

INOCULATION FOR LEGUMES

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Inoculated Legumes Are Missouri's Main Hope for Soil Upkeep.

There is scarcely a progressive farmer today who does not recognize the value of legumes, such as clover, alfalfa, soybeans and others, for feed and for soil improvement. Getting a stand of these crops is not always an easy matter, however. Sometimes the failure is due to neglect in supplying essential conditions needed for all crops, but in many cases it is due to the failure to provide the one condition needed by legumes as distinguished from other crops; namely, the presence of proper bacteria.

WHAT IS INOCULATION?

Distributing these bacteria for the legume along with the seed is what is meant by the term "inoculation". Many years ago it was learned that beans, for example, can grow on a soil too poor for other crops; and that other crops following do better than before. To get this beneficial effect it was only necessary to inoculate the bean field or to scatter on it small amounts of soil taken from a place where beans had grown before. As we now know, this treatment put on the new field the root bacteria needed by the beans to make their best growth.

LEGUMES ARE DIFFERENT

Legumes are not only different from other crops in needing bacteria on their roots for best growth, but as a result of these bacteria they are richer in both protein and minerals. Consequently, they are a more highly prized feed. This higher nitrogen content comes about through the bacteria they house in the nodules on their roots. These minute creatures make it possible for the plant to gather most of its much needed nitrogen from the air, instead of being forced to depend on the nitrogen in the soil organic matter or humus. This means that legumes have access to 70 million pounds of nitrogen over every acre instead of being forced, as are the non-legumes, to depend on the 2,500 pounds of nitrogen in the soil, which is about the average of the soils of Missouri.

LEGUME NODULES ARE CENTERS OF NITROGEN FIXATION

It is within the nodules and not in the leaves or stems that this nitrogen gathering activity takes place. They vary in shape, size and location on the roots, depending much on the plant and soil conditions. They are easily stripped off when the plant is pulled out of the soil, so the casual observer, carelessly pulling the plants, fails to find them. In young plants they are firm and clearly visible but as the plants get older they tend to slough off. This is especially true about the time the seed forms. At this time the plant ceases its growth activity, the nodules decay, the bacteria are spread through the surrounding soil and are there left to await the growth of the next crop and another active nitrogen gathering season.

FALSE NODULES

Occasionally other kinds of nodular growths appear on the roots of plants, sometimes called galls. These are different from the true nodules, in being gnarly, swollen root tissue instead of regularly shaped growths encircling the root or at one side of it. The false nodules are caused by parasitic eel worms or nematodes that infest many crops and may be expected in the southern part of Missouri, though not often in the northern part of the State. Recent reports have shown this pest of no small concern to soybean growers of Southeast Missouri.

LEGUMES NEED BACTERIA

It is to supply the necessary bacteria for the crop that inoculation is recommended. Legumes will often grow without bacteria. If they do, they must feed on the nitrogen of the soil in the same manner as corn, oats, wheat

and grasses. They can consequently be little richer in nitrogen than other crops and can scarcely be better feed so far as their protein is concerned. Inoculated legumes, on the other hand, are usually rich in this respect in both the seed and hay. Alfalfa hay, for example, is the equal of rye bran, while the soybean seed is richer in protein than any cut of beef. This property gives legumes their high feeding values and makes them especially desirable as part of the ration for young animals.

To produce the protein, the plants need much nitrogen, the low supply of which in the soil organic matter is supplemented by the bacteria taking it from the unlimited supply in the air. Through some unknown means the bacteria living within the nodules are able to take nitrogen from the soil air and give it to the plant. In return, the plant gives them a home and food. The plant and bacteria work cooperatively, and in consequence the plant is much richer in nitrogen while the bacteria multiply profusely.

Further, legumes need bacteria to serve as "soil builders". They can function in this capacity only when they add nitrogen to the soil's low supply. It is their power to use the atmospheric nitrogen through bacteria and build it into complex compounds of the plant tissue to go back to the land in crop refuse or barnyard manure, that gives them high standing as "soil improvers". Without bacteria, they do not have this function; but, like the non-legumes, are merely "soil robbers" and contribute nothing to soil upkeep. For the purpose of soil improvement, legumes must have their appropriate bacteria.

INOCULATION NEVER HARMFUL

So far as known, bacterial inoculation has never been harmful. Some persons have the impression that this treatment of supplying bacteria is a preventive measure against plant disease. It has no specific effect in this respect, though it may have some indirect effect. Legumes with plenty of bacteria make healthier and sturdier plants, and in this way may possibly not be as susceptible to diseases as those having a weakened condition from nitrogen shortage because of lack of bacteria.

IS INOCULATION ALWAYS NECESSARY?

"Must I inoculate my seed to get a good crop?" is a common question but not so simple to answer. To inoculate a legume crop at every seeding is

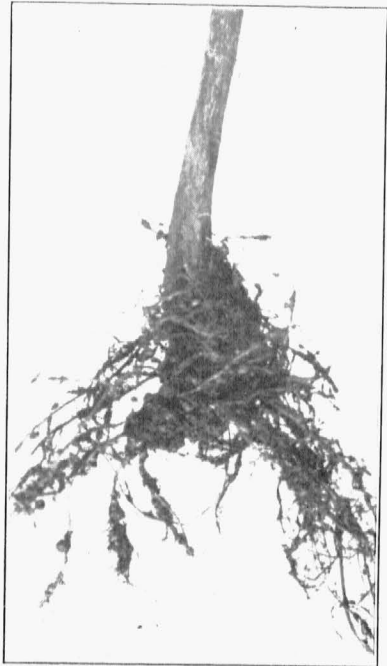


Fig. 2.—False nodules. Gnarly root growths are not nitrogen gathering centers, but scars from nematode or similar injury.

both laborious and expensive, and if not needed it is a waste of time and money. On the other hand, the failure to inoculate, when needed is gross neglect and results in a real financial loss. It is important to know when a leguminous crop should be inoculated or when the bacteria must be introduced into the soil.

Unfortunately, no chemical test or other rapid means can be used to determine when bacteria are needed on a field. The only certain method of answering this question is to grow the leguminous crop. If root nodules do not develop at all, or develop on only a few scattered plants, then that crop will be improved by inoculation. If, however, some nodules develop on each plant, inoculation is not necessary. Under the latter conditions the growth of one crop will enable the few bacteria in the soil to multiply and produce numerous nodules during the next season's growth of the crop, provided this legume is again seeded on the land within a few years. To test a soil in this manner requires time, and many farmers prefer to inoculate rather than wait for the results of such an experiment. Although no other test will decide the question with certainty, yet there are some general facts that may aid in the decision.

Such crops as red clover and cowpeas which have been grown in this State for many years, probably need no inoculation, except in rare cases. In some isolated sections where neither of these two crops has ever been produced, it may be possible that even red clover and cowpeas will do better if inoculated. Probably we may learn that better bacteria may be found and that we may help clover by giving it inoculation with special bacteria. No direct evidence for such a statement is available, but the ease with which these crops are started in the general farming districts of the State where they have been widely grown indicates that the inoculation for these crops is not the most important requisite in establishing them.

Such, however, is not the case with sweet clover, alfalfa, soybeans, or with any other leguminous crop that is new to the district and has never been raised on the farm in question. These, as a rule, need to be inoculated when planted for the first time. None of the three crops last mentioned is native to the State, nor have any of them been extensively grown. On this account the bacteria adapted to each of them have not been widely scattered over the farming sections, and when a crop of alfalfa, sweet clover or soybeans is planted on a field for the first time it will need inoculation. The labor and expense required for this simple treatment are too small to trust to inoculation by chance, with the risk of a poor crop. Occasionally some seeds carry a few bacteria into the field, which inoculate a few scattered plants and slowly spread to other parts of the field through distribution by animals, flood waters, winds or other chance agencies, but this is too slow when artificial inoculation is so easy and costs so little. Most any legume if left to grow continually will in time develop nodules much like any area naturally develops a wild pasture. Natural inoculation is possible, but very slow. In a progressive farming system one cannot trust to such hit-or-miss methods but must insure the benefits of the soil improvement by providing the inoculation at seeding whenever there is doubt regarding the supply of the right kind of bacteria in the soil. On soil where the legume in question, or cross-inoculating crops, have never grown, inoculation is certainly needed.

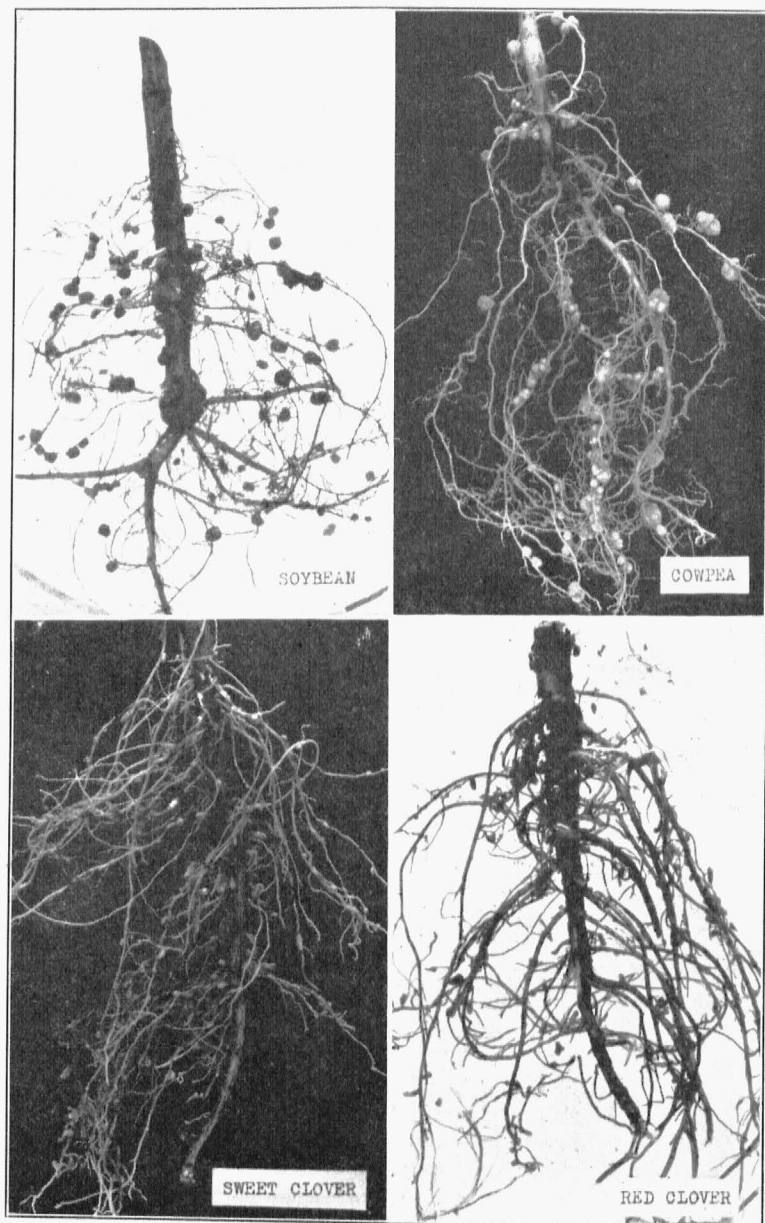


Fig. 3.—Nodule-bearing Roots of the Four Leading Legumes. Upper left, soybean; upper right, cowpea; lower left, sweet clover; lower right, red clover.

SOME LEGUMES INOCULATE OTHERS

Occasionally when one crop has been well inoculated, this may serve for some other legume, though not necessarily for all legumes. Legumes do not cross-inoculate universally. Some have a single kind of bacteria which will grow on no other plant, and they must be inoculated with that specific kind of bacteria for their best growth. On the other hand, one kind of bacteria may be common to two or more types of plants. It is a well established fact that alfalfa can be inoculated with the bacteria from sweet clover, and that the cowpea may be cross-inoculated with the wild partridge pea. Likewise, red clover, white clover and all other true clovers will inoculate each other. Soybeans, however, have a particular kind of bacteria not yet found on any other legume.

Classified in accordance with their ability to cross-inoculate, the common legumes may be separated into the following groups:

1. The true clovers, including red, white, alsike, crimson, mammoth red, Egyptian and others.
2. Alfalfa, yellow and white sweet clover, bur clover, black medic or yellow trefoil and fenugreek.
3. Cowpea, partridge pea, peanut, velvet bean, Japan clover, lima bean, wild indigo, beggar weed and tick trefoil.
4. Garden, field and sweet peas, vetches, lentils and broad bean.
5. Garden, field, navy, kidney and scarlet runner beans.
6. Soybeans.
7. Lupines and serradella.

All the legumes in any one of these groups have the same kind of bacteria in common.

Bacteria are not generated by legumes. Because sweet clover and alfalfa inoculate each other, many persons are likely to think that simply seeding sweet clover will inoculate the soil for alfalfa. Such is not the case. If proper bacteria have never been introduced, artificially or by chance, they must be applied when the first of these two crops on the soil is sweet clover as well as when it is alfalfa. When the proper bacteria are present sweet clover often gets into alfalfa and smothers it, because conditions favorable for alfalfa are also favorable for sweet clover. The soil is, however, no better supplied naturally with the bacteria for sweet clover than it is with those for alfalfa the first time one of these crops is grown. The need of inoculation cannot be met by substituting sweet clover since it cannot generate the bacteria needed.

METHODS OF INOCULATING

There are two general ways of distributing legume bacteria; (1) by transferring soil from a field where the same legume has been growing with plenty of nodules, and (2) by the use of pure cultures, or artificial cultures, of the bacteria grown especially for the purpose.

The Soil Method.—The use of inoculated soil was the means first employed for introducing the proper legume bacteria into a field, and this was accompanied with such good results that it has become established as good procedure. By this method from 300 to 500 pounds of inoculated soil are scattered over each acre of the field and disked or harrowed in before seeding. The soil so distributed is collected from the surface six inches of a field on which

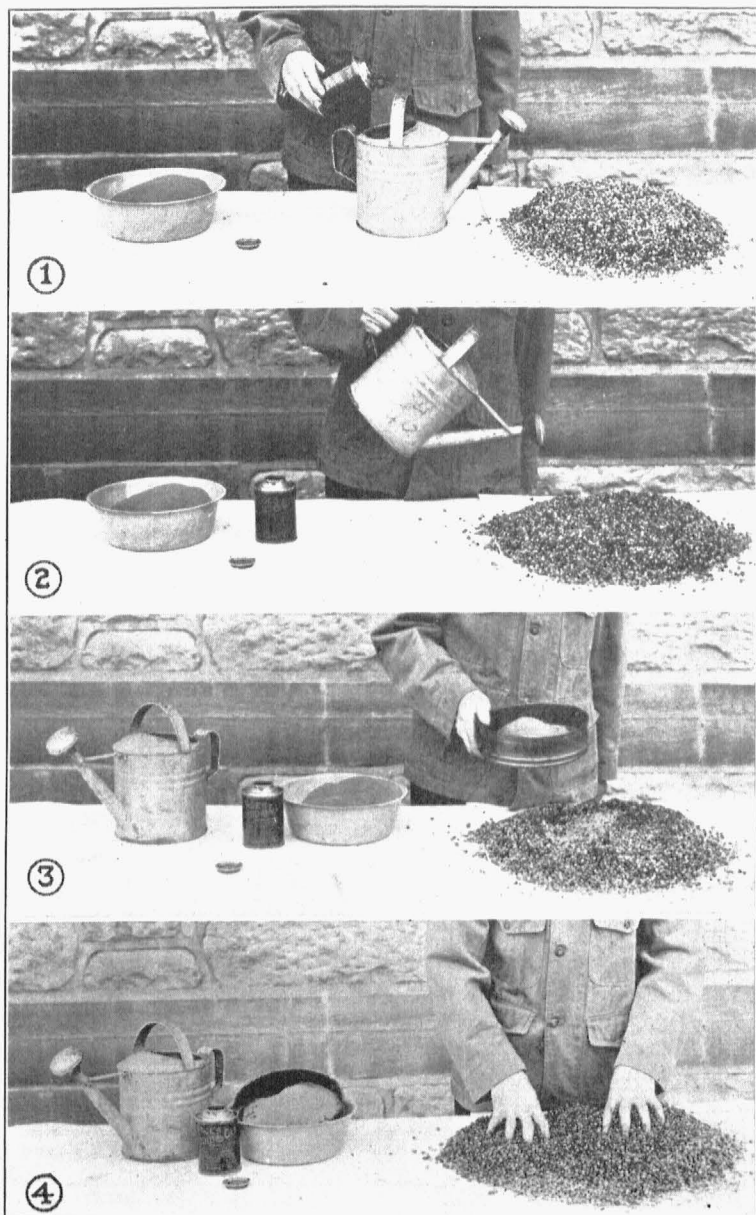


Fig. 4.—Inoculation by the Soil Method. (1) Making the glue solution. (2) Sprinkling the seeds. (3) Applying the infected soil. (4) Mixing the soil and seed.

the same legume—or one which cross-inoculates with it—has been grown recently with many nodules. Extensive exposure of this soil to the sun before scattering is thought to be detrimental to the bacteria, but definite evidence fails to prove that this is as harmful as might be thought. Useless exposure to the sun, however, should be avoided.

This method is laborious and has been simplified by applying the dry infected soil directly to the seed, which has been moistened, but not wet, with a glue solution. This consists of 1 pound of liquid furniture glue or $\frac{1}{3}$ pound dry glue to 1 gallon of water. With many seeds, simply moistening with water is as effective as the glue. Enough soil may well be used to equal about one-third or one-half as much soil as seed by weight. Increasing the amount of soil is advisable unless it is certain that the soil was heavily infected with nodules at the time it was gathered. The moistened seeds, if not dried by the soil added, should be spread out to dry rapidly and prevent molding. This method has been widely used and found satisfactory with the possible objection that the soil causes excessive wear in certain types of distributing machinery.

To avoid this difficulty it is possible to use only inoculated muddy water, sprinkling it over the seed and stirring it until every seed is moistened. For this purpose 1 quart of soil, obtained from a field where abundant nodules were produced on the desired crop is mixed with about 1 gallon of water and stirred well. After it has settled for a few minutes, the muddy water is put on the seed. This method has been considered satisfactory except where it is necessary to use very sandy soil.

In using the soil it is well to remember that unless the soil is thoroughly stocked with the bacteria it cannot serve for inoculating purposes. To make certain of its infection, it should be collected in the fall of the year or in the season when one can still see the nodules on the roots. With special effort to collect the dirt near the roots, including both roots and nodules, there is no danger of this method failing. Soil so collected can be bagged, allowed to dry and stored until the next season and still serve as inoculating material. Individuals expecting to inoculate new fields from old, or to sell seeds into new territory, may well adopt this practice for supplying inoculation.

The Culture Method.—This method, like the soil method, scatters the bacteria for the legume at the time of seeding, but uses bacteria produced for such purposes in special laboratories. The bacteria are grown on vegetable jelly and distributed to the farmer on this or on some other medium. The method of distribution is not so essential, as long as the bacteria are living and of the right kind. The advantages of this method are its simplicity and ease of handling. No great expense is involved in using the cultures. There is no danger of introducing dangerous diseases, destructive insects or noxious weed seeds. The cultures must not be used carelessly, however, since the bacteria are living organisms and die when stored too long or subjected to excessive heat or cold. Directions for using are always supplied and, if followed with reasonable care, this method of inoculation should be successful. In its early history it did not prove very satisfactory, but present methods of culture production have made it generally reliable, and it bids fair to replace soil methods quite widely.

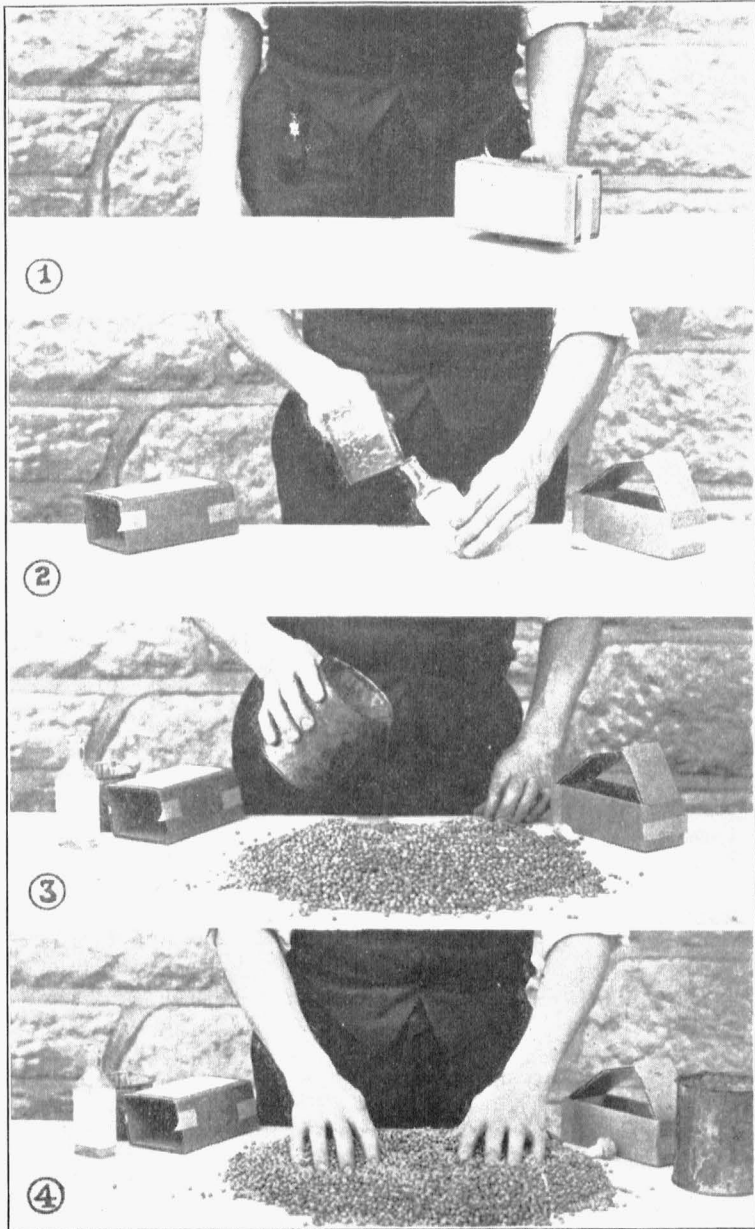


Fig. 5.—Inoculation by Artificial Cultures. (1) The culture. (2) Adding water to culture. (3) Applying culture to seed. (4) Mixing moistened seed.

ADVERSE CONDITIONS PROHIBIT THOROUGH INOCULATION.

Sometimes the first crop growth of a new legume develops only a few nodules on each plant, even though it was given thorough inoculation. This may possibly be due to one of two causes. (1) The bacteria may be present only in small numbers because they have not had time to multiply or to be scattered through the soil away from the place where they were put with the seed. (2) Another possibility is that some unfavorable soil condition may have kept the legume plant and bacteria from doing well.

In the former case, cultivation of the soil will distribute the bacteria, since they do not have ability of their own to move through the soil but must be scattered by soil water, cultivation and other agencies that carry them along. Also, a second crop of the legume will allow them to increase and give the soil good infection.

If the soil condition is at fault, this must first be remedied by special soil treatment before the legume will do well and the bacteria be of benefit. The most common conditions unfavorable to legumes are those of poor drainage and lack of lime. Reports of inoculation failure have come from areas of the State with the sour soils and heavy, tight subsoil. Under such conditions apparently the organisms find difficulty in establishing themselves, even though the legumes may make some growth. They cannot be expected to live long in soil hostile to them and supporting their host plant poorly, and must be introduced again after these conditions are remedied.

HOW OFTEN MUST A FIELD BE INOCULATED?

Legume bacteria do not live in the soil indefinitely in the absence of the plants on which they feed. For this reason inoculation may be needed when a legume is grown again on land after several years of cropping by non-legumes. However, the length of time the bacteria remain active in the soil in the absence of the legume on which they live is not definitely established. Experiments by the Missouri Agricultural Experiment Station have shown that sufficient numbers remained in soil left for six years without legume crop to give thorough inoculation when this crop came back on the soil again. Short lapses of time, such as one round of most common crop rotations on fairly good soil, do not permit the bacteria to die, and so reinoculation is unnecessary. Should soil conditions be unfavorable, or the lapse of time long, the cost of inoculation is so low that it is safe to say "when in doubt, inoculate".

SMALL ACREAGE OF NEW LEGUMES ADVISABLE FOR BEGINNERS

Whenever a new legume is seeded for the first time, it is good policy to attempt it only on a small acreage. Such procedure offers opportunity to become acquainted with the habits of the crop and the best methods of handling it, without the chance of a heavy loss of money and labor in case of failure. If this small area is inoculated, soil may be taken from it to inoculate large fields on years following. It is well to leave a part of this small area uninoculated as a means of learning whether or not the soil in the community already contains the proper bacteria for the crop in question.

INOCULATION IS NO CURE-ALL.

While inoculation may be the difference between success and failure of legumes in some instances, it is by no means a cure-all for soil troubles. It fits only special cases and must be administered properly. The bacteria are living organisms and must be handled accordingly. Their use will be a failure if they have been destroyed by exposure to intense heat or to frost for any length of time. It is not certain how injurious the effect of the sun is for short periods, but as a precautionary measure neither the bacteria nor the inoculated seed should be needlessly exposed.

The bacteria must multiply in the soil and they can do so significantly only in the presence of a crop. It may be necessary for a second or third crop to be grown before the root system can be said to be thoroughly inoculated. Further, they require satisfactory soil conditions if they are to flourish. In very sour soil their growth can be improved by lime. If there is doubt regarding the sourness of the soil it is well to have the soil tested by the county extension agent or by the Missouri Agricultural Experiment Station. This test is made free of charge on samples taken according to the Station's directions. For a legume, as for any other crop, the seed bed should be well prepared, the soil well drained and if the soil is very acid it should be limed. When all these requirements are met, and the inoculation is given in addition, the legume crop should be successful. Well inoculated legumes should find a place in every system of rotation in order to assist in keeping the soils permanently fertile.

DISTRIBUTION OF CULTURES

The laboratory of the Department of Soils, University of Missouri, is growing the bacteria for soybeans, sweet clover, alfalfa and other legumes for distribution among the farmers of the State at cost of production and delivery. These are grown on vegetable jelly, from which they are washed and put on the seed. Complete directions for use are sent with them. They are recommended where no infected soil is readily available. No guarantee for the cultures is possible other than that they leave the laboratory in good condition.

WHY INOCULATE—

- Because it makes bigger legume crops.
- Because it means hay with higher feeding value.
- Because more nitrogen is left by the roots in the soil.
- Because it gives more nitrogen to go back to the soil as farm manure or green manure.
- Because it makes a deeper rooting crop that helps to bring up to the surface some plant food minerals from the deeper soil layers.

WHEN TO INOCULATE—

- When the legume has never been grown before.
- When the legume has not been grown on the field recently.
- When the legume goes on a field where one is not certain that it has grown before.
- When the legume goes on a sour soil recently limed.

LEGUME GUMPTION

When in doubt, inoculate!

Grow legumes for feed and improve the soil at the same time.

The principle of inoculation has never been condemned although the methods of distributing bacteria once were.

“Bacteria on legumes not only work for nothing, but even pay for the privilege.”

Inoculated legumes can use the bountiful stock of nitrogen in the free air which pervades even the soil; other crops must depend on the limited supply of costly soil nitrogen.

The greater the proportion of legumes that can be turned under, either directly or in the form of manure, the easier it will be to maintain the fertility of the soil.

The method of inoculation is not so important as the certainty of getting living bacteria for the particular crop.

Air dried soil well stocked with bacteria is good inoculant as long as twelve months.

Legumes and bacteria are good illustrations of cooperation. Working separately, they suffer; working cooperatively, they prosper.

Earlier farming which did not demand present high yields nor consider the need of maintaining the soil might afford to disregard inoculation; progressive farming cannot.

Inoculation is no cure for all legume failures. It will not replace good seed, good seed-bed, tillage, lime and soil fertility.

A good crop of inoculated legumes is like a Muscle Shoals nitrogen gathering factory on one's own farm.

Farming without legumes may be compared to writing checks on the bank without making any deposits.