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INOCULATION WITH NODULE-FORMING BACTERIA

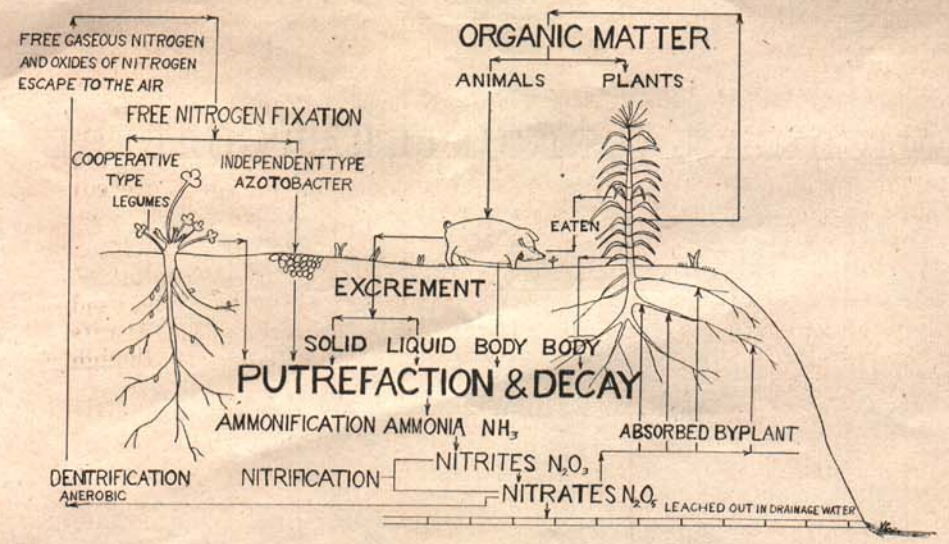
BY

DEPARTMENT OF BACTERIOLOGY AND HYGIENE.

1. *Plant Food.* The usual practice of the farmer results in removing the plants or parts thereof from the field where grown and forgetting to return them or their equivalent in potential plant food. It happens, however, that when the plant debris is returned to the soil *it is not plant food until is broken down and made soluble, for plants can use only that which is soluble.* It is largely the work of the various microbes in the soil to render soluble the insoluble organic and inorganic matter in the soil.

2. *Microbial Food.* The plant and animal matter which is or should be returned to the cultivated field is the food for the soil microbes. They digest it and render it soluble, incidentally causing the soil water to become a more powerful solvent of the natural inorganic or rock particles in the soil and thus rendering both the organic and inorganic particles available for the growing plant. Without the active growth

of microbes in the soil there can be no soil fertility and no productive agriculture. *We should feed the soil bacteria.* (See illustration.)



3. *Cheap Nitrogen.* The most expensive, commercially, of the plant food elements is nitrogen. Fortunately, microbes can be encouraged to remove large quantities of nitrogen from the air (where it occurs to the extent of about 80 per cent.). This can be done in two ways: (a) Symbiotic, (see illustration, cooperative type): Special bacteria attack the rootlets of leguminous plants (alfalfa, clovers, peas, beans, vetches, etc.), causing the formation of nodules and feeding upon the plant juices and in turn giving the plant nitrogen compounds built up by the bacteria from atmospheric nitrogen. (b) Non-symbiotic, (see illustration, independent type): Certain bacteria, including those referred to above, can feed upon the organic matter in the soil (manure, green manure, etc.) and with a part of the energy thus obtained take nitrogen out of the air and fix it in the soil.

4. *Soil Inoculation.* If microbes do so much for the plant by their activities in the soil, would it not pay to encourage their growth and even to introduce cultures of certain microbes into the soil? Usually if the soil is properly underdrained, tilled and supplied with organic and inorganic food material the microbes will be found present and active, but in the case of the *nodule-forming nitrogen-fixing bacteria* (cooperative type), it has been found profitable to add cultures of the microbes to the soil. The addition of other kinds of bacterial cultures is not known to be necessary or profitable as yet.

5. *Nodule-forming Bacteria.* When the proper bacteria are present in the soil, some plants, such as alfalfa, clover, peas, beans and other legumes develop nodules upon their roots in which these bacteria live in enormous numbers. In these nodules the free nitrogen of the air is so changed that these plants are able to make use of it in their growth. At the Illinois station, it was shown that 40 lbs. per acre of nitrogen

might be added in this way to a single cutting of alfalfa, a gain of more than six dollars per acre. Besides this, a large amount of combined nitrogen had been stored in the soil for the next crop. A crop of legumes *without nodules* would get all of its nitrogen from the soil as do the non-leguminous crops and would exhaust the soil of this element of fertility in the same manner. There is *no reasonable doubt* as to the benefit to legumes of the proper nodule bacteria. Faulty methods of inoculation and ignorance of the many factors connected with this practice, however, have in the past given rise to much dissatisfaction and disappointment. Moreover the condition of the soil may prevent nodule development, and the crop may fail even though proper inoculation methods have been employed.

6. *Bacteria-laden Soil,* or soil taken from a field where a crop of the desired legumes has shown a good development of nodules, may be used to inoculate soil which does not contain these bacteria. The results obtained by this method have been almost uniformly satisfactory, though it is not entirely without objectionable features. Besides being somewhat cumbersome—from 100 to 500 lbs. of soil per acre are ordinarily used—there is always the possibility of introducing the seed of objectionable weeds or of spreading plant disease.

7. *Pure Cultures* of nodule bacteria suitable for the various legumes may be used in inoculating the seed just previous to sowing. This method has been used very extensively during the past ten years, usually with marked success. In its favor may be mentioned ease in shipment, assurance of a tested strain of bacteria, freedom from danger of spreading weeds or plant disease, convenience in application and economy. The earlier history of the inoculation of seed by means of pure cultures is largely a record of failures, and seed inoculation, therefore, for a time fell into general disrepute. But further study of the life and habits of the nodule-forming bacteria with improvements in pure culture methods has made seed inoculation safe and desirable.

8. *To Inoculate or not to Inoculate.* Under favorable conditions, nodule bacteria may live in the soil for years. Therefore, it is seldom of advantage to inoculate for a leguminous crop which grows naturally on the field to be seeded with the production of nodules and which is being successfully grown in short rotations. However, it must be remembered that soil may need inoculation for other legumes. A specific strain of bacteria is required for each of the following: Common clovers, alfalfa and sweet-clovers, soy beans, cow peas, peas, vetch. If it is not known whether any one of these crops will show nodules naturally, it is advisable to insure their presence by proper inoculation. By inducing an earlier and more abundant development of nodules, inoculation may be profitable even in soils which contain the proper bacteria in limited numbers. Inoculation may not be of benefit: (a) if the proper bacteria for the desired crop are already present in the soil in sufficient numbers; (b) if the condition of the soil is such as to hinder the growth of either the plants or the bacteria.

9. *Commercial Cultures.* The cultures put upon the market by many commercial firms are just as reliable as those sent out from the state institutions. We would hesitate about purchasing any cultures for soil or seed inoculation advertised as capable of doing anything

other than nitrogen-fixation in association with the legumes. We would also discount to some extent the claims made by some salesmen even in connection with nitrogen-fixation and crop benefit and we doubt many claims made regarding the time for which cultures will remain efficient.

10. *How to get the Cultures.* Cultures may be procured from reliable commercial firms engaged in their manufacture or sale or in some cases the cultures accompany the seed, especially alfalfa seed. Pure cultures will be sent from this laboratory *in any quantity* to anyone in Michigan wishing to use them for seed inoculation on the farm or garden or for demonstration before clubs, schools or other meetings, or our cultures may be procured through the local farm bureau or county agriculturist. The price of the culture is twenty-five cents for enough to inoculate a bushel or less of seed. Cultures will be sent free to those who wish them for demonstration or educational purposes.

11. *When to get the Cultures.* The laboratory recognizes the possibility that cultures may deteriorate and, therefore, does not recommend the use, after *twenty days,* of cultures forwarded by mail. It sends cultures about *one week* before the time specified for seeding. The cultures should be ordered accordingly. If kept in a cool, dark place, the cultures may be good for as long as forty to sixty days, but it is better to order as needed and use soon after receipt.

12. *How to Use the Cultures.* Full directions for use accompany each two-ounce bottle of culture. The directions are so simple and easy to follow that inoculation is not a task that should be shunned.

13. *What to Expect.* The evidence of success from the use of pure cultures or any form or method of inoculations, is the formation of nodules, compared with the absence of nodules when no inoculation is used. The absence of nodules, however, may not prove the culture at fault. One should not consider a luxuriant crop a sure proof of the success of the inoculation nor should a poor crop be considered a proof of the failure of such treatment. If nodules are formed the crop is getting the benefit of nitrogen that is necessarily fixed by the association of nodule-forming, nitrogen-fixing bacteria with legumes. The bacteria will not effect seed germination either for good or for bad. Improper physical condition or poor cultivation of the soil cannot be corrected by treatment of seed with pure culture. Moreover, do not expect inoculation to replace the need of lime, humus, proper climatic conditions and good seed. In eight years 43,982 cultures have been sent out.