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Inoculation of soils

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INOCULATION OF SOILS

BY

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ROOTS OF BUR CLOVER SHOWING TUBERCLES

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*First Annual Report, 1888. Second Annual Report, 1889. Third Annual Report, 1890. *Fourth Annual Report, 1891. *Fifth Annual Report, 1892. *Sixth Annual Report, 1893. Seventh Annual Report, 1894. Eighth Annual Report, 1895. Ninth Annual Report, 1896. Tenth Annual Report, 1897. Eleventh Annual Report, 1898. Twelfth Annual Report, 1899.

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INOCULATION OF SOILS.

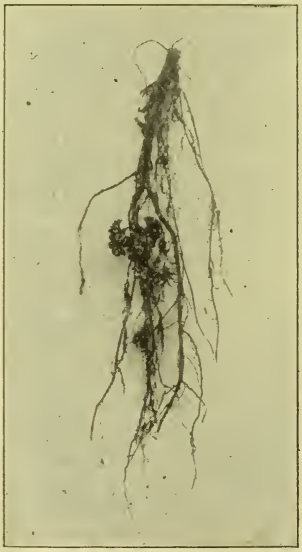
Air—Two and a quarter centuries ago the important discovery was made that the air we breathe and that is everywhere about us, was made up, very largely, of a mixture of two gases. One of these called oxygen, was found to be a gas absolutely necessary to the life of animals. The other called nitrogen was fouud to be a gas which animals could not breathe when pure, and in which a candle would not burn. Yet strange to say this nitrogen constitutes nearly four-fifths of the air we breathe; while oxygen constitutes only one-fifth. Besides these two gases there is always present in the air, a very small quantity of carbonic acid gas. It comes from, decaying substances, from fires and from the breaths of animals. So in a short time the air would be loaded with it and we should all die, if there were not something to take it out of the air and put oxygen in its place.

Relation of Air to Plants—For a long time after this discovery no one knew or even thought that this air about us had any relation to plants. Finally some one accidentally discovered, that, if a few plants were placed in a space containing nothing but impure air, that is, air containing a good deal of carbonic acid gas, this air would soon be purified again. Evidently then the plants did it. In other words, it soon became known that one thing plants did was to take up carbonic acid gas and give off oxygen. Consequently we readily see how dependant we are on plants.

But the question that agitated the people most during all those years was, did plants do anything with the nitrogen in the air? Could plants take up the nitrogen from the air, in the same way that they took up the carbonic acid gas, and use it to aid themselves in growing? Here was this great ocean of air about us, fifty or more miles in depth, and four-fifths of which was nitrogen and yet so far as any one could tell plants were unable to take it and use it. So farmers went on, and are yet going on,

buying nitrogen at the rate of 12 to 15 cents per pound. It is the most expensive fertilizer element the farmer has to buy and perhaps one of the most needful. As late however, as 1850 a French experimenter declared that certain plants cou d take up the free nitrogen of the air and put it into a form that could be used by the plants as food. For this he was ridiculed and scoffed at until life became almost a burden. Nevertheless, farmers began to find that if they raised a good crop of clover on a piece of ground they could raise a good crop of wheat on that same ground the next season. Any intelligent Southern farmer knows that, if he plows under a crop of cow peas or hairy vetch his crop of whatever follows will be increased in yield. And there lies the whole secret.

A Remarkable Property of Leguminous Plants—Examine, if you will, roots of bur clover (see picture on cover), hairy vetch or alfalfa and in most cases you will find small white tubercles or nodules on them. Inside of these nodules are hundreds of minute germs or bacteria, that have the power of gathering up the free nitrogen of the air and putting it into a form that the plant can use as food. Then here we have the two factors ready to our use without cost that will go far toward enriching and improving our worn out land; and increasing our crops. One is the air, four-fifths of which is nitrogen and fifty miles deep all over the earths the other leguminous plants, such as hairy vetch, cow peas, velvet beans, clover, alfalfa, melilotus, and many others. It is quite probable



VETCH ROOTS PLAT I. SHOWING TUBERCLES.

that this power is not restricted to leguminous plants alone but they are preeminently the nitrogen-gatherers. Just how the germs inside the nodules take up the free nitrogen and work it over into available food for the plant cannot be told. They do it however and that is enough for our present purpose. They not only manufacture enough available nitrogen for the plant on which they live, but store up goodly quantities in the nodules, which will go to the succeeding crop. Moreover after the vetch or clover is cut, the nodules decay, setting free the little germs, which will live in the soil and produce nodules on the next crop of vetch. Thus the farmer may go on enriching his soils by planting leguminous crops.

Inoculation of Soils.—It is quite probable that if we were to examine the roots of vetch, clover, or peas in certain parts of our State we should find no tubercles on them. It is even more probable that we would find localities in which the roots had but a few nodules. In both these cases more of the germs need to be added to the soil. In other words the soil needs to be inoculated. One can always know whether the soil, on which clover, vetch, or peas are growing, is deficient in nitrogen-gathering germs, by examining the roots of these crops. If the roots bear no tubercles then there are no germs in the soil. If the roots bear only a few, small tubercles then the soil is in need of more germs.

Field Experiment with Hairy Vetch (Vicia Villosa.)—In the month of October, 1898, an experiment with hairy vetch was begun to determine, if possible, what effect the inoculation of the soil might have on its immediate growth. For this purpose a piece of ground, on which it was supposed vetch had never before been grown, was selected. This piece was divided into three equal plats, and eight rows of vetch, two feet apart, were sown in drills on each plat. Each plat of eight rows was treated differently, as the following will show.

The first eight rows, beginning on the east side, were inoculated by bringing earth from a field on which vetch was growing, that had plenty of nodules on the roots. Care was taken to get the earth close about the roots, even many of the vetch roots with nodules being mingled with the earth, to be sure of inoculation. This dirt was then scattered in the drills on top of the vetch which had already been sown. Both were then covered with soil.

The second plat of eight rows was also sown in drills, but no earth or water containing germs was put with the seed, so that this plat was supposed to be wholly uninoculated. The object was to have this plat serve as a check to the two others.

The third plat of eight rows was also sown in drills, but the seeds were first wetted with water containing nodule germs. Some earth, from the same field of vetch used in the first plat, was placed in a pail of water. It was then stirred thoroughly and allowed to settle. The seed were then wet with this water and planted immediately.

Of course in sowing an acre or more of vetch it would be necessary to allow the seed to dry so that they could easily be scattered.

PLAN OF VETCH PLATS.

EAST.	NO. 1.	NO. 2.	NO. 3.
	Inoculated by scattering dry earth in drills.	Not inoculated, to serve as a check.	Inoculated with water containing germs.
	Yield of green forage, 79 pounds. Increase in yield due to inoculation, 64.6 p. c.	Yield of green forage, 49 pounds.	Yield of green forage, 64.5 pounds. Increase in yield due to inoculation, 34 p. c.

Results—The stand of vetch on these three plats was not at all promising. They had been sown so late that they did not get a good start in the fall, and this, followed by our extreme cold winter, caused the plats to look very thin in the spring. No. 1 looked especially discouraging. By the latter part of April, however, this plat had out-

grown No. 2 nearly twice. The growth was splendid and covered the ground with a thick mat. Some of the plants were so strong as to be in bloom at this time. A week later the roots in this plat were examined for nodules. Great clusters of them were found (Fig. 1), besides multitudes of individual ones. At the same time the roots of vetch in No. 2 were examined. A few nodules were found, but all were small and not so vigorous in appearance as those of plat 1. It was evident, however, that this plat had been slightly inoculated, either by vetch having been grown there before, or by some germs having been scattered over it in our work, or by the wind, from an adjoining field. The inoculation changed our final result somewhat, very probably, yet it was wholly inadequate for the needs of the crop, as will be seen.

The plants on plat 2 at this time were not so tall, were less rank in growth, and were evidently suffering more from drouth. This was probably due to the fact that the ground was not well covered, and hence evaporation took place more readily. None of them were in bloom.

Plat 3, although it had appeared the best of the three in the spring, was now (in April) second to plat 1. The roots showed fewer nodules than plat 1, but many more than plat 2. The growth of vetch was much ranker and heavier than on plat 2, and to the eye appeared nearly as good as that on plat 1.

Actual Weight of Green Forage on the Three Plats.—On May 20th, before the seed were fully matured, the vetch was cut and carefully weighed. The green forage grown on plat 1 weighed 79 pounds. That on plat 2 weighed 48 pounds, while plat 3 yielded 64½ pounds.

In other words, by inoculating the soil with dry dirt, plat 1 gave an increase in yield over plat 2 of very nearly 65 per cent. To be accurate, 64.6 per cent. Plat 3 gave an increase in yield over plat 2 of over 34 per cent. But

the above increase was obtained in face of the fact that our plat used to serve as a check was inoculated to a small degree. If this had been absolutely free from germs, I confidently believe the increase would have been double. That is mere speculation, however, and we had best confine ourselves to actual results.

Let us see what our results would give on an acre:

Suppose an uninoculated field to yield one ton of vetch per acre. Then according to the yield on plat 1, by inoculation, that field would yield 1 65-100 tons per acre, an increase not to be despised. On a field of twenty acres, at the same rate, the yield would be increased from 20 to 33 tons.

Addition of Available Nitrogen to the Soil.—Perhaps, after all, the thing most important in this experiment was the proof of the plant food in the way of nitrogen, added to plats 1 and 2. Each nodule found on the roots of the vetch in those plats represented a certain amount of available nitrogen, ready for the succeeding crop of wheat, oats, or what not. Each nodule was a nitrogen fertilizer factory for the farmer, gathering the nitrogen from the air in the soil and putting it in the form of food. The number of nodules on plats 1 and 3 far exceeded that on plat 2, hence the amount of available nitrogen left in the soil must have been correspondly greater. In other words, the more thoroughly a crop of vetch, cow peas, alfalfa, or clover is inoculated, the more plant food it adds to the soil. If uninoculated, these crops probably add no more nitrogen food than any other crop.

Will the Germs From One Kind of Plant Produce Nodules on the Roots of Another Kind of Plant?—At the same time we sowed the above plats of hairy vetch we also sowed at some distance from them three similar plats of the common vetch (Vicia sativa). These three plats were treated in exactly the same manner as those of hairy vetch. The earth for inoculation was ob-

tained from the same field of hairy vetch that was used in the first experiment. The roots of the vetch in plats 1 and 3 were covered with an abundance of nodules. Hence, in this case, the germs of one species of vetch produced nodules on another and different species of vetch. Unfortunately the common vetch produced no stand in the spring. It was nearly all washed out by the heavy rains of early winter.

In the case of plat experiments with crimson clover, I used soil obtained from about the roots of red clover, and found that an abundance of nodules was formed on the crimson clover roots.

Without going into a scientific discussion as to whether there is a different species or variety of germ for every species of plant, suffice it to say that probably the germs from any one clover will inoculate all other clovers to a greater or less degree. Likewise the germs from any vetch will inoculate all other true vetches. Our experiments above established this in at least two cases. In other words, the germs from one plant will inoculate other plants closely related to it. In fact, it has been shown by experiment that the germs from beans will inoculate peas and vetch, for these are all closely related.*

*MacDougall in Trans. Bot. Soc., Edin., 1897.

However, the very best results will be obtained by using germs from the same plant as that which we are going to inoculate.

Necessity of Other Fertilizers in the Soil.—It must not be imagined from what has been said that leguminous plants, if inoculated, will perform miracles of growth. One will be doomed to disappointment, for they will not. It must be remembered that they need phosphoric acid and potash as much as ever. These they cannot gather, and although they can gather nitrogen they cannot live by nitrogen alone. So in cases where

the above fertilizers are absent from the soil they should be added in order to obtain the best results.

Methods of Inoculating Soils.—There are at least three methods of inoculating soil with these germs. One method is to find a field on which a crop of vetch, peas or clover has grown, on the roots of which an abundance of nodules was developed. In such a case one may be sure that the soil of the old vetch or clover field is full of germs that escaped from the nodules when they decayed. Then draw dirt from this field, about one ton to the acre, and scatter as evenly as possible over the one to be inoculated. It should then be quickly harrowed in, especially if it is a hot, clear day, because sunshine kills the germs. The dirt should be taken preferably from two to three inches below the surface. A second method is to obtain some earth from an old inoculated vetch or clover field, put it in a vessel and pour water on it. Then stir thoroughly, allow it to settle, and use this water to thoroughly wet the seeds to be sown. The water thus obtained is full of the germs from the soil, which will stick to the seeds as they dry. Here again we should use care and not dry the seeds in the sunlight. It seems to me that this is the most economic way of inoculating a field. It is not a difficult matter to spread out a bushel or two of clover or vetch seed on an old cloth or tight floor, and sprinkle with plenty of the muddy germ water. The seeds may be left right there until they dry, if they are in the shade, and then are ready to sow. A third method is to buy from Victor Koechl & Co., 79 Murray street, New York City, a material known as nitragin. This is simply a gelatinous substance full of the germs one wishes to use. It is made in Germany, and consequently in the trip across the ocean, and then to us, it is very liable to ferment and spoil. We ordered it in the winter, however, and had no such trouble. It costs $1.25 per bottle, and to inoculate an acre two bottles are needed. Full direc-

tions for use accompany each bottle. In ordering always state the kind of germs desired, whether it is clover, vetch, pea, bean, or alfalfa, etc.

Summary.—The air all about us is composed principally of two free gases, oxygen and nitrogen.

Leguminous plants, such as clover, vetch, peas, beans, alfalfa, etc., are able to take up the free nitrogen of the air and change it to a form that can be used as food. A part of this the plants use immediately in growing and a part is left in the ground for the succeeding crop. These leguminous plants are able to do this by means of bacteria or germs that grow on their roots and produce nodules there.

In some soils these germs are not present at all, while in some soils they are present, but not in sufficient numbers to produce the best results. Such soils should be inoculated.

By inoculation is meant the adding of the germs in some way to the soil.

Experiments with vetch have shown that the crop is greatly increased by inoculation, and at the same time that nitrogen is added to the soil.

Experiments show that the germs from one plant will inoculate plants very closely related. But the best results will probably be obtained by using germs from the same species of plant one wishes to inoculate.