are generally unfavorable to both nodule bacteria and legumes.

(3) Where previous crops of the legume to be grown have been unsuccessful.

(4) Where virgin soils have been recently cleared or broken, and brought under cultivation.

(5) When neither the legume to be grown nor others of the same cross-inoculation group have been grown previously.

Under conditions such as those listed above, nodule bacteria are likely to be in such small supply as to be of little if any value to a legume so that a crop has to depend mainly on soil nitrogen. If the soil is low in available nitrogen, a poor yield or even a crop failure may result. If the soil is rich in available nitrogen the legume will yield relatively well, simply by drawing heavily on the soil nitrogen. In such a case there is still a definite need for inoculation, as introduction of nodule bacteria may allow the crop to obtain at least part of its nitrogen from the air and thus lessen the drain on the soil.

As a pasture forage, bird's-foot trefoil is gaining in popularity in some parts of Canada. However, difficulties have been experienced in getting it to nodulate properly in many areas and for this reason it is given special mention here. Unless care is taken to inoculate this crop properly whenever it is sown, poor establishment and low yields are likely to result.

Other situations exist where inoculation is advisable even though the need for it may not be acute. For instance, inoculation is recommended when a legume is to be cultivated after it or other members of the same cross-inoculation group have not been grown for several years. This is more likely to be true on soils with a coarse structure, as shown by recent work in Australia where nodule bacteria have been found to die out more quickly in coarse-textured than in fine-textured soils.

Even when the soil appears to have sufficient bacteria to produce nodules on plants, inoculation may be of some benefit by introducing a strain of bacteria that is more efficient than that already present in the soil. Inoculation may be especially helpful in infertile and slightly acid soils where plants, though well nodulated, do not produce a good crop. Reinoculation has been successful not only for alfalfa but also for clovers and peas, the bacteria of which are supposed to be more generally distributed in Canadian soils.

An unusual situation appears to exist in many parts of Saskatchewan where difficulty has been experienced in demonstrating any response to inoculation in alfalfa. The reason for this remains somewhat obscure and requires further investigation. However, dust storms are not uncommon in the province and it seems likely that soil particles, which are blown great distances in these storms, act as carriers for the nodule bacteria. This, together with the low acidity and fine texture of the soils in Saskatchewan, may account, at least in part, for the lack of response of alfalfa to inoculation.

METHOD OF INOCULATION

Inoculate by coating legume seed with a prepared culture of the required strain of nodule bacteria. The cultures exist in various forms but most commonly the commercial types available in Canada have nodule bacteria mixed in with finely ground peat. The mixture is packed in an airtight container and sold in amounts sufficient to treat one bushel of seed or less. Such cultures are sold by seed houses under various trade names. Always state the legume crop to be inoculated when ordering a culture.

Several companies now produce a "mixed" culture made up of bacteria from two different cross-inoculation groups. This culture serves a dual purpose in that it is suitable for inoculating the common clovers as well as alfalfa and sweet clover, but it is of no value for any of the other legume groups.

Inoculation of legume seed with a peat culture can be done successfully by the "syrup" method. In this method the seed should first be mixed thoroughly with a slightly sticky liquid which, on drying, will help the peat particles stick to the seed. A suitable liquid can be made by dissolving two tablespoons of corn syrup in a quart of warm water.

Add only just enough liquid to dampen the seed. As a rough guide, about 1½ pints of solution is sufficient for 60 pounds of small seed such as alfalfa or clover, and ½ pint for 60 pounds of large seed such as peas or beans.

Next sprinkle the powdered inoculant over the moistened seed and combine it thoroughly so that all clumps are broken and each seed bears traces of inoculum. When inoculating bird's-foot trefoil, two to three times the amount of inoculant suggested on the container should be added.

As soon as the seed is dry, sow it without delay. Seed dries quickly, especially if it is turned occasionally. The seed should not be allowed to dry in direct sunlight as this will kill the bacteria.

Of a number of methods of applying inoculant tested at the University of Guelph, the syrup method described above has proved by far the most successful for bird's-foot trefoil. In fact, it is the only procedure recommended in Ontario for inoculating this legume.

Different methods of inoculation, as described on culture containers, may be used for legume seed other than bird's-foot trefoil. If for any reason peat cultures are used dry, mix two or three times the normal amount of culture with the seed.

PRECAUTIONS

Remember that nodule bacteria, such as those found in a commercial culture, are living organisms. Take the following precautions to ensure that the bacteria survive.

Care of Bacterial Cultures

Containers for bacterial cultures are marked with an expiry date. Use the culture before that date, as the number of bacteria may decrease rapidly at the end of the "safe" period.

If a culture is to be stored before it is used, place it in a refrigerator but not in the freezing unit. If no refrigeration is available, store in a cool, dark place away from direct sunlight.

Care of Inoculated Seed

It is important to sow legume seed as soon after inoculation as possible. On occasion, if seeding is delayed by rain or a breakdown, the seed may be stored in a bag in a cool, dark place for a few days. If extra culture is readily available, however, the wisest plan is to reinoculate just before seeding gets under way again.

Treatment of Acid Soils

Many soils in the more humid areas of Canada are too acid for nodule bacteria to survive for long periods and lime must be applied before beneficial effects will result from inoculation. Further information on the treatment of acid soils can be obtained from Canada Department of Agriculture Publication 869, *Lime and Other Soil Amendments.*

Very acid soils require not only the addition of lime but also the trace element molybdenum. This element must be applied to the soil in very small amounts and only at the direction of an expert.

Effect of Seed Disinfectants on Nodule Bacteria

Seed disinfectants in the form of copper or organic mercury dusts are particularly harmful to nodule bacteria. For this reason seed that has been chemically treated with materials of this type to prevent disease should not be inoculated. Under these circumstances it is advisable to add the legume culture to sawdust or vermiculite or other inert material to provide sufficient bulk. You should then drill the mixture into the soil before seeding.

Recent findings indicate that some other types of seed disinfectants which contain no copper or organic mercury are less harmful to nodule bacteria. Legume seed may be inoculated after treatment with this type of disinfectant, but use two or three times the usual amount of bacterial culture. It is most important to apply the bacterial culture immediately before planting. If it should become necessary to store disinfected seed that has been inoculated for even a short period, it is recommended that the seed be reinoculated just before seeding gets under way again.

Nodule Bacteria Need Moisture

For best results, sow inoculated seed in a moist seedbed at the recommended seeding depth. Serious losses in the number of bacteria are likely to occur if inoculated seed is left suspended in dry soil. If inoculated seed is broadcast it should be harrowed or otherwise covered as soon as possible.

Attention to Other Legume Requirements

Although inoculation sometimes means the difference between success and failure, remember that it is but one factor in successful legume production. An inoculated crop requires the same careful seed selection and preparation of the seedbed as an uninoculated crop. Furthermore, the nodules that are produced on legume roots in association with bacteria can provide plants with nitrogen only. All other nutrients necessary for legume growth must be in sufficient supply in the soil or even the best of bacterial cultures will be of little value.

CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in:	
LINEAR			
inch	x 25	**millimetre**	**(mm)**
foot	x 30	**centimetre**	**(cm)**
yard	x 0.9	**metre**	**(m)**
mile	x 1.6	**kilometre**	**(km)**
AREA			
square inch	x 6.5	**square centimetre**	**(cm^2)**
square foot	x 0.09	**square metre**	**(m^2)**
acre	x 0.40	**hectare**	**(ha)**
VOLUME			
cubic inch	x 16	**cubic centimetre**	**(cm^3)**
cubic foot	x 28	**cubic decimetre**	**(dm^3)**
cubic yard	x 0.8	**cubic metre**	**(m^3)**
fluid ounce	x 28	**millilitre**	**(mℓ)**
pint	x 0.57	**litre**	**(ℓ)**
quart	x 1.1	**litre**	**(ℓ)**
gallon	x 4.5	**litre**	**(ℓ)**
bushel	x 0.36	**hectolitre**	**(hℓ)**
WEIGHT			
ounce	x 28	**gram**	**(g)**
pound	x 0.45	**kilogram**	**(kg)**
short ton (2000 lb)	x 0.9	**tonne**	**(t)**
TEMPERATURE			
degree fahrenheit	°F-32 x 0.56 (or °F-32 x 5/9)	**degree Celsius**	**(°C)**
PRESSURE			
pounds per square inch	x 6.9	**kilopascal**	**(kPa)**
POWER			
horsepower	x 746	**watt**	**(W)**
	x 0.75	**kilowatt**	**(kW)**
SPEED			
feet per second	x 0.30	**metres per second**	**(m/s)**
miles per hour	x 1.6	**kilometres per hour**	**(km/h)**
AGRICULTURE			
bushels per acre	x 0.90	**hectolitres per hectare**	**(hℓ/ha)**
gallons per acre	x 11.23	**litres per hectare**	**(ℓ/ha)**
quarts per acre	x 2.8	**litres per hectare**	**(ℓ/ha)**
pints per acre	x 1.4	**litres per hectare**	**(ℓ/ha)**
fluid ounces per acre	x 70	**millilitres per hectare**	**(mℓ/ha)**
tons per acre	x 2.24	**tonnes per hectare**	**(t/ha)**
pounds per acre	x 1.12	**kilograms per hectare**	**(kg/ha)**
ounces per acre	x 70	**grams per hectare**	**(g/ha)**
plants per acre	x 2.47	**plants per hectare**	**(plants/ha)**

Examples: 2 miles x 1.6 = 3.2 km; 15 bu/ac x 0.90 = 13.5 hℓ/ha

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