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Inoculation of Legumes

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Iowa farmers are coming more and more to realize the value of growing legumes, not only because of their value as hay and forage crops, but also because of their soil-enriching properties. The fact is often overlooked, however, that if the legume is not well inoculated, or supplied with nodules on the roots, it will have less value for feeding purposes, and its beneficial effects on the fertility of the soil will be very materially reduced.

Well inoculated legumes are essential in every well planned rotation to build up and maintain the fertility, or crop-producing power of the soil. Large beneficial effects are evidenced on the succeeding crops, which make the practice distinctly profitable. Hence, farmers are urged not only to grow more legumes but to grow *inoculated* legumes.

WHAT IS LEGUME INOCULATION?

Legume inoculation is the introduction into the soil of certain bacteria which bring about the formation of nodules on the roots of the plants. These nodules are round, club-like or Y-shaped swellings or growths, and they usually appear when the inoculated legumes are about three or four weeks old. The bacteria live and multiply in the nodules, where they perform the function of taking nitrogen from the atmosphere and supplying it to the legume. When legumes are inoculated, or supplied with nodules, therefore, a large part of the nitrogen which they contain comes from the air and only a relatively small amount is taken from the soil.

About 12 different kinds of bacteria are known which bring about the inoculation of the various legumes. Of this number, six are of practical importance. In general, only three are of significance in Iowa, the alfalfa bacteria, which will also inoculate sweet clover, the red clover bacteria, which will also inoculate alsike and white clover, and the soybean bacteria, which will inoculate only soybeans. When legumes are to be inoculated, therefore, it is necessary that the inoculating material contain the right kind of bacteria for the particular legume.

WHY SHOULD LEGUMES BE INOCULATED?

Legumes should be inoculated for three reasons: First, to induce the best crop growth; second, to increase the yield and value of the crop; and third, to increase the nitrogen content of the soil, if the legume is utilized as a green manure.

Often when legumes are grown on the soil for the first time, and particularly with alfalfa or sweet clover, lack of good inoculation causes the failure of the crop. Some legumes, such as soybeans, when grown under favorable soil conditions, will grow quite satisfactorily without inoculation. In general, however, the practice of inoculation, when all other favorable growing conditions are provided, is a desirable means of securing the largest crop yield.

Altho inoculation usually increases the yields of legumes to a marked extent, there are some exceptions. Some experiments in Iowa have shown that on certain soils, the yield of soybeans was not affected by inoculation. There may be other Iowa soils which are fertile enough to produce maximum crops of soybeans without inoculation.

But even if greater crop yields are not always secured by inoculation, the protein content, and hence the value of the crop, is always increased. In the experiments referred to above it was found that the protein content of different varieties of soybeans increased with the more thoro inoculation of the plants. Since the value of hay is largely determined by its protein content, the inoculation of legumes is very desirable from this standpoint.

Without inoculation, or in the absence of the proper bacteria, legumes take all of their nitrogen from the soil. When nodules are present in abundance on the roots of the legume, however, a large amount of this necessary food constituent is taken from the atmosphere. The presence of the nodules shows that the plants are inoculated with the right kind of bacteria and that they are drawing upon the unlimited supply in the atmosphere for much of the nitrogen which they need.

Only when legumes are inoculated, and therefore able to utilize the nitrogen of the atmosphere, can they be expected to increase the fertility of the soil. The actual amount of nitrogen which may be added to the soil by the growing of inoculated legumes is extremely variable, depending upon the soil type, the individual soil conditions and the particular legume which is grown, but primarily upon the way in which the crop is handled. If the legume is cut for hay and only the roots and stubble are left to be turned under, there may be little or no addition of nitrogen to the soil. If only the seed is removed and the remainder of the crop plowed under, a considerable increase in nitrogen may occur. But if the entire crop is plowed under as a green manure, the largest amount of nitrogen will be supplied to the soil. While the value of using leguminous crop residues and of green manuring with legumes is partly due to the incorporation of organic matter with the soil, the increased soil fertility is mainly attributable to the addition of nitrogen. Hence, the value of growing legumes from the soil fertility standpoint is largely determined by the inoculation of the crop and the amount of nitrogen fixed from the atmosphere.

The soil-enriching properties of leguminous crops have been evidenced by many experiments and by extensive farm experience. Large increases are secured in the yields of corn and small grain crops grown in the rotation following the legume crop or following the turning under of a legume as a green manure. Frequently the yields of succeeding crops are increased for several seasons. To permanently maintain the nitrogen content of the soil, the growing of inoculated legumes, and the plowing under of such crops as green manures, are essential, if the purchase and application of large amounts of expensive commercial nitrogenous fertilizers are to be avoided.

WHEN SHOULD LEGUMES BE INOCULATED?

Inoculation should be practiced whenever a legume is to be grown on any area for the first time, for if the particular legume has never been grown on the soil in question, there is no assurance that the proper bacteria are present. Inoculation is also recommended if the legume has not been grown on the particular area for many years. In the absence of the growing plants the bacteria do not retain indefinitely their inoculating efficiency, or their ability to produce nodules. Bacteria should be introduced into the soil by inoculation whenever there is reason to suspect that the proper organisms are not present, or that they have become weak and inefficient.

In Iowa the crops which nearly always respond to inoculation are alfalfa, sweet clover and soybeans. Sometimes it may be desirable to inoculate red clover, tho it is usually assumed that the red clover bac-

teria are naturally present in most Iowa soils. It is possible, however, that altho they are present, their efficiency may be low and in such a case it may pay to inoculate.

HOW SHOULD LEGUMES BE INOCULATED?

The two methods in common use for inoculating legumes are the soil method and the use of commercial cultures.

THE SOIL METHOD

This method involves the utilization of soil from a field where the same legume has previously been successfully grown and well inoculated. This inoculated soil may be used in a number of different ways, several of which will be described here.

The Soil Broadcast Method. By this method, the soil is broadcast at the rate of 100 to 500 pounds per acre, over the area to be seeded, and disced in immediately. This is necessary to prevent exposure of the inoculated soil to the sun, which tends to reduce its inoculating efficiency. The best amount of soil to use, when following this method, is about 300 pounds. The objections to it are that it is laborious and time-consuming and may be quite expensive if the soil must be shipped in or hauled from a considerable distance. Because of these objections, some of the following methods of using soil for the inoculation of the seed are coming to be preferred.

The Soil-Paste Method. When this method is employed, screened inoculated soil is mixed with sufficient water to form a paste which has the consistency of cream. This is poured over the seeds, which are then mixed thoroly and spread out to dry. Three or four pints of soil are necessary to inoculate a bushel of soybean seed. One to two pints per bushel would be sufficient for clover and alfalfa seed. The seed should be planted as soon as possible after inoculation with this and all other modified soil methods.

The Sugar Solution Method. By this method the seeds are moistened with a solution made slightly sticky by dissolving one to four tablespoonsful of sugar in a quart of water. Dry soil sifted over them in a sufficient amount to absorb all of the moisture, and then the seeds are mixed thoroly.

The Glue Method. This is very similar to the sugar solution method except that glue is used. One or two ounces of furniture glue are dissolved in a gallon of hot water and allowed to cool. The seeds are then sprinkled with this solution and mixed thoroly. Screened inoculated soil is distributed over the seeds, which are again mixed thoroly, dried and screened, if necessary, to prevent them from adhering to each other.

The Dust Method. This is probably one of the most common soil methods. It consists of collecting inoculated soil from around the roots of well-inoculated growing legumes. This may contain portions of the roots and nodules from these legumes. The soil is then dried and screened and mixed with the seeds before planting.

The Compost Soil Method. In the inoculation of soybeans, it has been found quite satisfactory to use a compost, prepared from the roots and nodules of well-inoculated soybeans, composted with soil. In the summer or early fall a bushel or two of soybean roots and nodules with the soil that clings to the roots are collected. A small box with

the bottom removed is placed on the ground, and in it are placed alternate layers of the roots and nodules and about two inches of the soil. The material is then allowed to compost, undisturbed, until ready for use. For the inoculation, the compost is mixed with water to make a thick soil-past, and this is added to the seeds, which are then spread out to dry.

All the Soil Methods Give Good Results

All of the various modifications of the soil method described herein were tested in the soybean experiments mentioned earlier, and all were found to give excellent results. It seems that while the use of glue or sugar in the preparation of the inoculation does no harm, the results when water alone is used are quite as satisfactory. In the tests of the methods it appears that the main consideration should be the use of a sufficient quantity of soil from an area where the same legume has been grown and has been thoroly inoculated. The experiments with soybeans indicate that it does not make much difference how the inoculation is brought about.

Some Objections to the Soil Method

The chief objection to the soil method is that frequently properly inoculated soil is not available on the particular farm where the legume is to be grown, or even on a nearby farm. To secure well inoculated soil is often very difficult and may be quite expensive if the soil must be shipped from a distance. It is not enough merely to get soil from a field where the same legume has been grown, but information must be secured to show that the crop on this soil has been well inoculated. Then, too, there is the danger of introducing objectionable weed seeds or plant diseases into the area to be seeded. One should know definitely that there were no noxious weeds present in the field from which the soil is taken, and that the legume growing on that field was not diseased. The principal objection of many farmers to the soil method is the trouble involved in securing suitable soil and in applying it to the area to be seeded, or in preparing it for use.

THE COMMERCIAL CULTURE METHOD

At present about 10 companies are manufacturing and selling commercial cultures for legume inoculation. The method of preparing these cultures is quite variable, but it usually consists of growing the organisms in pure culture in the laboratory, after which they are transferred to a humus or jelly-like medium and placed in cans or bottles for distribution and sale. Some of the companies sell directly from the factory, others thru various agents.

A list of commercial cultures which are sold in Iowa at the present time is given below. It should be emphasized that the Agricultural Experiment Station does not recommend any particular culture, nor can it guarantee successful inoculation from the use of a commercial culture.

FARMOGERM. The Earp-Thomas Cultures Corporation, Long Island City, N. Y. This is an agar or jelly-like preparation in a small glass bottle, fitted with a patented ventilated stopper.

HUMOGERM. The Earp-Thomas Cultures Corporation, Long Island City, N. Y. This culture is prepared on a humus medium, containing about 20 percent moisture and sold in a small tin can, with a perforated top plugged with cotton.

LEGUME BAK. The Edwards Laboratory, Lansing, Mich. This is a soft agar or jelly-like preparation in a glass bottle, fitted tightly with a cork stopper.

McQUEEN'S INOCULATOR. The McQueen Bacteria Co., Baltic, Ohio. This preparation is a dry, light colored, soil-like culture, in a pasteboard container with a tin top and bottom.

MULFORD CULTURE. H. K. Mulford Co., Philadelphia, Pa. This is a soft agar or jelly-like culture in a glass bottle, fitted tightly with a solid rubber stopper.

NITRAGIN. The Nitragin Co., Inc., Milwaukee, Wis. This culture is in a moist humus medium in a flat, round tin box in the top of which there are several small holes.

NOD-O-GEN. The Albert Dickinson Co., Chicago, Ill. This culture is prepared on a stiff, jelly-like medium in a small glass bottle, fitted with a special stopper for ventilation.

NODULE-BACTER. Standard Inoculation Co., Troy, Pa. This is a preparation of a soft agar or jelly-like medium in a glass bottle fitted with a special stopper for ventilation.

NODULE-GERM. A. A. Berry Seed Co., Clarinda, Iowa. This culture is in a moist, humus medium in a tin can, in the top of which there are several small holes.

URBANA CULTURE. The Urbana Laboratories, Urbana, Ill. This culture is prepared on a soft agar or jelly-like medium in a glass bottle fitted tightly with a cork stopper.

The Choice of a Commercial Culture

There is no one "best" culture. Successful inoculations and some failures have been reported from the various cultures. The choice of a culture must be left to the individual, who may follow personal preference, or be guided by the cost or the ease of securing the culture.

Commercial Cultures Should Be Dated

Opinions differ regarding the length of time that commercial cultures retain their value. Some companies recommend that their cultures be used within one year, while others claim that theirs will be good for five years. All agree, however, that the organisms will not remain alive in the cultures indefinitely. Hence, all commercial preparations should be dated and a statement attached stating how long they will be good for use. This would protect the farmers from using cultures which may be too old to give good results and it would also protect the companies from the accusation of selling worthless cultures.

THE SOIL METHOD VERSUS THE COMMERCIAL CULTURE METHOD

Neither the soil method nor the commercial culture method can be recommended unqualifiedly as the "best" method for the inoculation of legumes. Some experiments have shown the two to be about equally satisfactory, while each method has proven superior in other tests. Recent studies at the Iowa Agricultural Experiment Station over a three-year period on the inoculation of soybeans have indicated better results from the soil method. The various soil methods have been quite satisfactory, while the results from the commercial cultures used have not been consistently good. Results with other legumes might be quite different, however, since it is generally conceded that soybeans are more difficult to inoculate than many other legumes.

The relative cost of the two methods cannot be accurately estimated. The commercial cultures are quite definite in price, ranging from 50 cents to $1 per bushel of seed, depending upon the particular culture and the amount of culture material purchased. The actual cost of the use of the commercial cultures can, therefore, be determined, provided no account is taken of the time required to apply the culture to the

seed. When soil is used, however, it is very difficult to calculate the cost of the inoculation. If an accurate record were kept of the time required to secure the soil and prepare it for inoculation, and this labor cost were calculated, it is probable that the commercial cultures might be cheaper in some cases. This would certainly be true if it were necessary to secure the soil at considerable distance, and a freight charge and hauling charge were involved. In general, however, the soil method is probably cheaper.

The chief advantage of commercial cultures is that they are convenient to secure and use. However, successful inoculation may be secured by either method.

CONDITIONS DESIRABLE FOR SECURING THE BEST INOCULATION

Inoculation is not a cure-all. It will not insure a successful legume crop if some other necessary condition for the best growth of the plants is lacking. It will not make up for the use of poor seed, nor will it provide a good crop if the seasonal conditions are unsatisfactory. If the soil conditions are not at the best for the legume growth, the largest crops yields will not be secured even if some inoculation is obtained. In general, the best inoculation will be secured in soils where the most desirable conditions for crop growth are provided.

If the soil is not properly drained, the installation of tile is the first operation usually required to insure thoro inoculation of the legume. The proper preparation of the seedbed will aid in obtaining the best inoculation. If the soil is acid, most legume bacteria will not function properly and often very few or no nodules at all will be formed. Before seeding many of the legumes, therefore, the soil should be tested, and if it is acid, the amount of lime shown to be necessary by the test should be applied.

Many soils are not well supplied with organic matter and some may be lacking in certain essential plant food constituents, which will prevent the best inoculation. The application of farm manure to soils low in organic matter will generally improve the conditions for securing inoculation. Iowa soils are apt to be lacking in available phosphorus and the addition of a phosphate fertilizer may often be helpful in securing the greatest inoculation. Acid phosphate has been found in a number of experiments to be very desirable for a crop like alfalfa.

Inoculation does not insure the best crop growth, but when it is practiced along with other desirable soil treatments, it may help greatly in securing the largest yields and it enables the legume to use the atmospheric nitrogen.

THE INOCULATION OF SOIL FOR NON-LEGUMES

In years past, many preparations for the inoculation of non-legumes have appeared on the market. None of these cultures have ever been found of value. Some of them have been distributed for several years, but usually they have been short-lived, and their manufacture has soon ceased. Experimental tests of these materials have not shown that they would appreciably increase crop yields. Perhaps a culture may be devised in the future which will prove profitable, but at present farmers are advised to refrain from using cultures for non-legumes on anything more than an experimental test basis. When considering purchasing any culture material, it will be well to consult the County Agent or write to the Agricultural Experiment Station for advice.

GENERAL RECOMMENDATIONS

The following general recommendations regarding inoculation are offered:

1. Legume inoculation is recommended whenever the same legume has not been grown on the land previously, if a number of years have elapsed since the legume was grown on the area, or if the crop grown previously was not inoculated.

2. Inoculation of legumes is important to permit of securing the best crop growth, to increase the yield and value of the crop, and to allow for the utilization of the nitrogen of the atmosphere and thus conserve the supply in the soil.

3. Either the soil method or the commercial culture method may be used successfully. When well inoculated soil, free from weed seeds, plant diseases and insects, can be secured in the immediate vicinity, the soil method may be considered preferable. Many farmers may prefer to use a commercial culture, however, largely because of its convenience.

4. The various modifications of the soil method offer little choice and farmers may follow their personal preference in selecting a method.

5. There is no "best" culture among the commercial cultures. If the directions for use, supplied by the company, are followed, any one may be expected to give satisfactory results.

6. All commercial cultures should be dated, in order that farmers may know that they are using cultures which are not older than the companies think they should be for successful results and in order that the companies may protect themselves from criticism.

7. The conditions desirable for securing the best inoculation of most legumes include the proper drainage and cultivation of the soil, the application of lime to remedy any acidity, the additon of manure to supply organic matter if the soil is deficient in this constituent and often the use of a phosphate fertilizer.

8. Farmers are advised not to purchase cultures for the inoculation of non-legumes until they are recommended by the Agricultural Experiment Station, or until they have tested the particular culture on a small area and satisfied themselves of its value.