
# LEGUME INOCULATION

FOR many centuries it has been recognized that plants belonging to the legume family differ in a striking fashion from other cultivated plants in the effect of the crop growth on the state of fertility of the soil. The custom of including a legume crop in the rotation has been based upon observations, made in early times, that the productivity of the soil is better following a good growth of legumes—beans, peas, clovers, vetches, alfalfa, etc.—than after a non-leguminous crop. The ability of legumes to enrich the soil was known to early Greek, Roman and Chinese farmers, who found that they could keep on cropping the same land if they rotated their crops and included legumes.

It was not until the latter half of the nineteenth century, however, that the explanation of the difference between legumes and non-legumes was found. It concerns the manner in which these two groups of plants obtain their supply of nitrogen. Whereas all non-legumes are dependent upon the supply of nitrogen in the soil, legumes are able to draw on the unlimited quantity of this element in the air. Four-fifths of the air consists of nitrogen; and legumes, by making use of this supply, which is quite unavailable to other plants, are able to conserve in a large measure the supply of this element in the soil. Not only this: the nitrogen in the soil may be noticeably increased by growth of a legume crop if the nitrogen so gained is returned to the soil, either by ploughing under or by returning the manure after the crop is fed to animals. A good crop of legumes turned under may add to the soil 40 to 100 lb. or more of nitrogen per acre.

### Legumes Require Bacteria

About fifty years ago it was found that in order to make use of the nitrogen of the air, legumes require the co-operation of bacteria, and that without the proper bacteria they are forced, like non-legumes, to depend upon the nitrogen in the soil. These useful nitrogen-gathering bacteria, if present in the soil, enter the roots of the legumes, where they grow and multiply, stimulating the root to grow a small knot or tubercle, commonly called a nodule, at the point where they enter. Nodules vary in size, shape and location and may be readily recognized when an inoculated legume plant is carefully dug up and the roots washed free from soil. (*See* Fig. 1.)

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FIG. 1.—Nodules on root of young pea plant (left) and young bean plant (right).

It is inside the nodules that the bacteria perform their work, forming a partnership with the plant for their mutual benefit. When the legume dies, the nodule bacteria return to the soil, where they remain ready to reinfect the next crop. Without a suitable crop plant, the bacteria decrease in numbers, particularly in acid soil, and after a few years may be so scarce that successful re-infection of a crop may not be possible without reinforcements in the form of inoculation.

## Varieties of Legume Bacteria

Although the bacteria associated with the various kinds of legumes are closely related, different varieties have become so adapted to certain plants or groups of plants that they are unable to produce nodules on other kinds of legumes. The alfalfa bacteria, for instance, are able to produce nodules on sweet clover as well as alfalfa, but cannot do so on the common clovers, or on peas or beans. Pea bacteria are useless for alfalfa, clovers or beans, but are adaptable to vetches. It is therefore important to know, when using a culture, just what legumes may be inoculated. The extent to which bacteria are able to infect legumes has been worked out, and the following groups indicate the practicable limits of "cross-inoculation" for the more common legume crops:

1. Alfalfa, white and yellow sweet clover.
2. Red, white, mammoth, altaswede and alsike clover.
3. Peas, vetches, sweet peas.
4. Garden and field beans.
5. Soybeans.
6. Cowpeas, lespedeza.
7. Lupines and serradella.

Not all cultures of legume bacteria of the same "cross-inoculation" group are alike in the benefit they bring to the plant. Some strains may be very efficient in gathering or "fixing" nitrogen for the host plant, while others may be of little or indeed no value. The presence of nodules, therefore, is in itself no definite guarantee of nitrogen fixation. It is of importance that the strain of bacteria infecting the root be of high nitrogen-fixing capacity.

## Inoculating With the Proper Bacteria

If legumes, therefore, are to benefit from the supply of nitrogen in the air, it is necessary for the soil to contain a sufficient supply of an efficient strain suitable to the group to which the legume being cultivated belongs. Where the soil does not contain them, it is advisable to add the bacteria, or in other words, to inoculate. While there is no simple soil test for the presence of the proper bacteria, there are certain circumstances which indicate whether inoculation is required.

When neither the crop being grown nor others of the same cross-inoculation group have been previously cultivated, inoculation is strongly recommended. This is specially the case with alfalfa, sweet clover, soybeans and lupines. Furthermore, if previous crops have been unsuccessful, with roots showing none or but a few nodules, inoculation is well advised, especially if soil and climate are otherwise favourable to the crop. Legumes may often thrive well without root-nodules on soils of more-than-usual fertility. Under such conditions the crop is drawing its nitrogen wholly from the soil and depleting that supply like non-legumes. In such cases inoculation may allow the crop to obtain part of its nitrogen from the air and thus lessen the drain on this plant food from the soil.

Inoculation is advisable when a legume is grown after a lapse of several years, for the proper bacteria may have almost or completely died out. Badly drained and acid soils are unfavourable both to bacteria and legume, while a hot dry soil also hastens the disappearance of the bacteria.

Even when the soil appears to have sufficient bacteria to produce nodules on the plant, inoculation may be of benefit by the introduction of a strain of bacteria more efficient than that already present in the soil. This may be specially noted in less fertile and slightly acid soils where the plants, though well nodulated, do not produce a good crop. Re-inoculation has been successful, not only for alfalfa, but also for clovers and peas, the bacteria for which are supposed to be more generally distributed in Canadian soils.

## Methods of Inoculation

There are two general methods of inoculation: (1) the transfer of soil from an old-established field growing the same crop, and (2) the addition of pure cultures of bacteria to the seed.

*The soil-transfer method* consists in scattering soil on the new field at the rate of 200 to 500 pounds per acre, using only soil taken to a depth of five or six inches from an old field. This method is at best cumbersome and often expensive, while there is the risk of adding weed seeds and spreading insects and plant disease. However, in many cases it may be used to advantage, particularly where pure cultures may not be readily available. A modification of this method consists in making a paste with the soil and water to which a little glue is added, and mixing this with the seed to be sown so that each seed is well coated. After drying, the seed is sown.

*The pure-culture method,* which consists in applying specially prepared cultures of the proper bacteria to the seed just before sowing, is recommended as being more effective and convenient. Such cultures, sometimes called "nitro-cultures," are distributed in Canada by a number of institutions and various seed houses and other commercial firms, some being sold under various trade names. Cultures appear in various forms, usually on agar (jelly) or mixed with peat (humus).

The preferred method of applying the cultures, which usually come in bottles or tins containing sufficient to treat one bushel of seed or smaller amounts, consists in first mixing with water (skim-milk may be used to advantage with the jelly cultures). The mixture is poured over the seed, which is stirred until all clumps are broken up and each seed is moist. After the seed has been allowed to dry, away from direct sunlight, it is ready for sowing.

Cultures should contain large numbers of living bacteria of effective strains and should be reasonably fresh. The Dominion Department of Agriculture maintains a control of inoculants offered for sale.

## Beneficial Effects of Inoculation

The beneficial effect of inoculation may be manifest in various ways, depending on the crop, the soil, and climatic conditions. There may be a direct effect on the crop, noted in an increased yield or better quality, or both. Increases in crop yield may be quite striking where the need for inoculation is great. This is particularly true on soils low in nitrogen and lacking suitable bacteria. However, even a small increase hardly noticeable to the eye will repay the small cost of the culture. In other cases the benefit may be found in a better quality of crop, inoculation making for a higher protein content, with consequent improved feeding value. The effect of inoculation on the soil itself is important, depending naturally upon how much of the crop is returned to the land. Not only does inoculation spare the soil's nitrogen, but if the legume is turned back by ploughing under, the addition to the soil of the nitrogen fixed may be very considerable, while it is in a form which becomes readily available to other plants.

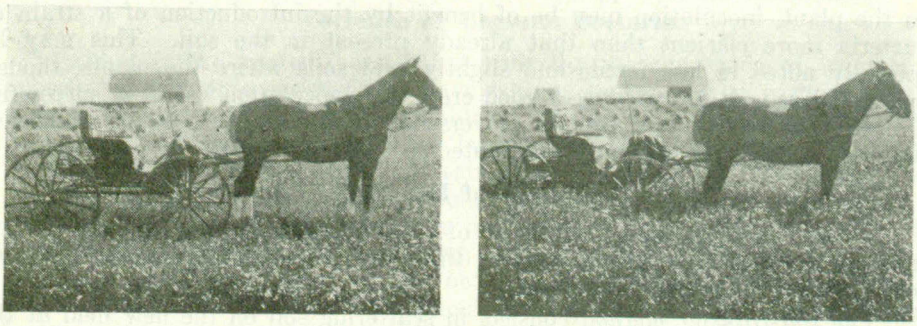

FIG. 2.—Alfalfa plots, Lacombe, Alta. At left, uninoculated, and at right, inoculated plot.

Although in some cases inoculation may mean the difference between success and failure, it should be remembered that it is but one factor in successful legume production. The best of cultures will be ineffective if other conditions for a good legume stand are not met. An inoculated crop requires the same care in seed selection and in the preparation and tillage of the soil as an uninoculated crop. The purpose of inoculation is not to supply an easy way to grow legumes, but to provide for better growth by adding bacteria which enable the plant to make the most of its environment. The bacteria cannot supply the crop with lime or such plant food as potash or phosphates. Inoculation, therefore, is most effective on soils sufficiently well limed and containing adequate mineral food.

Further advice on legume inoculation and information as to sources where cultures may be obtained, may be had from the Division of Bacteriology and Dairy Research, Science Service, Department of Agriculture, Ottawa.

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