Eighth Portion.

For the determination of soluble silicic acid treat the mineral in a platinum crucible with conc. KOH solution upon the water bath for one-quarter to one-half hour. Avoid too great concentration of the liquid, as the silicic acid dissolved would be reprecipitated. If it be suspected that the mineral decomposes, heat only for a short time. The contents of the crucible are transferred to a beaker, diluted strongly, washed by decantation with boiling water until no further reaction of KOH is obtained. The residue is heated and weighed; the operation is repeated until the weight is constant.

If, upon decantation, the precipitate should not settle or should run turbid through the filter, a slight acidulation of the wash water will frequently serve. In case free quartz was present, this would become partly soluble on heating. In such case the mineral is treated several times with KOH solution, decanted each time, as described, but only heated and weighed once, which weight must then suffice.

College of the City of New York, May, 1890.

A CONTRIBUTION TO THE QUESTION OF ASSIMILATION OF ATMOSPHERIC NITROGEN.[1]

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Translated by L. H. Friedburg, Ph. D.

The question of the intervention of atmospheric nitrogen in the nutrition of plants is certainly one of the greatest importance for the chemist as well as for the physiologist.

Almost forty years ago Boussingault and Ville published the

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[1] Mémoires couronnés et autres Mémoires publiés par l'Académie royale de Belgique, 1889. Tome XLIV.

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results of their researches, which contradicted each other, and since then the question has been under constant discussion.

Chemists, knowing nitrogen as an element very indifferent in respect to combination, have, almost without exception, sided with Boussingault, who maintained that nitrogen did not participate at all in the nutrition of plants, unless it had previously entered the molecule of ammonia or of nitric acid. The question has within a few years assumed a new phase and to-day we must admit that the balance inclines sensibly towards the side of the "Nitrists."

This is not to be understood in the sense of an immediate fixation of elementary nitrogen by the cells (Ville, Franck), but rather of an indirect introduction of it into the nutrition of the plant. In this regard some investigators discuss the question of enrichment of the soil by way of micro-organisms, or consider the fixation of nitrogen by organic matter as going on under the influence of electricity (Berthelot, Dehérain, Gautier and Drouin, Tacke); others defend the opinion that this fixation is provoked by microbes living in a state of symbiosis in the interior of the nodose roots of vegetable plants (Hellriegel and Wilfarth, Bréal).

Considering the naked soil, Schlœsing has denied its enrichment by atmospheric nitrogen and he defends his opinion in several papers presented quite recently to the Academy of Paris. The number of soils which he has studied in this regard is daily growing and *he has not yet found a single one which, being void of vegetation, could fix gaseous nitrogen.*

Several authorities, also, (Wolff and Kreuzhage, Atwater, Putensen), have found in the crop of certain vegetable plants *more* nitrogen than was contained in the soil and the fertilizers of artificial cultures, although without always giving an account of other possible sources or losses of nitrogen and without expressing an opinion in regard to the origin of the surplus obtained.

This, it seems to me, in few words, is the actual position of this question.

The purpose of the following research is to contribute to the solution of the "nitrogen problem," establishing from this point of view the complete balance of a culture of lupines, which has been executed under absolutely determined conditions. I have chosen the lupine, because the "nitrists" consider this vegetable plant as particularly endowed with the faculty of drawing nitrogen from the subtile source of the atmosphere.

In order to state our problem, let us call—

N^r total nitrogen contained in the crop;

N^g total nitrogen contained in the seed;

N^s total nitrogen contained in the soil at the beginning of the experiment;

$N^{s'}$ total nitrogen contained in the soil at the end of the experiment;

N^e total nitrogen furnished by the fertilizer;

N^p total nitrogen contained in the rain water (ammoniacal, nitrous-, nitric-);

$N^{p'}$ total nitrogen contained in the drainage water;

N^x atmospheric nitrogen.

From these figures we are able to deduce the following equation:

$$N^r = N^g + N^s + N^e + N^p + N^x - N^{s'} - N^{p'};$$

from which follows:

$$N^x = N^r + N^{s'} + N^{p'} - N^g - N^s - N^e - N^p.$$

Supposing that each of these items was exactly determined, this second equation will allow us to establish the value of N^x and to decide whether, in the production of a certain weight of lupines obtained under the conditions of our experiment *there was or was not an intervention of atmospheric nitrogen.* This equation, which must give us a categorical answer for the cultures *without* nitrogenized fertilizer and also for those receiving "nitric" nitrogen may leave us in doubt in regard to those, the fertilizers of which contain ammoniacal or organic-nitrogen. For, we know, according to the researches of Reiset, Ville, Lawes and Gilbert, König, Morgen, Schlœsing and Pichard, that nitrification causes a loss of free nitrogen, which is insignificant or *nil* in the case of slow nitrification of organic nitrogen of the soil; it is a little higher at that of ammonia but important enough in case of nitrification of organic nitrogen of fertilizers. If the arrangement of our experiments allows us with certainty to trace the nitric nitrogen which results from this oxidation and to find it again in the plant, or the soil or waters of drainage, this is altogether different for the emanation of elementary nitrogen, the determination of which escapes us. A gain in nitrogen noted in this case is therefore necessarily a minimum, if this gain be not hidden through a loss of elementary nitrogen.

For this first series of experiments I have put aside the question as to how, by what mechanism or chemism, the intervention of elementary nitrogen might eventually take place. I desired above all to settle the question *whether* the fixation of gaseous nitrogen takes place, because, as I have said before, the question is far from being decided.

The arrangement of our experiments should also permit us to verify the assertion of certain nitrists, who, in spite of the culture experiments of Proost[1] and others, pretend that the faculty of certain leguminous plants to transform elementary nitrogen into organic substance, exists to such a high degree, that they will not utilize, or only utilize in an absolutely insignificant proportion, the nitrogen offered to them in the form of fertilizing matter.

Our experiments have been performed in vegetation compartments the perfect description of which we have given in our paper, a contribution to the chemistry and physiology of the sugar beet.[2] We refer here to the fact that the arrangement of these boxes allows to realize the following advantages:

1. A perfect separation of the experimental soil, as well as the fertilizing elements and the liquids circulating in that soil, from the surrounding earth.

2. Equal exposure of all boxes to rain, heat and light.

3. The compartments receive exclusively that quantity of rain which falls on the surface of one square metre, and all danger of loss of water is avoided. From this it is evident that all the vegetation boxes are under conditions absolutely comparable.

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[1] Revue des questions scientifiques, 1886.

[2] Mémoires couronnés et autres mémoires publiés par l'académie royale de Belgique, 1889; vol. XLIII.

With respect to the special point of this study of the nitrogen question, I add, that the dimensions of the vegetation boxes offer this great advantage : they admit of experimentation in each case with a certain number of plants (36) and thus of work independent of the influence of the individuality of the plants themselves. I am convinced that one of the principal causes which has led to contradictory conclusions, so frequent in physiological research, is to be found in the non-observance of this rule of experimentation.

CONCLUSIONS.*

1. In growing plants of yellow lupines (*Lupinus lutens*) in sand containing the bacteria of soil, but very poor in nutritive elements, using vegetation compartments so arranged as to allow a perfect control of all conditions of the experiment and further, accurately determining the proportion of nitrogen contained in such sand before and after the experiment, as well as in the seed, the waters of rain and drainage, and in the crop, we observe finally, considering the total of roots, soil and aerial part, an important gain in nitrogen, due to the intervention of atmospheric nitrogen.

2. This gain increases with the quantity of organic substance produced. In our experiments it amounted to three times the quantity of the mineral fertilizer (potassium and magnesium sulphates) used. This phenomenon does exist, when an abundance of sodium nitrate is used as a fertilizer. The gain is partly hidden by a loss of elementary nitrogen, due to the nitrification of ammonia and of organic nitrogen in the compartment, where the sodium nitrate was replaced by an equivalentquantity of nitrogen in the form of ammonium sulphate or of dried blood (sterilized).

3. Contrary to the opinion of some authors, our experiments proved, that the lupines absorbed and assimilated (that is

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*Concerning the raw material used as well as the mode of procedure followed and the detailed analytical data, we refer to: *Bulletin de la station agronomique de l'état a Gembloux*, 1890, No. 47. From these extensive experiments, the following conclusions were reached. L. H. F.

to say utilized for the production of organic substance) nitrogen which was furnished in the form of a fertilizer.

4. The nodes of the roots of lupines are sensibly richer in nitrogen than the rest of the plant, particularly in those experiments which show an increase of nitrogen. However, this observation cannot be used as a support for the hypothesis according to which the presence of nodosities, or of microbes inhabiting the same, should be the exclusive cause of the assimilation of atmospheric nitrogen:

(*a.*) Because the increase of nitrogen is not only noticeable in the plant alone, but also in the soil;

(*b.*) Because the gain of nitrogen by enrichment of the soil has been obtained in the culture of plants which did not possess nodosities upon the roots.

5. The pure culture proves the identity of micro-organisms of the soil in which the lupines grew with those occurring in the nodosities of the root of this plant.

I stated at the beginning of this paper, that the aim of my study was to contribute to the nitrogen question, by taking account of nitrogen furnished and lost in a culture of lupines, performed under conditions which would give complete control of the course of the experiment, in order to decide whether an intervention of atmospheric nitrogen exists or not. I have to conclude by answering this question in the affirmative.

This first statement being now made, we shall have to ask in addition whether the important increase which balances our account of lupine culture can be explained (in spite of the small probability which a calculation, based upon the researches of Schlœsing offers) by the presence of *combined* nitrogen, diffused through the atmosphere, or whether it must really be attributed to an intervention of *elementary* nitrogen.

A new series of experiments, performed under particular conditions, will allow us to answer this part of the question. We shall also repeat the above experiments with other leguminous plants and finally with other families of plants.