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Address of Dr. Hubbard
on Nitrogen

The matter embraced in this Bulletin is recommended to the careful consideration of every farmer, as treating in a clear and exhaustive manner one of the most exhaustive subjects relating to Agricultural progress.

E. C. BETTS.

ALABAMA DEPARTMENT
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NITROGENEOUS MANURES.

ADDRESS OF PROF. WM. C. STUBBS

BEFORE THE STATE AGRICULTURAL SOCIETY ON THURSDAY, AUGUST 6TH.

Mr. President, Ladies and Gentlemen:

At the special request of several members of this convention, my subject has been assigned me. Though technical in its character, and involving some of the latest scientific researches, I shall endeavor as far as possible, to divest it of chemical terms, and present it in a plain, practical manner.

Nitrogen is the desirable element in nitrogenous manures. In its natural condition it is a gas; lighter than air, and noted for its negative properties. It can neither support combustion nor sustain life. It is not combustible. It has but little chemical affinity; forms but few compounds, and these of so little stability, that the slightest disturbance of their molecular equilibrium, causes them to assume instantaneously a gaseous condition, thus giving rise to some of our most dangerously explosive substances. The well known force of gun powder, gun cotton and nitro-glycerine in its various forms of dynamite, dualin, rendrock and giant powder, is due to the presence of this ingredient and its instability in these compounds.

Nitrogen is an abundant element constituting four-fifths of the air, in which we live, move and have our existence,

and yet is the most costly ingredient in all fertilizers. It is an essential element in all plant food, and while the foliage of all land plants are bathed in an atmosphere so rich in this substance, yet carefully conducted experiments have demonstrated their inability to utilize it in a free state. Hence the supply of plants must be furnished in some of its compounds, mainly ammonia and nitric acid, and organic substances capable of yielding these compounds on decomposition.

The atmosphere has, however, furnished all the nitrogen in the world, not directly, but by processes of oxidation and decay, the details of which are even yet but imperfectly understood. Minute quantities of nitric acid and ammonia are always found in the air. From the latter, they are easily removed by the rains and dews, and carried to the soil, where they serve at once as plant food. Nitric acid is formed in the air by electrical discharges, silent or audible. The peculiar sulphurous odor, perceptible after a thunder storm attended with great electrical display, is familiar to us all. This odor is due to ozone, an allotropic condition of oxygen—endowed, however, with greater activity and higher oxydizing power. A small quantity of this same substance (ozone) is generated in every act of combustion and oxidation, and accompanies the oxygen which is exhaled from the green foliage of plants. This ozone readily oxydizes the nitrogen of the air to nitric acid, which is washed to the soil by the falling rains.

From the above we would infer that plants which possess the largest leaf surface would exhale the largest quantity of ozone and produce the largest amount of nitric acid. Experience and experiments have demonstrated the truth of this inference. Compare clover with wheat, cow-peas with oats, cotton with corn. The custom of crossing cotton with corn which prevails in our "black belt" is approved by the researches of chemistry—even though the "Entomologist" would decry it as a fruitful way of propagating that cormorant of insects, the "boll worm," and the "Botanist" condemn it as an uncertain method of securing full fertilization of the corn grains by the pollen from the tassels. The cotton in this instance becomes the purveyor of nitrogen for the corn. By this agency then of ozone generated in various ways, the atmospheric nitrogen is primarily rendered available to plants.

The ammonia found in the air may result from combustion, or by the action of vapor of water and air upon organic matter at a high temperature, or it may be formed by the action of alkalies, (soda, potash and lime) on albuminoids—it may be the resultant of the reduction of nitric and nitrous acids, or it may proceed from the decay or destructive distillation of any organic substance containing nitrogen. Its name originated at the temple of Jupiter Ammon in Lybia, Asia Minor, where the manure of camels was subjected, by inquiring monks, to the destructive influence of the alembic of the alchemist.

These two substances nitric acid and ammonia are thus constantly present in minute quantities in the air and are mutually convertible, the one into the other. Here oxidation prevails and nitric acid is the result, there reduction preponderates and ammonia is left. "It is only as the one or the other resultant of this ceaseless action is withdrawn from the sphere of change that we can assign it permanence and identification. The quantities brought down by the rain and which we weigh and measure are the resultants of forces that constantly oppose each other. The idea of rest or permanence is as foreign to the chemistry of the atmosphere as to its visible phenomena." These substances are only of appreciable use to plants after the rains have carried them to the soil.

Carefully conducted experiments extending over many years have shown that the quantity of nitrogen, thus annually supplied to the soil, is from eight to twenty pounds to the acre, varying with location, distance from large cities

and quality of crops. This is equivalent to the nitrogen contained in from 100 to 250 pounds cotton seed meal.

Both nitric acid and ammonia are capable of supplying directly nitrogen to plants. The former enters the plant as such during all periods of growth, and is capable, alone, of supplying directly all the nitrogen needed by plants. The latter is utilized at certain periods of growth and by certain families of plants, but its ready susceptibility to oxidation into nitric acid renders it doubtful as to whether it enters the plant as ammonia or nitric acid. On reaching the soil neither of these compounds remain as such. The ammonia is either volatilized or subjected to chemical changes. It is converted into nitric acid or into the insoluble double "humates." We are familiar with the permanently good effects of the application of large quantities of stable manure. Now, in the decomposition of the stable manure, the ammonia and humic acids formed, unite at once with the bases of the soil and form double insoluble salts, which thereafter are but slowly available as plant food. We know, too, the excellent results accruing from an application of lime, plaster or salt upon lands rich in "humus"—the unloosening of the ammonia from its double union.

Nitric acid on reaching the soil must be utilized at once by the growing crop, or else it will be either leached beyond the reach of plants or reduced to an insoluble form.

Thus far we have spoken only of the atmospheric supply of nitrogen, the only supply in the beginning of plant-life on the globe, but now, after the accumulation of the remains of vegetable and animal life through countless ages, this annual supply of nitrogen, though vast in the aggregate, is yet insignificant compared with the vast reservoirs stored away in our soils.

In using the expression "nitric acid," we mean this substance in combination with bases, such as potash, soda, lime, etc. The bases are omitted, simply because in the acid itself

the nitrogen is found. Nitric acid is never found free in soils—always in combination.

From the rainless coasts of Peru and Chilli we obtain nitrate of soda. In Bengal, India, during the dry season, an efflorescence occurs upon the surface of the soils, which is scraped off, purified and sent into the markets and sold as nitre, saltpetre, or nitrate of potash. So rich are these soils that several crops of grain are removed from them during the rainy season. This saltpetre is an ingredient of gun powder, and so urgent were the demands for the latter during the late war that our Confederate Government established a regular "Nitre Bureau" and men were employed whose sole occupation was the manufacture of "nitre."

Sheltered caves and caverns became theatres of active chemical operations. The dirt, which had remained undisturbed under old houses for a century, was subjected to lixiviation. "Nitre beds" were found on every hand and the ingredients necessary therefor were carefully collected and judiciously manipulated.

The manufacture of nitre in beds or plantations has been known and practiced for centuries. Even now, in some countries it is made the duty of every adult male inhabitant to keep a nitre bed and contribute annually so many pounds of nitre to his government.

But what is a "Nitre Bed?" Roughly constructed it consists of refuse organic matter containing nitrogen, a small quantity of a mild alkali, as lime or ashes, a little moisture and all mixed with a quantity of porous earth so as to generate heat and have free access of air. Fermentation soon ensues, the nitrogen becomes oxidized into nitric acid which unites with the alkali. By subjecting this earth to lixiviation and crystalization nitre is obtained.

This conversion of nitrogenous compounds into nitric acid is called *nitrification*. It is really a chemical change, occurring whenever certain conditions are fulfilled. These conditions have been recently studied and are now well un-

derstood. They are First, organic matter containing nitrogen. Second, aeration as oxygen of the air. Third, presence of a mild alkali, as a carbonate e. g. lime. Fourth, certain degree of heat and moisture, and fifth, the "nitric ferment."

Messrs. Schlossing & Muntz have found after patient investigation, that all nitrification was due to the presence and work of a living principle—a vegetable germ—a ferment analagous to the vinegar germ, that increased by fructification and multiplication of itself, that can be isolated and distinguished under the microscope by its shape, size and characteristic appearance, and they have called it "nitric ferment." This germ can be destroyed like other germs; chloroform, deprivation of oxygen, heat of boiling water, all destroy it. Excessive humidity prevents multiplication. This ferment flourishes best in an earth rich in vegetable matter and no soil can be fertile without it. Its reactions are accomplished within definite limits of temperature. Below 41 degrees F. its action is very feeble; it is appreciable at 55 degrees F. As the temperature is raised beyond this point the quantities of nitrates formed are rapidly increased, reaching the maximum at 98 degrees, and then decreasing until we reach 131 degrees F., when there is no trace of it. Other things being equal, ten times more nitrates can be obtained at 98 degrees than at 59 degrees. Temperature then is an important factor in the production of nitrates. Free access of oxygen is an indispensible condition, and a superabundance of air should always be found circulating through the pores and interstices of a nitre bed. If this is prevented by excess of moisture, a retardation in the formation of nitrates is apparent. Still the presence of moisture is absolutely necessary and nitrification is more active, as the humidity is increased, provided you do not reach the degree of saturation which prevents the free circulation of air, if so, their nitrification is relaxed or completely arrested. A weak alkali is necessary to the production of nitre. In the soil

this alkali is usually the carbonate of lime. Lastly, nitrification takes place with the same intensity in the dark as in places feebly lighted, but in stronger light a marked relaxation takes place, due to secondary phemomena. In the soil, when the surface particles are alone subjected to direct light, this influence cannot be great.

With this explanation of the theory of nitrification, let us turn to our soils. Under the influence of this nitric ferment, nitrates are being formed in every productive soil by the nitrification of the original nitrogenous humic matters of the soil, or from the decay of crop residues (roots, leaves and stubble) or from the nitrification of organic nitrogenous manures, as cotton seed meal, dried blood, fish scrap, stable manure, etc., or from oxidation of residues of ammoniacal manures not previously nitrified. These nitrates are found mainly in the first nine inches of the soil, and if not at once utilized by growing plants, they will either be leached beyond the reach of the plant, or transformed to ammonia and this in time to an insoluble form.

That there is a heavy loss of nitrates by leaching, is susceptible of easy demonstration by analyzing the water from the drain pipes. Messrs. Lawes & Gilbert have determined this loss upon their soils to be from 30–80 pounds of nitrogen per year, depending entirely upon the character of the soil, kind of crop, and nature of manure. Loose, porous soils favor leaching, while retentive ones favor reduction of nitric acid to ammonia. Bare fallow, favors both nitrification and leaching. If bare fallow in summer is followed by a wet fall or winter, a serious loss of nitrogen occurs. The leaching from lands occupied with crops is far smaller than from unoccupied lands. Nitrates are formed most rapidly during the summer and early fall, and the leaching begins with the fall of the first rains thereafter. Drainage water from lands fertilized with nitrogenous manures alone contained large quantities of nitrates. Nitrate of soda when applied as manure, suffers loss from leaching

using large quantities of cotton seed and stable manure alone, are annually sinking a large amount of money in loss of the most costly ingredient of fertilizers. Better far for them that they exchange a portion of their cotton seed for acid phosphate than to use an excess of nitrogenous manures alone.

Again, an undue preponderance of nitrogen in our manures, unnaturally develops the organs of vegetation at the expense of the organs of reproduction, or as we often say in common parlance, causes our plants to "run to weed." The necessity of humus, or vegetable matter, in our soils is now apparent. Humus is never destitute of nitrogen, and often rich in it, and by the process of nitrification, is an unfailing source of nitrogen to our crops. Continuous clean culture is rapidly depleting our original stock of humus in our soils, and such a rotation of crops which shall at least once in three years involve the turning in of a green crop, should at once be instituted to arrest depletion. A deep-rooted green crop would also utilize the nitric acid in the lower layers of the soil and thus place it within reach of the succeeding crops.

The value of under-draining is also rendered apparent, since nitrification is partially or wholly checked by excessive moisture. Excessively wet weather is injurious to crops, because in tenacious clays it arrests nitrification, and in porous sands or loams it washes the nitrates as fast as formed beyond the reach of plants.

Since the oxygen of the air is an important condition of nitrification, we see a reason for frequently stirring the soil with the plow and continuing this during the period of growth. It tells us also why the crust of the earth should be broken after every rain. It suggests to us the propriety and economy of always keeping our soils occupied with a crop, and of never leaving a "bare fallow."

The temperature at which nitrification is suspended is rarely reached in the South; therefore we can safely say

with the first rain. Sulphate of ammonia suffers conversion into nitric acid almost immediately after its application to soils, and if wet weather prevails conversion is complete in a few weeks. Cotton seed meal is more slowly converted into nitric acid. Manures containing proper proportions of nitrogen, phosphoric acid and potash, give little or no waste nitrate in the drainage, but with excess of nitrogen or deficiency of ash constituents the nitrates produced are imperfectly assimulated by crops and appear in the drainage water.

Again. Nitrates are always found in the waters of springs and rivers, varying in quantity according to the fertility of soils and proximity to cities. Hence, wells in crowded cities are always condemned by sanitary boards.

Let us draw some practical conclusions from the foregoing remarks. We learn that nitric acid and ammonia are the forms in which nitrogen are supplied to plants—that on account of their ready solubility they should be used as manures, with great caution, and never applied except to a crop sufficiently advanced in growth to appropriate them at once. As top dressings for grain in early spring in small quantities, several times repeated, they are to be recommended especially upon soils with retentive sub-soils.

As sources of nitrogen in fertilizers for cotton and corn, to be applied in early spring, ere the crops are planted, they have utterly failed to produce satisfactory results. They have accordingly been justly superceded by nitrogenous manures, such as dried blood, fish scrap, tankage and cotton seed meal, which slowly nitrify and gradually supply the crop with nitrogen just when its growth demands it.

Again, since nitrogenous manures, when used alone, are subject to far greater loss by leaching than when applied with proper proportions of mineral fertilizers, we readily see what a wasteful folly it is to apply cotton seed and stable manure to our crops, unless accompanied in the right proportions with acid phosphate and kainite. Planters, in

that nitrification proceeds throughout our winters. The conditions of the ground, from which the cotton crop is removed in the fall, are peculiarly favorable to nitrification which proceeds without interruption throughout the winter. Should no crop occupy the ground during this time, the heavy rains of winter and spring will wash a large quantity of nitrates from the soil. This annual depletion of our soils seems under our present system unavoidable. The discovery of a crop which could profitably occupy the ground between the gathering of one cotton crop and the planting of another would be a great boon to Southern agriculture. At present, cotton, known to be one of the least exhaustive crops, is under our present system of leaving our lands in "bare fallow" during the winter, proving to be one of our most exhaustive.

Applying now the principles learned in the foregoing pages to our chief crops, we think we can explain many phenomena hitherto but imperfectly understood. Corn, our staple grain, belongs to the cereals, and the known demand of wheat, oats, barley, &c., for nitrogen has caused many chemists to provide for an abundance of nitrogen in all manures for this crop. But it has been found that it does not always respond to large doses of nitrogen. Why not? Unlike other cereals, it is planted in the spring and gathered in late fall, thus getting the benefit of all the nitrates produced during this time. From the atmosphere, by rains, and from the soil, by nitrification, large amounts of nitrogen have been supplied, nearly enough in many instances to supply the crop. On poor soils, destitute of vegetable manures, nitrogenous manures properly combined with mineral elements, will always pay.

If mineral manures be wanting, corn will not thrive in soils filled with vegetable matter, nor vice versa. Therefore we can readily see why corn gives different responses to different manures on different soils.

The same remarks are applicable to cotton. The cotton

plant, as a whole, contains a large amount of nitrogen, but we all know by experience that only a small amount is necessary in the manures best adapted to it, and this small amount must be properly mixed with a large quantity of phosphoric acid. There are several reasons why cotton requires less nitrogen than corn, prominent among them are the following: It has a long tap-root, and is thus enabled to gather nitrogen from the lower layers of the soil. It has a large leaf surface, which generates more ozone which increases its atmospheric supply of nitric acid. It is cultivated oftener and later in the season than corn, thus inducing greater nitrification and its period of active growth extends further into the season than corn, thus getting the benefit of the heavy nitrification of late summer and early fall. These will explain why cotton does not require manures rich in nitrogen.

A few general reflections and we are through.

The ease and rapidity with which the crab grass takes possession of our corn fields in late summer and fall, after the cessation of growth by the corn, is often noticeable. Grasses flourish the best when supplied with heavy doses of nitrates. May not the nitrates now so abundantly formed be the cause of the luxuriance of the grass?

Again, experience has taught us that our cow peas do best when planted in summer. The pea is regarded as a renovator of soils; it has the power of assimilating large quantities of nitrogen and storing it away in its seed and foliage, ready when turned under, on account of its succulent nature, to give it to the growing crop. May not the true explanation of its success as a late crop, and as a renovator of soils, be, that it finds abundant supplies of nitric acid at this season which it could not obtain earlier, and storing it away in large quantities, is ready when decay comes to yield it up in an easily assimilable form.

Another reflection: Our long dry summers without rains, so destructive to cotton and corn, are followed by ex-

cellent small grain crops, if the latter are grown upon fallow land or those just occupied by cotton. The explanation may be that the large amounts of nitric acid formed during the summer and fall, remaining unused in the upper layers of the soil, is ready when disolved by the rains of winter to be used by the small grain.