Nitrogen in the Soil

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The soil, to the agriculturist, is the decomposed rock of the geologist, usually with other material, the product of life, intermingled with it. It is the loose porous coating, covering the earth wherever plant life is found. According to its position, soil is divided into two great classes. 1st sedimentary, or that remaining on the flat tops of mountains, where it is formed, and, 2nd transported. It is of the economic soils that we shall deal, they being, by far of most economic interest.

Erosion, or rock wearing, is caused by changing temperature, moving ice and water and the chemical action of air, water and plant and animal residues. The water then takes it up and rolls or carries it off down the hills to lower level, where the movement is less rapid and the soil particles are deposited. On the way down the pieces are worn round and ground fine. Parts of other rocks are mixed in, and by the time it is deposited in the river valleys, it is a pulverized, palpable conglomerate mass of rock dust.

For years it has been covered with a grass and forest growth. Wild beasts seek food and shelter in its depths, and the birds of the air live among its branches.– The soil no longer resembles that washed down from the hill side. Decaying leaves and trees have added to it, until now a deep mulch lies thick all over the surface.– We will now follow its history a little further.– To clear away the forest and scratch up the soil and the virgin growth of corn is the result. The second crop, because of better cultivation, exceeds perhaps the first.– and for many years the abundance of the crop depends solely on the treatment it receives from nature and from man.– Too many farmers never think of the fertility of the soil– This year's crop was as good as last year's and perhaps better than that of the year before. They see the corn grow from the soil and is not soil everywhere abundant? How then can our crops ever fail.–

Plant food consists of some twelve or fourteen elements, Carbon (C), Hydrogen (H), Oxygen (O) Nitrogen (N) Calcium (Ca) Potash (K) Magnesium (Mg) Iron (Fe) Sulphur (S) Phosphorus (P) Chlorine (Cl) Iodine (I) and Silicon (Si) Of these, the first four are organic gaseous elements, being before used by plants, the product of life, and then again reduced to gases when the life form is burned. - The others are inorganic, and remain in the ash of the plant when it is burned. The organic elements were not in the soil when formed but have been accumulating through all these years.

The functions of a soil to the agriculturist are two fold. - 1st a mechanical support and 2nd a laboratory for the preparation of plant food and a reservoir for its storage, from which it can be drawn from time to time. Now whatever system of cropping is followed, the draughts or inroads upon these food products are bound to leave their impressions upon the soil. - The effect may be great or little according to the judiciousness of the cropping. and returns made to the soil, but heavy crops of corn and wheat, cannot be taken from the land year after year, without removing large quantities of plant food. - There are many means of returning these elements to the soil, from the use of barn yard manure to the use of chemical fertilizers. costing eighteen cents a pound. - But we will pass these all and take up a special one, having to do with the furnishing of the element nitrogen. (N) to growing plants. This element is indispensable to all growing plants. It is the essential constituent of albumen, which, in some form, has under recent research in agricultural economy been found to be the most essential of elements to both plant and animal organisms. All work of limb or brain is at the expense of N. All building up or development of muscular tissue is by the addition of N. All plant and animal reproduction is at the expense of highly organized nitrogenous material. What wonder, then, that the harvesting of N into plants and the furnishing of N to the soil would be of prime importance.

Nitrogen exists in nature in three forms. 1st The salts of the soil, 2nd Ammonia compounds in the air, and 3rd Free N of the air. Many of the salts of the soil are soluble, and being generally in very limited quantity, are soon used up as plant food or washed away. The ammonia compounds are in very small amount and do not furnish nearly sufficient N. for growing plants. while of the free N of the air, no plant has the power of taking it up and fixing it as a part of plant tissue. The only course left then would seem to be to add nitrates from some organic matter or from some of the beds of nitrates found in other countries.— This is, practically, the way it must be done, but, within recent years there has come under observation a method by which the free atmospheric N. is added to the plant by means of intermediate organisms.— That the free N would be an inexhaustible boon of wealth could it be readily utilized by plant or animal no one will deny.— But this priviledge is reserved to a microscopic bacterial form, living upon the roots of leguminous plants and perhaps a few other families.— That these plants have the power of using the free N. in some form, has long been suspected, but not until the Rothamstead experiments was the general truth known.— The method of experiment was somewhat as follows.— The soil was carefully analyzed and the amount of N it contained determined.— The amount in the seed was also determined as was that in the air.— After the plant had fully grown the amount in each was again determined and found to have increased in the leguminous plant but to have decreased in the soil and air to the same extent.

But the means by which this important gain is made:— It has also been noticed for a long time that upon the roots of these same plants grow little bunches or tubercles. For a considerable time, it was discussed from what source these arose, some claiming them to be insect galls, another roots and others that the growth was from the plant itself.— But Helrigel disproved this idea. He found that if the soil in which the peas were grown had been sterilized, that no nodules appeared, but that if infusions of water, from non-sterilized soils, be poured over the sterilized soil, that the nodules did grow.— Again if this water were boiled before pouring it over the soil, no nodules appeared as before.— all tending to prove that the infection came from the soil in the form of some organic body that could be killed by heat.— These results have recently been verified by Ward and others and the results more thoroughly studied.— The significance of these nodules has only recently been discovered. Certain German investigators among whom are Frank and Helrigel, have found among the organic contents of the nodule, first a few long filaments, which finally change into forked rod shapes, which have been named bacteroids. It is now known the bacteria live in the soil in hosts and collect on the roots of the leguminoseo. - If the root is old and the bark thick, the bacterial forms are not strong enough to pierce it, but if the roots are young and tender, as in the case of sprouting roots, they are easily inoculated. - The shape of the nodule and the form in which it appears on the roots, are also characteristic of the plant. - In Alfalfa (Medicago Sativa) the nodules present a very peculiar appearance, arranging themselves in a fan shape, radiating from a point, with the nodule somewhat lengthened and cysted at the outer end. - The clover (Trifolium Pratense) nodule is a single bunch, growing on either the main root or side roots without distinction. The peanut nodule is a larger one than either the clover or alfalfa one and grows on the main stem arranged thickly around it. - It grows here exclusively for two or three weeks when others appear on the lateral roots. Those of other plants also vary largely in size, shape, and arrangement from the almost microscopic to those of the honey locust, measuring from half to three-quarters of an inch in diameter. - globular and surface channelled. -

Now this tubercle must not be mistaken for the bacteria. It is an abnormal growth of plant tissue caused by the bacterial mycelium growing and ramifying in and around among the growing plant cells, and serving as a protection to the young mycelial growth. - The immediate process by which this transformation is made is not yet understood. Whether the bacteria utilizes it, and the plant absorbs it from the bacteria, or whether the plant transforms it directly, only facilitated by the bacteria, or whether the change is made by the combined life of both forms is yet an unsettled question. -

For personal observation of some of above facts, as well as what verification could be obtained, two series of experiments were undertaken in the college green house. - The first consisted of three plots of good loam soil, on which Soy Beans had been grown the previous season. In one was planted Soy Beans, in the second Red Clover and in the third peanuts, on Friday February 23" - 1894 The second series consisted of sixteen plots arranged as per diagram:–

Row	Red Clover	Indian Corn	Soy Beans	Pea Nuts
1				
2				
3				
4				

Experiment 2 was planted March 21" '94 The plants of both experiments were kept growing under favorable circumstances until they were dug and examined May 11" – The soil in Experiment 2 was in:—

Row 1 – Sterilized Blue River sand. – It was sterilized by being kept red hot, for an hour and a half, in an iron box, over a coal fire, The sand was then washed free as possible of whatever organic matter it might contain, The plants in this row had no fertilizer added to them and were watered always with distilled water. –

Row 2. – was good loam like that used in Experiment 1 —

Row 3 – was also of sterilized sand but when the seeds were planted there were placed in contact with them nodules from growing Alfalfa roots, dug the day before, March 20th - The plants were up on March 27th and were then treated with solutions of Calcium and Magnesium sulphate and with potassium phosphate (K_2HPO_4)

Row 4 was of river sand but not sterilized. It was provided with bacteria in a manner similar to row 3. - and in addition to the food elements added to Row 3, Row 4 had Calcium nitrate, ($CaNO_3$) - The object of Rows 3 and 4 being to see if the plants of Row 3 would do as well on the N. it must get from the atmosphere as would those of Row 4 which had the N. added to them in soluble form. Rows 2, 3, & 4 were watered with hydrant water. -

Experiment 1 was for observation of roots from time to time, to dig them up and note their appearances at different ages. Clover was the first to appear above ground and throughout the experiment the growth was good. - Nodules were found on its roots on March 26th - thirty-one days from planting. They continued to grow in number and size and on April 16th small ones began to appear on the peanut.- None were ever found on the Soy Bean even up to May 11". This experiment proves the presence of bacteria in the soil growing beans, and that if it requires different species to inoculate different plants, that all must be in the soil to more or less extent.-

Experiment 2 - Dug also May 11" presented some quite suggestive facts.- The clover of Row-1- started well but by April 10" it had made no growth over that of the first week. The plot was then replanted and the plants came up thick and looked well for a week when they began to disappear - and on May 11" but ten plants were growing nor were they any larger than at the end of the first eight or ten days - The roots were fine and pale and bore no nodules. The clover of Row 2 was normal but not any better than, if as good as that of Row 3 - which was strong, vigorous, tall and deep green.- The clover of Row 4 was not as good as that of Row 3, which fact must be explained on the ground of having been fed too much alkali food or something of the sort, as it had an even chance with that of Row 3 with the addition of N.- The roots of both Rows 3 and 4 had the normal number of nodules.-

The corn of Row 1 had made a good growth, and had large vigorous looking roots, though the leaves had been dying from the ends for several days. The roots and seed shell were partly covered with gray mould. It was fair in Row 3 and good in Row 4. quite an appreciable difference.-

In Row 1 the Soy Beans had grown four inches high. Each had two leaves and two cotyledons. They looked quite well.- Those of Row 3 were weak and dried. The root had dried or rotted out. but those of Row 4 were better and stronger than those of even Row 2. None of them bore nodules.-

In Row 1 there were four peanuts from one to four inches high, withering and dry; but a very characteristic contrast was noticed in comparing a plant from Rows 1 or 3 with a plant from normal soil. The normal plant of equal age was sixteen inches high, the plant from Row 1 was four inches.- The root of the latter was short and bore not a nodule, while the hypocotyledon was very fleshy and white and succulent.- The root of the normal plant was hard and covered with nodules.- while the hypocotyledon was dry and hard.- The peanuts of Row 4 were stronger and larger than those of Row 3. But now comes an important fact. that, while the plants of Row 3 made a fairly good growth, not a nodule could be found on a peanut from either Row 3 or 4 -

From this data, several really important facts can be deduced, and on the whole the experiments have proven even more satisfactory than was anticipated. - It was intended to do considerable microscopic work in connection with the experiment, with several purposes in view, but time has not allowed. - Among the important conclusions that can be drawn from the above are the following: ——

1" - That sterilization prevented any formation of bacteria on the clover. -

2" That the N added to Row 4 was not necessary where bacteria is provided in the soil as in the clover of Row 3 -

3" - That corn does comparatively better in sterilized soil than do the leguminoseo where no fertilizers are used. - This is but natural and would be expected as corn requires less N than leguminoseo. -

4. Corn grows better, comparatively in soil having N compounds added than do leguminoseo

explained on the ground, that they do as well in un-nitrified soil as in soil possessing N, by means of their bacteria. This corn cannot do.—

5"— The abnormal condition of the roots of the Soy Beans in Row 3 is sufficient to warrant a throwing out of this plot.— It is, therefore not antagonistic to our other assertions.—

6"— The fact of Soy Beans of Row 4 being better than those of Row 3 points to the general good condition of Row 4—

7" There being no nodules on the peanut in Rows 3 and 4, was rather a surprise after finding them on the clover. It will be remembered that the bacteria used in inoculation came from alfalfa roots Some doubt was felt as to the success of the inoculation, but that nodules grew on the clover of Row 3 proves, 1" that alfalfa nodules can inoculate the clover or 2" that clover bacteria were connected with them in being planted, or 3"— that they were added subsequently from the air— which is indeed highly improbable—

8'— Their not inoculating the peanut need not be detrimental to the theory that alfalfa species can inoculate other plants than alfalfa, when it is remembered that alfalfa and clover are much closer related than are alfalfa and peanuts. However, it seems that alfalfa species cannot inoculate peanuts, since the clovers of both Rows 3 and 4 were inoculated and the peanuts of the same rows were not.