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HE NITROGEN PROBLEM IN AGRICULTURE

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by

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CHAPTER I.

THE INTRODUCTION.

The Importance of Nitrogen in Agriculture.

Among the elements which have been proven necessary for plant life, Nitrogen must be given first place. It is more likely to be lacking under poor systems of soil management than any other element, and when it is added it has a more distinct and rapid effect upon the plant. It also costs the farmer more per pound than any other element. These things and the large amounts of nitrogen removed by plants and lost in other ways tend to make the nitrogen problem the most important in many sections of the country, and in most types of farming.

The History of Nitrogenous Fertilizers.

In early times when animal excrement was used as a fertilizer, it was thought that the action was purely physical. This is shown by the French word manoevrer, which means to work with the hand, from which the English word manure is derived. The chemical action and the use of mineral saltsfor increasing the yield of crops was first published by Sir Kenelm Digby in 1669. He says, "By the help of plain salt peter, diluted in water and mingled with some other fit earthly substance, that may familiarize it a little with corn into which I endeavored to introduce it, I have made the barronest ground far outgo the richest in giving prodigiously plentiful harvest." The true reason for his results was only partially understood. It was not until 1804 that De Sausure recognized the necessity of the chemical ingredients of the plant for the growth of the plant. About 1804 Liebig advanced his theory that certain elements are necessary for plant life. He recognized ten elements which are absolutely necessary for plant life and of these nitrogen is the most important.

The fact that nitrogen must be present in a combined form was first clearly demonstrated by Laws, Gilbert and Pugh in 1857.

The Nitrogen Cycle.

There are two of the elements essential to plant life which go through complex cycles. These are carbon and nitrogen, but the carbon cycle is not so important because the plant can use the carbon dioxide of the air, while the nitrogen of the air, although it forms about 77 per cent, can not be used by plants to any appreciable extent. Some of the details of the nitrogen cycles will be considered later, but at this point a general outline of the cycle will be given.

As has been mentioned above, the air contains about 77 per cent of free nitrogen, but no cases have been found where free nitrogen is used by higher plants. Higher plants use nitrogen only in the form of nitrates or of ammonia, the former being the most common. Bacteria and the lower plants may use nitrogen in other forms including the free state, and in this way take an important part in the nitrogen cycle. The nitrogen taken into the plant combines with carbohydrates or fat to form living proteins. These proteins are either eaten by animals or they fall to the ground when the plant dies and undergo decomposition. If they are eaten by animals, they may be used as a source of energy and be excrated in a less complex state which is usually urea (CON_2H_4), or they may be retained in the animal's body in the form of animal proteins, which are returned to the soil at the death of the animal; or, if the proteins are eaten and are not digested, they may be returned to the soil in their original state. The plant and animal proteins (and their decomposition products) undergo a very complex decomposition. The earlier stages are often carried on by fungi, while the later stages are carried on by bacteria. The nitrogen is usually changed into ammonia, in which state it is acted upon by several specific types of bacteria which change the nitrogen into the nitrite stage. An entirely different group of bacteria then oxidize the nitrites into nitrates, which are again used by the plants. Denitrifying bacteria may act on either nitrates or nitrites reducing the nitrogen either to a lower form or to free nitrogen. Free nitrogen may also be liberated from ammonia and probably from other nitrogenous compounds. This loss of combined nitrogen must be replaced in some manner. This is done by the action of electricity (lightning) and by nitrogen fixing bacteria, such as the symbiotic leguminous bacteria. These will be studied more in detail later.

The Future Supply of Nitrogen.

The future supply of nitrogen available for higher plants, is a question mentioned by some writers. With the methods of rotation using legumes and the electrical methods of fixing the nitrogen of the air for commercial use, there is little probability of the supply not being large enough. The great question, therefore, is to obtain the future supply in the most economic manner. It is upon this question, and the question of how to retain as much as possible of the combined nitrogen now on the farm, that the following observations will attempt to shed light.

CHAPTER II.

NITROGEN FIXED FROM THE AIR.

Legumes

Among the means of adding nitrogen to the farm or to the world's supply of combined nitrogen are the methods of fixing nitrogen from the air. This is carried on either by bacteria or by electricity. If there is an oxidation of atmospheric nitrogen by any other means at present, it is so slight that it may be left out of consideration. Any increase in the future supply of nitrogen to the farm must come from this source, or from deposits of nitrogen, which has been fixed from the air in the past.

The most important means of adding nitrogen to the farm and also to the world's supply, is the growth of leguminous crops, which are either used as green manuring crops, or the crop is harvested, fed to the stock and then the manure is returned to the land. It has been shown that most legumes growing on ordinary soil fix about two-thirds of their nitrogen from the air. If the crop is removed, about two-thirds of the nitrogen is removed, thus there is no increase in the nitrogen in the soil. If the soil is already rich in nitrogen the legume will take its nitrogen from the soil and only a very small amount is fixed from the air. Thus the legume should be grown on soil poor in available nitrogen, or should be made to follow in a rotation, some crop which draws heavily on the nitrogen supply. When a good stand of a legume like alfalfa is obtained, it should be grown there for several years, harvesting the crop and adding the manure to other sections of the farm. Thus the legume is kept on soil poor in nitrogen and it is forced to take its supply from the air.

The nitrogen fixing power, which is peculiar to legumes, is due to the growth of symbiotic bacteria which are found in the nodules found on the roots of the legumes. The bacteria depend upon the host plant for most of its energy. It takes the nitrogen from the air and changes it to some form in which it can be used by the host. This form is probably a nitrate or possibly as ammonia, no quantity of nitrogen accumulates in the nodules, thus the exact form is not definitely known.

Fixation by Non-symbiotic Bacteria

Another means of fixing atmospheric nitrogen is by means of non-symbiotic bacteria, which normally live in the soil. There is as yet no means of cultivating these on artificial media and thus innoculating the soil. This has been attempted but without success. It has long been known that uncropped land increases in fertility and in nitrogen content. When rocks decay leaving a soil free from nitrogen some nitrogen fixing organism must be the first growth. Some of the plants which are first seen on these soils such as fungi and algae may fix nitrogen from the air, but their growth is usually due to non-symbiotic or possibly to symbiotic bacteria.

Fixation by Electricity

In the fixation of atmospheric nitrogen by means of electricity both the natural and the commercial processes and possibilities will be considered. The process is the same in both cases. The electricity passing through the air, which is composed almost entirely of nitrogen and oxygen, causes these two elements to unite in the form of either nitrous (NO) or nitric (NO_2) oxide. If the former is produced it is immediately oxidized to the dioxide form by contact with more oxygen.

This result is produced when lightning passes through the air and the nitrogen thus combined is brought to earth in the rain or snow.

The nitrogen content of rain and snow is given in the following table published by Frank T. Shutt, M.A., F.I.C. in The Proceedings of The Royal Society of Canada (1908):

Month and Year	Precipitation in inches			Nitrogen parts per million				
	Rain	Snow	Total as inches rain	Free NH	Album-inoid N	Nitrates and Nitrites	Total	Pounds per acre
1907 March	1.55	11.50	2.70	2.25	.049	.193	.467	.286
April	2.59	7.25	3.32	.32	.056	.120	.496	.372
May	1.56	7.50	2.31	.082	.033	.065	.181	.094
June	2.20		2.20	.49	.156	.147	.793	.395
July	3.73		3.73	.275	.117	.145	.537	.454
Aug.	1.13		1.13	.369	.102	.114	.585	.150
Sept.	3.32		3.32	.503	.129	.137	.769	.579
Oct.	2.70	1.00	2.80	.434	.085	.193	.712	.452
Nov.	3.37	5.50	3.92	.349	.063	.064	.476	.423
Dec.	.81	34.75	4.28	.349	.096	.171	.616	.597
1908 Jan.	.13	30.25	3.16	1.56	.059	.149	.364	.260
Feb.	.96	35.25	4.48	.098	.053	.106	.257	.261
Total for 12 mo.	24.05	133.00	37.35					4.323

Forty-six samples of rain water were analyzed and 32 of snow. 74% of the nitrogen was as ammonia or its salts. 26% was as nitrates or nitrites.

Dr. N. H. J. Miller in an article "The Composition of Rain Water at Tothemsted" in the Journal of Agricultural Science, Vol. I, Part 3, Oct. 1905, reports that the rainfall of one acre during 13 years contained annually 3.84 pounds of nitrogen as ammonia, nitrites and nitrates, 70% of which was NH_3. This is very similar to the results obtained by Shutt at Ottawa, which as recorded above was 4.32 pounds of nitrogen per acre per year, 74% of which was NH_3.

Since the nitrogen fixed by electricity is deposited only as nitrites or nitrates the ammonia must be due to some other cause. This is probably the ammonia which passes off into the air during fermentation processes, and which is thus returned to the soil in this manner. The albuminoid nitrogen is largely due to dust.

The high cost of nitrogenous fertilizers, the large per cent of nitrogen in the atmosphere, and the undesirable features in the handling of nitrogenous fertilizers now available, have been the causes for a wide investigation of the possibilities of fixing atmospheric nitrogen on a commerical scale. Basic calcium nitrate and calcium cyanamide are the fertilizers which have been made in this manner. Their manufacture depends upon an abundant supply of lime and chey power, which is usually water power.

The first important commercial production of nitric acid from atmospheric nitrogen was by the Bradley-Lovejoy process at Niagara Falls. Air was passed through a rapidly alternating high tension electric spark. The oxidized nitrogen was then absorbed in water forming nitric acid. This factory did not last long because of the development of the Berkeland-Eyde process in Notodden, Norway, where lime and water power were cheap. This process used a spark spread by powerful magnets so that more air, which was forced through, came in contact with the spark and was acted upon. The air was conducted to towers where the nitrogen was absorbed in an excess of lime, producing a mixture of lime, nitrites, and nitrites. The principal component of this mixture seemed to be a definite $2\ Ca\ O\ N_2\ O_5\ \ 3\ 1/2\ H_2\ O$ which is a true basic lime nitrate.

Another method is to pass air through a long tube through which an electric arc 30-50 feet long, is maintained continuously for months. The acid produced is stronger than that produced by the other methods. In this method as is the case with most of the other methods where nitric acid is produced, lime is added and calcium nitrate $(Ca\ N\ O_3)$ is the form used as a fertilizer.

The Rankin process is secret and not known to the public. It was a lower tension current. The company proposes to use their acid in making superphosphate or reverted phosphate, which using nitric instead of sulphuric acid, would contain nitrogen instead of sulphur and thus making a very valuable fertilizer containing both nitrogen and phosphorous.

Another method of fixing nitrogen from the air is in the manufacture of calcium cyanamide. This is a comparatively new fertilizer in the commercial form. It is formed by passing a current of air, which is rich in nitrogen, over calcium carbide, which is heated to a high temperature. The air rich in nitrogen is produced by absorbing a large part of the oxygen from it, by one of several methods. If the calcium cyanamide produced is applied just before seeding it has an injurious effect on the germinating seeds, but if it is added a week or so before, so that the processes of nitrification have a chance to act and change it to some other form, it will often produce as good results as the same amount of nitrogen added in the form of sodium nitrate or of ammonium sulphate. In the form in which it is produced in this country it contains about 20 per cent of nitrogen.

The following results were obtained in experiments upon the effect of cyanamide on the germination of seeds, which were carried on by F. T. Shutt and H. W. Charlton at the Ottawa Experiment Station. The two fertilizers, calcium and potassium cyanamide-carboxylic acid ($Ca(C\ N.N\ H)_2\ CO_2$ and $K.\ CN.\ NH.\ CO_2$) were used. These are products of the fixation of atmospheric nitrogen. The presence of these compounds in amounts less than 5 mg. of nitrogen per 100 grams of soil did not prove injurious to the vitality and germination of wheat and pea seeds. The potassium compound was slightly more injurious to the seed than the calcium compound. The fertilizers were added in a water solution, with which they form a chemical combination. The later stages in the conversion to an available form are the bacterial nitrification processes which were described in one of the earlier paragraphs.

CHAPTER III.

MINERAL SOURCES OF NITROGEN.

Sodium Nitrate or Chili Saltpeter.

Among the mineral sources of nitrogen the most important one, which is used as a fertilizer, is sodium nitrate or "Chili salt peter". This contains nitrogen in the form of a nitrate, to which form most other nitrogenous fertilizers must be converted, before they can be used by the higher plants. Thus the nitrogen in this form is the most readily available.

Practically all of the nitrate of soda on the world's market at the present time comes from Chili. It occurs there in a number of waste desert plains where anything can grow. In the towns in this region the only vegetation is grown on soil which is imported. The region is very dry, and the water has to be piped from the Andes mountains or distilled from the sea. The nitrate of soda is found wixed with other soluble salts, of which common salt is the most common. These soluble salts are dissolved out of the crushed caliche or rock in which they are mined, and from this solution the nitrate is crystallized out by itself, because it has a different point of solubility from the other salts. The crude caliche usually contains from 14 to 75 per cent of sodium nitrate, mixed with sodium sulphate, sodium chloride, iodine salts, and small proportions of magnesium, lime, potash, and insoluble matter. The final product is 95 per cent nitrate.

The Government of Chili, although not owning the deposits of saltpeter, places a tax of $.458 per 101.41 pounds upon the exportation of the nitrate, and also controls the further distribution of the lands. Germany and England now practically control this great industry, but there is now an American syndicate owning nitrate fields, the nitrate railway running from the port of Coloso to Agras Blancis, the main port, and several nitrate factories.

There has been much discussion upon the time it will take to exhaust the Chili deposits. There are many estimates, but most of them agree that under the present control, and the present increase in demand, that the nitrate now in sight will last for two or three hundred years.

The United States is steadily importing more nitrate from Chili. In 1900 she imported 184,247 tons valued at $4,736,807, while in 1910 she imported 544,559 tons valued at $16,548,036. Although many substitutes are being used in this country, and the use of legumes as nitrogen gatherers is becoming more common, the prospects are that United States will continue to increase her imports of Chili saltpeter. Much of this is used for other purposes than as a fertilizer.

Potassium Nitrate.

Potassium nitrate would make a remarkably good fertilizer, because of its containing two of the three elements which are liable to be lacking in soils. This must be excluded from the list of fertilizers, because of its high price, due to its use in the manufacture of gunpowder, and other more productive industries.

Ammonium Sulphate.

In the last few years ammonium sulphate has come to be one of the most important fertilizers in this country. This has been due to the introduction of improved methods of amnufacture of several substances, where in the past large quantities of ammonia were lost. Although ammonium sulphate has been used as a fertilizer for many years, the use of improved methods in saving the gas which is lost in many lines of manufacturing, is still in its infancy. Ammonium sulphate is made as a by-product of coke manufacture, gas works, shale works, iron works, the manufacture of bone blick, and by the distillation from all organic waste materials, such as leather, hoof and horn scraps. At present there is a great loss of ammonia around tanneries, which will eventually be converted into fertilizers. The ammonium sulphate is made in all the above industries by the distillation of the ammonia which is absorbed in sulphuric acid to form ammonium sulphate.

The commercial sulphate of ammonia found on the market, is one of the most concentrated nitrogenous fertilizers. It usually contains 22 to 25 per cent of ammonia or 18 to 21 per cent of nitrogen. The pure salt contains 25.75 per cent of ammonia and is a pure white. The commercial compounds contain impurities, which make it a greyish or brownish color. The most common impurities are an excess of moisture, or acid, and some insoluble matter. It often contains small quqntities of ammonium sulphocyanate, which is extremely poisinous to plants. The presence of this substance can be determined by dissolving a small amount of the fertilizer in water and adding a few drops of ferric chloride, which will produce a blood-red color in the presence of the sulphocyanate.

There are a few disadvantages of using sulphate of ammonia as a fertilizer. First, it can not be added with lime or basis slag, because of the valatilization of the ammonia. Second, ot is apt to produce an objectionable acidity in the soil, if it is used continuously. As the ammonia is used up, the sulphuric acid radicle combines with the basic elements in the soil like calcium, until they are all used up and then will unite with the water, forming a very strong sulphuric acid acidity in the soil.

The ammonia of the ammonium sulphate is very rapidly nitrified into nitrates, and thus should be treated similar to sodium nitrate in application. It should, however, be applied a short time earlier than the nitrate would be applied.

CHAPTER IV.

ORGANIC NITROGENOUS FERTILIZER.

Farm Manure.

The most important fertilizer in this and in other countries is farm manure, which is too often called "barn yard manure. The Missouri station states that a conservative estimate places the fertilizing value of the manure produced annually by farm animals in United States at over two thousand Million dollars."

Because of its great value, and because of the great losses due to its improper handling, farm manure should be given much more attention than can be given it here.

Farm manure varies more in composition than any other fertilizer. Even as it is excrated from the animal, no two samples will have exactly the same composition. The chief factors influencing the composition and value of farm manure, are the kind and age of the animal, the feed upon which the animal is fed, and the general condition and treatment of the animal.

Horse-manure is the most uniform manure produced by farm animals, because of the uniformity of the food, which usually consists of oats and hay. According to the average of experiments by Boussingaalt and Hofmeister, the total excrement voided by a horse in 24 hours was 28.11 lbs., containing 6.37 lbs. of dry matter, 18 lbs. of nitrogen and .92 lb. of mineral matter. If straw is used to absorb the liquid, it will require from 4 to 6 lbs. At this rate, in one year a horse will produce 11,720 to 12,450 lbs. of manure containing 69 to 73 lbs. of nitrogen.

The composition of cow manure is much more variable. It contains a very large per cent of water. One cow produces a much larger amount of manure in a given time than a horse. Boussingault found that a cow produces 73.23 lbs. of manure in a day, containing 9.92 lbd. of dry matter and .256 lbs. of nitrogen. In a year the nitrogen production of one cow will amount to 100 to 104.4 lbs. Cow manure is much more slowly available than horse manure, because of its watery nature, its tendency to dry forming hard resistant masses, and to its mucilaginous consistency. This makes the effect of one application last over a longer period.

Sheep manure is the richest of any produced by common farm animals. Both the feces and urine are richer than an equal weight produced by any other farm animal. In a year one sheep will produce manure containing 15.66 lbs. of nitrogen.

Pig manure may be a very rich manure, but the quality is so variable that no absolute statement can be made. This is because of the variation in the food fed to hogs. In a year the manure produced by one pig will contain from 22 to 27 lbs. of nitrogen.

The following tables taken from Hart's Agricultural Chemistry, show the variation in value and composition of the manures produced by the different farm animals.

Average Composition of Fresh Manures

Animal	Water	Nitrogen	Phos. Acid	Potash	Value per ton
Sheep	64.0 %	0.83 %	0.23 %	0.67 %	$3.39
Horse	70.0	0.58	0.28	0.53	2.55
Pig	73.0	0.44	0.19	0.60	2.14
Cow	77.0	0.44	0.16	0.40	1.89
Mixed	75.9	0.45	0.21	0.52	2.08

The Amount and Value of Manure per 1000 lbs. of Live Weight of Different Animals.

	Amount per day	Value per day	Value per year
Sheep	34.1 lbs.	7.2 cents	$26.09
Calves	67.8 "	6.7 "	24.45
Hogs	56.2 "	10.4 "	37.96
Cows	74.1 "	8.0 "	29.27
Horses	48.8 "	7.6 "	27.74

From this table it will be seen that the manure produced by 1000 pounds of live weight of live stock will be worth about $30., and the value of the manure produced by different animals is generally proportional to their weights.

The variation of farm manures caused by the difference in the age of the animal is illustrated by the difference in the value of calf and cow manure, as given in the table above. The reason for the calf manure having so much less value is that the fertilizing elements are retained in the body of the growing animal to build new tissue, while old animals execrate approximately the same amount of fertilizing elements, which are contained in their feed.

The third factor affecting the composition of farm manure is the feed of the animals producing it. This is apparent to a much greater extent with old animals, where there is neither gain or loss in weight. In this case the fertilizing elements execrated are equal to those in the feed of the animal. The following table from Bul. 34 of the Missouri Station, shows the fertilizing Value of Feeds.

Kind of Food	Value of N. per ton	Value of R. per ton	Value of K. per ton	Total fertilizing per T.
Cotton seed meal	$21.20	$3.00	$1.80	$26.00
Linseed meal	16.50	1.80	1.40	19.70
Gluten meal	15.00	5.30	.05	15.35
Wheat bran	8.00	2.92	1.60	12.56
Clover hay (red)	6.20	.46	2.20	8.80
Alfalfa hay	6.50	.50	1.70	8.70
Wheat	7.10	.90	.60	8.60
Oats	6.20	.30	.60	7.60
Corn meal	4.75	.60	.40	5.75
Timothy hay	3.75	.55	.90	5.20
Wheat straw	1.80	.15	.50	2.45
Skim milk	1.50	.30	.20	2.00
Corn ensilage	.85	.10	.35	1.30
Turnips	0.55	.10	.40	1.05

In the above paragraphs manure has been considered as the excreta of animals, but mixed with this in the form in which it is used for a fertilizer is some kind of litter. This is added chiefly for the purpose of absorbing the liquid part of the manure, which contains most of the nitrogen. They also contain some fertilizing elements. Straw is the most common form of litter. It usually contains only from

.581 % of nitrogen and has only fair absorptive powers, though it improves the soil physically. Sawdust and shavings are also used, but they do not add so much fertility. Dried peat makes a very good litter. It has good absorptive powers and contains more nitrogen than the manure itself. It often contains 3 or 4 per cent of nitrogen, which makes it in itself a good fertilizer.

Though farm manures have been considered here as nitrogenous fertilizers, they are primarily general fertilizers. They not only add all three of the critical elements to the soil, but they add organic matter to the soil and thus increase its moisture-holding capacity, which may be more necessary than the fertility. The handling of the manure will be considered in a later chapter.

Common Fowl Manure.

The manure of the common farm fowls, such as chickens, pigeons, and ducks, is not as rich as it is commonly thought. It does not contain enough feritlity to be transported great distances, as is done with guano, but it does contain slightly more fertility than the common farm manures. It usually contains from 5 to 25 per cent of nitrogen, which becomes rapidly available because of its rapid fermentation.

Guano.

Among the richest and most concentrated general organic manures, guano must be given first place. The word guano comes from the Spanish word"huano", meaning dung. Most of the deposits of guano are found in the regions around Peru. It is derived almost entirely from the excrement of sea birds such as pelicans, penguins, gulls, but also contains the remains of some of these birds and of other animals. In this region there is a very hot sun and almost no rain, which tends to dry the excrement and preserve it. Some of the deposits are still in the process of deposition, but others are centuries old. Many of the deposits are over a hundred feed deep and are covered to a considerable depth with sand or a conglomerate.

There are two distinct types of guano, the nitrogenous and the phosphatic. The latter has been subjected to moist conditions, causing its fermentation and the loss of almost all of its nitrogen and potash. This type will not be considered here. The other type or nitrogenous guano contains as high as 20 per cent of nitrogen, though the products now on the market contain much less. The nitrogen is in a very easily available form, being mostly ammonia combined with oxalates, urates, humates, sulphates, phosphates, carbonates, and some organic forms. Because of this nitrogenous material, which is combined with large quantities of phosphorous and small quantities of potash, a small amount of fertilizer will produce a remarkable result. Storer states that 100 pounds of guano containing 9 % of nitrogen will furnish as much nitrogen as is ordinarily contained in a ton of half rotted stable manure, and the nitrogen is in a more available form. This is true to a much larger extent of the phosphorous contents.

Fish Scrap.

Early in the history of this country the value of fish as a fertilizer was realized. The Indians taught the colonists to put a fish into each hill of corn, and thus this may have been the first feritlizer to be used in this country. At present farmers near the sea coast may obtain fish scrap or what is often called fish guano. This may be obtained from the fishing centers and may include whole fish or its bones, heads, etc. The value of this fertilizer depends to a large extent upon its moisture contents. When well dry, it usually contains from 8 to 10 per cent of nitrogen and about the same of phosphoric acid. Thus when it may be obtained at a fair price, it makes a very good general fertilizer.

Sea Weeds.

In places near the sea coast sea weeds may be used as a fertilizer to good advantage. Sea weeds are of so mamy different varieties and of such varied composition that their exact composition can not be stated. As an average, they are equivalent to farm manure in fertilizing value. They may be dried in the sun and then transported, but they are usually used only when they may be obtained in large quantities for the cost of transportation. In the fresh state they contain from 70 to over 80 per cent of water. All seaweeds contain some common salt, which may, if used in very large quantities, injure the fertility of the soil. Some seaweeds are very high in nitrogen, others in potash, but they are generally low in phosphorous.

Slaughter House By-products.

With the growth and centralization of the meat packing industry, many of the by-products which were formerly destroyed are now used as nitrogenous fertilizers. Among these are dried blood, meat scrap, tankage, hair, hoof and horn meal, and waste leather.

The most valuable of the by-products is dried blood. It is quite high in nitrogen and ferments rapidly in the soil, thus becoming quickly available for the use of the crop. When the blood is dried properly, it is a dark red in color and contains from 13 to 14 per cent of nitrogen. Black dried blood is also found on the market. This has been dried too rapidly and may contain from 6 to 12 per cent of nitrogen. Both grades are good fertilizers, but a much smaller price should be paid for the black grade.

Tankage is the name given to a mixture of different waste products of the meat packing industry. This varies greatly according to the methods used in the different individual packing houses. The smaller houses often put in substances which the larger houses use for some other purpose, or sell under a different name. Most slaughter houses steam the tankage in order to remove the fats and gelatine. This makes the product much more available for the use of plants, as is the case with steamed bone meal, which forms a part of the mixture. Tankage usually contains from 4 to 9 per cent of nitrogen and from 3 to 12 per cent of phosphoric acid. Thus it supplies considerable quantities of the two most important elements in soil fertility.

There is often another very valuable nitrogenous fertilizer placed on the marked by the slaughter houses, which is called meat scrap. This contains some of the better parts of the animal, which can not be used for packing and are too good for tankage. This is also quite variable in composition, but usually contains from 10 to 12 per cent of nitrogen. Meat scraps and tankage contain the carcasses of deceased animals which are condemned by the inspectors. These must always be cooked in some manner, before they are made into fertilizer.

All the fertilizers made from the outer tissues of animals, or those tissues arising from the epidermis, are very slowly available for the use of plants. This group includes fertilizers made from leather, hoof, horns, hair and wool.

The waste leather of tanneries contains about 7 per cent of nitrogen and has been sold as a nitrogen fertilizer without change. This is so slowly available as to be almost useless as a fertilizer. It is also put onto the market as steamed and roasted leather. These are very little better. In the future the nitrogen in this form will probably be saved by its distillation off in the form of ammonia and its combination, so as to form ammonium sulphate, as has been mentioned in a previous chapter.

Hoof and horn meal is the residue left after the gelatine, fats and glue have been extracted from hoofs and horns. It is quite rich in nitrogen, containing about 14 per cent, but, like leather, it is very slowly available.

Wool and hair waste vary greatly in their composition and moisture contents. They may contain a large per cent of nitrogen, but it is so slowly available for the use of plants, that it is probable that it will be treated in the same manner as the waste leather, and the nitrogen sold as ammonium sulphate.

Other By-products.

There are a large number of nitrogenous fertilizers which are obtained as by-products of different industries. The nitrogen contents of some of these is given in table. Their value depends upon their nitrogen contents and its availability. They also contain other fertilizing elements, which add to the value. Some of the most important of these are cotton seed meal, which is now used mostly for stock feeding, castor pomace, pape dust and apple pumice. These make good fertilizer, when they may be obtained cheaply from a neighboring factory.

Sewage.

It is a well known fact that large quantities of nitrogen and other fertilizing elements are lost through the disposal of the city sewage. In many foreign countries the human manure from the cities is carted out into the country and applied to the land as a fertilizer. This can be done under the conditions existing there, where the sewage is not diluted to such an extent as it is in this country, and where labor is very cheap. In this country a ton of sewage contains only a pound or two of dry matter, and this contains only a small per cent of nitrogen.

The only possible way of utilizing the city sewage in this country under the present conditions is by means of sewage farms. There are several systems by which this may be done, but only a comparatively small amount of sewage can be added to any particular piece of land because of the injury caused by the filling up of the air spaces in the soil with a slimy substance, which thus injures the soil.

Because of the extreme poor quality of sewage and because of the greater importance of sanitary conditions, the use of sewage as a fertilizer on the farms is not profitable under the present conditions.

An attempt has been made to use sewage sludge treated in a filter press so that it contains only about 50 per cent of water. This sludge contains only 6 to 9 per cent of nitrogen, and thus, aside from its objectionable handling qualities, it is not a good fertilizer. It contains somewhat more of phosphorous, but this did not become rapidly available in cropping experiments.

Peat.

The only research work done for this thesis was the following plant house experiment on the availability of peat as a nitrogen fertilizer. Rape and corn were grown in four gallon jars filled with common pit sand. All the jars except the one containing the plot #9 soil received portions of the following nutrient solution at four different times.

50 gm. Ca. Hy $(PO_4)_2$ dissolved in 2500 cc H_2O

75 " K Cl " " " " "

40 " Mg SO_4 " " " " "

7500 cc

To this a few drops of ferric chloride were added. The corn and rape were both sown on March 1, but the rape seed was poor and did not germinate, so it was reseeded three weeks later.


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THE AVAILABILITY OF PEAT AS A NITROGEN FERTILIZER.

Jars	Fertilizers added	Weight of Crop in grams Corn	Rape
1 & 15	Blank	3.4	0.9
2 & 16	Peat I in lumps	34.7	13.8
3 & 17	Peat II finely ground	16.8	8.8
4 & 18	" " & garden soil inoculation	19.2	7.1
5 & 19	" " & manure"	18.7	6.7
6 & 20	" " & "(sterilized)	14.9	5.0
7 & 21	" " & $CaCO_3$	17.0	5.7
8 & 22	" " & CaO	13.8	7.0
9 & 23	Manure	17.7	3.0
10 & 24	Sodium Nitrate	75.0	35.4
11 & 25	Peat II light application	6.8	0.7
12 & 26	" " heavy "	19.1	9.8
13 & 27	Plot 9 soil- no fertilizers	16.7	13.1

The crops were harvested on May 8. Peat I mentioned in the table was a brown fibrous sample high in nitrogen. Peat II contained a much larger per cent of silt, and was black. Peat II was added in a ground form in all cases, but Peat I, in lumps, made a better growth. The manure added was fresh cow manure, free from bedding. This seemed to form gelatinous lumps which did not decompose readily. In this state the poorer peat gave just as good growth or better. It will be seen from the table that much of the peat is available as a nitrogen fertilizer.

In many states of the Union there are large peat marshes lying adjacent to poor sandy lands which are low in organic matter and nitrogen. Where the two types of land can both be had cheap, it may be profitable to put a heavy application of peat upon the sandy land and thus obtain good crops due to the increased nitrogen content and the increased water-holding capacity of the sandy land.

There are several processes of manufacturing nitrogenous fertilizers from peat. One of these is the Waltereck Process, which is described by P. T. Gessing in his book "Commercial Peat - Its Uses and Possibilities." "Peat (80% water) is automatically fed into hoppers which drop it into furnaces. Here it is subjected to moist combustion by means of a blast of air charged with water vapor at a regulated temperature. The resulting gases contain paraffin tars, acetic acid and ammonia. These are separated out in the order given. The ammonia is separated out by a stream of hot sulphuric acid which forms ammonium sulphate. The peat produces a minimum of 5 per cent ammonium sulphate.

The large plant erected at Carnlough, County Antrim, has finally confirmed the working and results of the process on a commercial scale."

The German government is working on a different process of making a nitrogenous fertilizer out of peat. In these processes the peat is used as fuel to produce the heat necessary.

The United States contains about 20,000,000 acres of peat land. Thus this is a great source of nitrogen which can be relied upon in the future.

CHAPTER V.

LOSSES OF NITROGEN FROM THE FARM.

Nitrogen in Crops Sold.

In most systems of farming the greatest loss of nitrogen and the most natural loss is through the crops sold. It is this great loss which is to a certain extent prevented by dairy and stock farming, that makes these lines of agriculture so popular in the older countries. When virgin land is cheap, it is natural for it to be farmed in an extensive manner with little or no attention paid to the loss of fertility.

The following table shows the number of pounds of nitrogen removed per acre by average crops of grain, etc., and the value of the nitrogen removed indicates the decrease in the value of the land due to that one crop, or the amount of money which would be required to put the land back in its original shape, figuring the price of nitrogen at 15 cents per pound. The nitrogen content is taken from Hart's Agricultural Chemistry.

Crop	Pounds of N. removed	Value of N. removed
Wheat, grain 30 bu.	34	$5.10
" straw	16	2.40
" Total crop	50	7.50
Barley, grain 40 bu.	35	5.25
" straw	14	2.10
" Total crop	49	7.35
Oat, grain 45 bu.	34	5.10
" straw	18	2.70
" Total crop	52	7.80
Corn, grain 30 bu.	28	4.10
" stalks etc.	15	2.25
" Total crop	43	6.35
Meadow hay, 3,360 lbs.	49	7.35
Red Clover hay, 4,480 lbs.	98	14.70

Nitrogen Lost in Dairy Products.

Dairy farming, where the milk is sent to the creamery and the skim milk and buttermilk returned, is the system of farming where the least nitrogen is lost from the farm in products sold. The butter contains mostly fat and thus very little nitrogen is lost. Where the whole cows milk is sold, 5.8 pounds of nitrogen are lost for every 1000 pounds of milk. This is a much smaller amount in proportion to the value of the product, than when the grain, hay etc. are sold.

Nitrogen Lost in Live Stock Sold.

The following table shows the amount of nitrogen removed from the farm in the live stock sold.

NITROGEN IN 1000 POUNDS OF VARIOUS ANIMALS AND THE SAME WEIGHT OF THEIR PRODUCTS.

Animal	Nitrogen in Pound
Fat calf	24.6
Half fat ox	27.4
Fat ox	23.2
Fat lamb	19.7
Store sheep	23.7
Fat sheep	19.7
Store pig	22.0
Fat pig	17.6
Wool (unwashed)	54.0
Wool (washed)	94.4
Cows milk	5.7
Hen's eggs	20.0

From the above table it will be seen that though the per cent of nitrogen is high, the nitrogen lost is much smaller than if the feed were sold.

Though the nitrogen lost by sale from the farm is much smaller in stock farming than in grain farming, there are other losses of nitrogen not found in latter. Not all the fertility in the feed fed to the animal finds its way back to later crops. There are many channels of loss of the fertility of farm manure. These will be considered in the next few paragraphs.

Loss Due to Improper Care of Manure.

Pastures are often located with streams running through them. Their banks are generally wooded and the cattle spend much of their time there. In this way the manure which they deposit is lost. Much manure is also deposited in woodland pastures, which may never be used to grow crops. This fertility is only partially regained in the grass and other vegetation which the animals eat.

Probably the greatest loss of nitrogen on a stock farm is through the improper sare of manure, which is deposited around and in the barns. The manure from the barn is usually thrown in a pile in the barn yard, and no further care taken of it. In this condition about half of the nitrogen is lost by the action of fermentation and the leaching effect of the rains. The New Jersey Experiment Station determined the loss of nitrogen due to this cause in four different samples exposed from 50 to 131 days. The average loss was found to be 51 per cent. The great loss due to leaching depends to a large extent on the fact that two thirds of the nitrogen of the manure is in the urea. The best way to prevent this loss is to haul the manure directly onto the fields. Here a great absorbtive power of the soil retains nearly all of the fertility.

The nitrogen in horse and sheep manure is greatly subjected to loss by means of fermentation. This is because of their dry nature, and the same result will take place when other manures dry out. The fermentation may be detected by an odor of ammonia.

To prevent the loss of nitrogen by leaching and fermentation, if the manure can not be hauled directly onto the field, it should be kept compact, moist, and away from the action of the rain. In Europe this is often done by storing the manure in water-tight concrete cisterns, which prevents the draining away of the moisture which penetrates it. This makes good manure, but is expensive. A more economical method for use in this country is the storing of manure in a shed or covered barnyard. The rain is kept off, and the manure kept compact by the tramping of the animals. The ground under this shed should be a puddled clay or be made of cement to prevent the liquid with which it must be kept saturated, from draining away.

Another natural source of loss of nitrogen from the soil is by denitrification. This may be due wither to the anaerobic bacterial action on nitrates or to the too rapid decomposition of organic matter. The former action takes place when the soil is filled with water, excluding all air. In this case the oxygen of the nitrate combines with carbon, forming carbon dioxide and liberating free nitrogen, which passes off into the air. The conditions favorable for this action are just the opposite of those favorable for nitrification and the growth of crops, thus the loss from this source is not great in most soils.

Denitrification.

The denitrification resulting from the too rapid oxidation of organic matter may be due to many causes. One of these is the continuous cropping with one crop. This is shown in Experiments by the Minnesota Station on fields cropped continuously with wheat. The loss of nitrogen annually was found to be 171 pounds per acre. Only 34.5 pounds was removed in the crop, thus 146.5 pounds must have been removed by denitrification. This loss of fertility is greatly decreased by crop rotation, and if a legume is included the land will gain in nitrogen if properly handled.

Large quantities of nitrogen are often lost when heavy applications of rich nitrogenous fertilizer. This is due to the same process of denitrification. Quick lime, when added to the soil, will produce a volatilization of ammonia, if it comes in contact with organic matter.

Loss Due to Soil Erosion and Leaching.

The loss of nitrogen by soil erosion and leaching, depends to a large extent upon the topography and character of the soil. In cases of bad side hill erosion, a large per cent of the surface soil, organic matter and nitrogen may be carried down to the lowlands or away in the streams. an ordinary cultivated soil, receiving only the water which falls directly upon it will not receive more water in one single rain than it can hold. Thus no nitrogen will be lost in the drains. Very sandy soils with a low moisture holding capacity and lands which receive moisture from lands above and which need draining, will often lose large quantities of nitrogen in the drain water. Boussingault found 0.0042 to 0.0086 grm. of nitric acid to the liter of water in the Seine River, and other streams were found to be equally rich. The Rhine he found to contain 0.008 to 0.001 grm. per liter. Taking into consideration the large quantities of water carried out to the sea in these rivers, this is a great source of loss of nitrogen.

One of the reasons that nitrate are so easily lost by leaching is that they can not be fixed in the soil in an insoluble form. If potassium nitrate were added to a soil the potassium would be fixed by the zeolites in the soil, but the nitrate radicle would remain in a soluble form subject to leaching. Ammonia may be fixed to a large extent, taking the place of some of the basic elements in a more insoluble form. Since these are the only soluble forms of nitrogen which accumulate in the soil, the largest quantity of nitrogen lost by leaching is in the form of a nitrate.

The largest quantities of nitrates are lost from the soil when summer fallowing is practiced. Here large quantities of nitrates accumulate which are leached out if subjected to heavy rains in the fall. The losses of nitrogen in this case are not limited to leaching, but much is lost through denitrification.

Nitrogen Content of Fertilizers.

No of Analyses	Fertilizer	Maximum	Minimum	Average
2	Nitrate of Potash	14.58%	11.60	13.09%
14	Nitrate of Soda	16.01	15.30	15.75
23	Sulphate of Ammonia	21.68	19.70	20.50
8	Saltpetre waste	3.30	.59	2.43
2	Nitre salt-cake			2.29
26	Peruvian guano	13.50	4.44	7.85
9	Bat guano from Texas	10.51	2.58	6.47
5	Cuba guano	2.74	.63	1.67
12	Dried Blood	13.55	8.10	10.52
1	Ammonite			11.33
1	Oleomargerine refuse			12.12
1	Felt refuse			5.26
1	Sponge refuse			2.43
3	Horn and hoof waste	15.49	11.84	13.25
1	Raw wool			12.88
5	Wool waste	10.20	1.18	5.64
5	Meat mass	11.50	9.69	10.44
1	Dried soup from Meat and Bone			9.97
1	Dried soup from rendering Cattle feet			14.47
1	Dried soup from Horse rendering			1.21

No of Analysis	Fertilizer	Maximum	Minimum	Average
2	Soap grease refuse	4.20	2.21	3.21
106	Bones	4.70	1.62	4.12
13	Tankage	8.07	4.60	6.82
49	Fish with less than 20 % water	11.40	6.81	7.25
9.	Fish with 20-40% water	7.41	4.22	5.86
1	Whale meat raw			4.86
1	Lobster shells			4.50
4	Castor-bean ponace	5.72	5.33	5.56
7	Cotton seed meal	7.26	4.02	6.66
1	Rotten brewer's grain			.72
6	Tobacco stems	2.91	.90	2.29
1	Cotton waste (wet)			1.30
2	Cotton waste (dry)	2.09	1.32	1.71
12	Muck	2.54	.26	1.12
9	Peat	1.40	.41	.75
1	Turf			1.94
1	Soot			----
7	Barnyard manure	.67	.34	.47
1	Hen manure (fresh)			.79
1	" " (dry)			2.13

Table taken from Rhode Island Bal. #8.

Approved by

A R Whitson

Prof. of Soils.