IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989

Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [ ] Coloured covers/ Couverture de couleur
- [ ] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [x] Bound with other material/ Relié avec d'autres documents
- [x] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

- [ ] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [x] Quality of print varies/ Qualité inégale de l'impression
- [ ] Continuous pagination/ Pagination continue
- [ ] Includes index(es)/ Comprend un (des) index

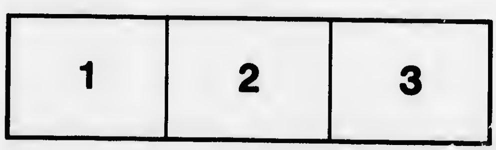
Title on header taken from:/
Le titre de l'en-tête provient:

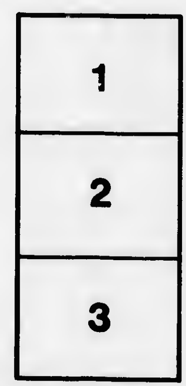
- [ ] Title page of issue/ Page de titre de la livraison
- [ ] Caption of issue/ Titre de départ de la livraison
- [ ] Masthead/ Générique (périodiques) de la livraison

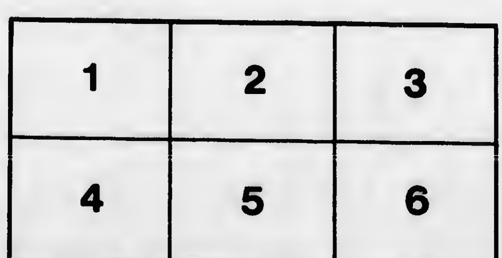
- [ ] Additional comments:/ Commentaires supplémentaires:

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X	12X	14X	16X	18X	20X	22X	24X	26X	28X	30X	32X
						✓					


1
2
3


1
2
3


1
2
3
4
5
6

BULLETIN 109.

SEPTEMBER, 1898.

Ontario Agricultural College and Experimental Farm

FARMYARD MANURE

BY

G. E. DAY, B. S. A., Agriculturist.

PUBLISHED BY

THE ONTARIO DEPARTMENT OF AGRICULTURE, TORONTO.

TORONTO:
WARWICK BRO'S & RUTTER, Printers
1898.

THE ONTARIO AGRICULTURAL COLLEGE

AND

EXPERIMENTAL FARM, GUELPH, ONT.

HON. JOHN DRYDEN, Toronto, Ont.,
Minister of Agriculture for Ontario.

JAMES MILLS, M A., LL.D	President.
A. E. SHUTTLEWORTH, B.A. Sc	Professor of Chemistry.
WM. LOCHHEAD, B.A., M. Sc	Professor of Natural History and Geology.
J. H. REED, V.S.	Professor of Veterinary Science.
H. H. DEAN, B.S.A.	Professor of Dairy Husbandry.
WM. RENNIE	Farm Superintendent.
C. A. ZAVITZ, B.S.A	Experimentalist.
G. E. DAY, B.S.A	Agriculturist.
H. L. HUTT, B.S.A	Horticulturist.
F. C. HARRISON, B.S.A.	Bacteriologist.
J. B. REYNOLDS, B.A.	Assistant Resident Master.
R. HARCOURT, B.S.A.	Assistant Chemist.
W. M. DOHERTY, B.S.A., M.A	Assistant in Natural History.
L. G. JARVIS	Manager and Lecturer in Poultry Department.
R. F. HOLTERMANN	Lecturer in Apiculture.
CAPTAIN WALTER CLARKE	Instructor in Drill and Gymnastics.
W. O. STEWART, M.D.	Physician.
G. A. PUTNAM	Stenographer.
A. McCALLUM	Bursar.

ADVISORY BOARD.

JOHN I. HOBSON, *Chairman*	Guelph, County of Wellington.
JOHN McMILLAN, M.P.	Seaforth, County of Huron.
EDWARD JEFFS	Bond Head, County of Simcoe.
G. B. BOYCE	Norham, County of Northumberland.
D. A. DOWLING	Appleton, County of Carleton.
WM. DONALDSON	South Zorra, County of Oxford.
C. C. JAMES, *Secretary*	Deputy Minister of Agriculture, Toronto.

BULLETIN 109.

FARMYARD MANURE.

By G. E. Day, B.S.A., Agriculturist.

I. CONSTITUENTS OF PLANTS.

To make a successful growth, plants require a number of substances. The chemical analysis of a plant shows it to contain the following elements: nitrogen, phosphorus, potassium, calcium, iron, magnesium, sulphur, carbon, oxygen, hydrogen, and a few other substances of less importance. All the elements named are essential to the growth of plants, and without them no plant can be produced. If only one of them is absent, the plant either will not grow at all or will make but an unsatisfactory growth, depending upon the importance of the element which is absent. Some of these elements are derived from the air and some from the soil; but it is only those which are derived from the soil which are under the farmer's control. Of the elements derived from the soil, those which are used in largest quantity and which are consequently in greatest danger of becoming exhausted, are nitrogen, phosphorus, potassium and calcium. These elements, however, do not exist in the soil as separate substances, but are found combined with other elements to form compounds; and, in speaking of most of them, it is customary to use the name of the compound instead of the single element. Thus, instead of speaking of "phosphorus" it is customary to say "phosphoric acid" or "phosphates," which are compounds of phosphorus and other elements; also, instead of saying "potassium" it is usual to speak of "potash," a compound of potassium and oxygen; and instead of "calcium" the term lime is used, since lime is the commonest compound of calcium found in the soil. Therefore the constituents of plant food in the soil which require most attention are nitrogen, phosphoric acid, potash, and lime. In many soils, however, there is abundance of lime, and, besides, lime is frequently found in combination with the other important substances and is thus applied to the soil along with them. The same may be said of iron, magnesium, and sulphur, which are the remaining elements derived directly from the soil by plants. Practically, therefore, the farmer may confine his attention to supplying the soil with nitrogen, phosphoric acid, and potash, unless in rather exceptional cases.

II. FARMYARD MANURE.

Farmyard manure is derived, either directly or indirectly, from plants, and consequently contains all the elements necessary for plant growth. It may be called, therefore, a *general manure*, that is to say, it supplies all the necessary elements of plant food. It does not follow, however, that because farmyard manure supplies all the elements of plant food, that it supplies them to all crops and soils in exactly the right proportion. For example, a certain soil is deficient in phosphoric acid and potash, but is rich in nitrogen. Now, if the deficiency in phosphoric acid and potash is made up by applying farmyard manure, there will also be added to the soil a considerable amount of nitrogen, and, according to the example quoted, there is already sufficient nitrogen in the soil in question, consequently the additional nitrogen is added at a loss. Arguments of this nature are frequently employed against farmyard manure as compared with special manures, or those which supply only one or two constituents of plant food, it being claimed that the use of special fertilizers admits of applying only those substances in which the soil is deficient and therefore constitutes economical manuring. It is also claimed that farmyard manure is bulky, heavy and expensive to handle, whereas most special fertilizers are much more concentrated. Still further, it is claimed that farmyard manure is comparatively slow in its action, because a great deal of the plant food which it contains is in such forms that plants cannot make use of it until the manure has fermented and decayed; whereas the plant food in many special fertilizers is in forms which plants can readily make use of, and consequently such manures give quick returns. These objections to farmyard manure are perfectly valid, and no doubt special fertilizers have an important place to fill under some systems of farming; but there are several things in connection with farmyard manure which must not be overlooked, and, in order to emphasise them, they will be dealt with separately.

1. Farmyard manure is a by-product. In many, if not in most cases, the profit from the animals fed leaves very little to be charged against the manure. As a result the farmer can afford to spend some extra labor upon it and to put up with its slower action. He may also afford to apply more of certain constituents than the crop requires; in fact, excessive application of plant food is liable to happen with any fertilizer, since no one is able to estimate exactly to what extent a soil is deficient in a given element of plant food. Further, in no case do plants take from the soil all the plant food applied in the fertilizer, frequently not more than half, so that in the case of expensive fertilizers the loss is a serious one.

2. Farmyard manure, as already stated, is slow in its action, the plant food which it contains being gradually made available for plants. But, though only a small portion of its plant food becomes available each year, the greater part of the unused plant food is not lost under judicious management, but is held in the soil for the use of succeeding crops. In the case of quick acting fertilizers, nearly all of their influence is confined to the year in which they are applied; and, though some have a more lasting influence than others, their effect upon succeeding crops is not nearly so marked as that of farmyard manure. The reason for this difference in effects upon succeeding crops is comparatively simple. Before plants can take up their food from the soil, it must be in such forms as will dissolve in the soil moisture or in the juices of the plant roots. When plant food is in such a condition it is said to be *soluble*, and it must be soluble before it can be available to the plant, so that the term *available* plant food means soluble plant food. Now, only a small portion of the nitrogen, phosphoric acid, potash, etc., in farmyard manure is in a soluble condition, and before the remainder of it can become soluble, the manure must undergo fermentation and decay. In the process of decay, the vegetable compounds of the manure are broken up, and the elements of plant food which they contain form simpler compounds which are soluble, and hence available to plants. It takes many years for the whole of the vegetable matter in an ordinary dressing of farmyard manure to decay, and since only soluble plant food can be washed out of the soil by rains, it follows that only a small portion of the plant food will be lost in this way, and that there will be a residue left over from year to year for a considerable length of time. On the other hand, special fertilizers which contain a large proportion of soluble plant food and are therefore quick in their action upon plant growth, are in danger of having any residue that may be left by the first crop washed out of the soil during the succeeding winter and spring, owing to the soluble

nature of the plant food they contain. This is especially true of soluble nitrogenous fertilizers, which leave practically no residue for succeeding crops. Phosphoric acid does not leach out of the soil in the drainage water so readily as nitrogen, because much of it is changed into insoluble compounds in the soil, after which it is but slowly made available for plants.

The lasting influence of farmyard manure is strikingly brought out in the Rothamsted experiments in England. At this noted experiment station, barley was grown for a great many years in succession on the same soil with different manures, and also without any manure. It will be sufficient for the present purpose to notice two of these plots. Plot 1 was continuously unmanured for forty years, and produced a crop of barley every year. Plot 2 received at the rate of fourteen tons of farmyard manure per acre every year for twenty years and was sown with barley each year. At the end of this period, plot 2 was divided into two parts. One part received farmyard manure at the same rate as before for twenty years more, while the other part received no manure of any kind during the next twenty years, and barley was sown every year on both parts. There are, therefore, two periods of twenty years each, and the results may be compared. The average yield of grain on the continuously unmanured plot for the first twenty years (1852 to 1871) was twenty bushels per acre. The average yield from the continuously manured plot during the same period of time was 48¼ bushels per acre. For the second twenty years (1872 to 1891), the average yield from the continuously unmanured plot was 13¼ bushels per acre; on the part of plot 2 which received no manure during the second twenty years, the average yield was 30¼ bushels per acre; while on the part of plot 2 which was continuously manured as before, the average yield was 49 bushels per acre. Thus, it will be seen that the influence of the first twenty years of manuring extends over the second twenty years, producing an average crop of 30¼ bushels, as compared with 13¼ bushels on the plot which received no manure during the whole forty years. Nor did the influence end there, for the experiment was continued longer, and during the next five years, 1892 to 1896 inclusive, the average yield from the continuously unmanured plot was 11½ bushels per acre; whereas on the part of plot 1 which had received farmyard manure from 1852 to 1871, but nothing after that date, the average yield during the same five years (1892 to 1896) was 24⅛ bushels per acre. Therefore, after twenty-five years without manure, plot 2 continues to show a marked advantage over the continuously unmanured plot, and no one can foretell how much longer the influence of that twenty years of manuring with farmyard manure will be traceable. To be sure, if the land had received but a single application of farmyard manure, the results would not have been so striking, but the example just given will serve to illustrate the lasting effect of farmyard manure, which is one of its remarkable and valuable characteristics.

3. Farmyard manure increases the humus (vegetable matter) of the soil. This action is extremely important, because humus, besides supplying plant food as was previously explained, also improves the water-holding power of soils, and makes clay soils more open in texture, more easily worked, and altogether more favorable for the development of plant roots. What were once barren sands have been brought to a high state of productiveness by simply supplying them with humus; and it is a well known fact that many clay soils which are now so difficult to manage, were much more easily worked and produced better crops when the land was new, the explanation of which is found in the fact that years of cultivation and cropping have reduced the supply of humus in the soil. A manure, therefore, which increases the supply of humus is worthy of much more care and attention than it frequently receives.

4. As the vegetable matter (humus) furnished by farmyard manure decays in the soil, substances are formed which have considerable influence upon the insoluble compounds of plant food contained by the soil, tending to make them soluble and fit for plant food. Humus makes clayey soils more open in texture, thus admitting air more freely; and air also has an influence in making insoluble plant food available besides being, in itself, absolutely essential to the growth of plant roots.

5. It is believed by some very good authorities that farmyard manure also adds to the soil certain organisms (bacteria) which exert a very beneficial influence in making plant food available.

III. SOLID AND LIQUID EXCREMENTS.

Farmyard manure is composed of the solid and liquid excrements of animals, and usually contains in addition some substance which has been used for bedding, such as straw, sawdust, etc. When food enters an animal's stomach, a portion of it is digested and its constituents used to form bone, muscle, blood, fat, milk, horn, wool, hair, or other part or product of the animal body. In addition, a part of the digested portion of the food is used to renew those tissues of the animal body which are constantly wearing out, for the wearing out process is very rapid and necessitates a regular supply of food to furnish building material for new structures in place of the old. Therefore, in the animal body there are two classes of waste material which must be got rid of, namely, the undigested portion of the food, and the waste or refuse material from the worn out structures. The undigested food is excreted in the form of solid excrement, though the solid excrement also contains other waste products in addition. The waste matter from worn out structures is excreted in various ways, but most of those substances which are of value to the farmer are removed in the liquid excrement or urine.

Composition of liquid and solid excrements. Any figures relating to the composition of animal excrements can be only approximate, because so many influences affect the composition of excrements that it is impossible to give exact percentages. Since the solid excrement contains the undigested portion of the food, it follows that it will contain all the undigested nitrogen, phosphoric acid, potash, and other constituents of the food. The liquid excrement, on the other hand, contains a large part of the worn out material of the animal body; and the main fertilizing constituents which it contains are nitrogen and potash with occasionally a little phosphoric acid. Now, the animal body is built up from the digested portion of the animal's food; and, since the nitrogen and potash in the liquid excrement once formed a part of the animal body, it follows that the nitrogen and potash in the liquid excrement originally came from the digested portion of the food. Thus, the solid excrement contains (along with some other substances) the undigested portion of the food, while the liquid excrement contains part of the digested portion of the food. From these facts it will be seen that the more indigestible the food, the greater will be the proportion of its constituents which appear in the solid excrement; and the more digestible the food the greater will be the proportion of its constituents which appear in the liquid excrement. There is, therefore, no definite or fixed relation between the composition of the liquid and solid excrements of any class of animals; but while that is the case, the study of the results of a large number of analyses will be helpful in forming some general conclusions. The following figures are given by Beal, and represent averages of American analyses:

PERCENTAGE COMPOSITION OF SOLID AND LIQUID EXCREMENTS.

Name.	Nitrogen. Per cent.	Potash. Per cent.	Phosphoric acid. Per cent.
Cattle excrement, solid	.29	.10	.17
Cattle excrement, liquid	.58	.49	
Horse excrement, solid	.44	.35	.17
Horse excrement, liquid	1.55	1.50	
Sheep excrement, solid	.55	.15	.31
Sheep excrement, liquid	1.95	2.26	.01
Swine excrement, solid	.60	.13	.41
Swine excrement, liquid	.43	.83	.07

Though the figures given in the table are merely approximate, still they indicate that the liquid excrement of all the animals mentioned, except swine, is richer in nitrogen and potash than the solid excrement; and since nitrogen is by far the most expensive of fertilizing constitutents, it follows that a ton of liquid excrement is worth much more than a ton of solid excrement.

The table, however, does not show what proportions of the fertilizing constitutents of the food are voided by animals in their solid and liquid excrements respectively. As the result of many years of investigation, Lawes and Gilbert, of the Rothamsted Experiment Station, have come to the following conclusions regarding the nitrogen of the food, which may be regarded as the most important fertilizing constitutent:

QUANTITIES OF NITROGEN VOIDED BY ANIMALS IN SOLID AND LIQUID EXCREMENTS.

—	Out of 100 lbs. nitrogen in the food there are:	
	Voided in solid excrement.	Voided in liquid excrement.
Fattening oxen	22.6 lbs.	73.5 lbs.
Fattening sheep	16.7 "	79 0 "
Fattening pigs	22.0 "	63.3 "
Milking cows	18.1 "	57.4 "

It will be noticed that all the nitrogen of the food is not accounted for in the table, but the remainder is used by the animal in increasing its weight or in producing milk. The figures in this table, as in the preceding one, are simply approximations; but they illustrate very forcibly that by far the greater part of the nitrogen voided by animals is contained in the liquid excrement.

It has therefore been demonstrated that the liquid excrement of animals contains the greater part of the nitrogen and a large proportion of the potash consumed by the animal in its food; and that liquid excrement (except that of swine) is worth more, pound per pound, than solid excrement.

IV. INFLUENCES WHICH AFFECT THE COMPOSITION OF MANURE.

Perhaps no substance with which the farmer has to deal is subject to such wide variation in composition as is farmyard manure. These variations in composition add to the difficulty of discussing the valuation, application, and other points in connection with the substance in question; and, to assist in an intelligent study of farmyard manure, it will be well, before proceeding further, to devote some time to the consideration of those things which affect its value.

Different kinds of Animals. The manure from cattle and swine contains a high percentage of water, frequently over 80 per cent. So far as water content is concerned they are very similar, but the manure from swine is somewhat richer in nitrogen than cattle manure. Horse manure contains less water than that of cattle and swine; fresh sheep manure contains rather more water than horse manure, but a higher percentage of fertilizing constitutents; while poultry manure is similar to sheep manure in water content, and usually contains a higher percentage of nitrogen than any of the others.

Use and Individuality of Animals. A full grown animal which is receiving barely a maintenance ration, which is neither gaining nor losing in weight, and which is producing neither young, nor milk, nor wool, nor any other product, must, of necessity, return in its manure practically all the fertilizing constituents of the food it consumes. Fattening animals return in their excrements from 85 to 90 per cent., and cows in full milk only from 65 to 75 per cent. of the fertilizing elements of their food, the amounts varying with the rate and character of the gain or the quantity and quality of the milk. Young animals which are growing rapidly and producing a large amount of bone and muscle make relatively poor manure, the fertilizing value of their food being frequently reduced nearly 50 per cent. before it reaches the manure pile. Age is therefore an important factor in influencing the character of the manure from fattening animals. Animals which are producing and rearing young, return poorer manure than those of like species and under like conditions which are not producing young. To some it may seem strange that fattening animals can gain rapidly in weight and yet return in their manure such a large proportion of the fertilizing constitutents of their food; but the main part of the increase in fattening animals is composed of fat, and pure fat contains no fertilizing constitutents.

Kind of Food. It is easy to understand the influence of food upon manure. The excrements of an animal are derived from the food which it consumes, and hence the composition of the food determines the composition of the excrements. Foods rich in nitrogen and mineral matter produce manure rich in the same constitutents, and foods poor in fertilizing elements produce manure of correspondingly poor quality. Thus, animals fed on straw and turnips make a very low grade of manure, while those whose ration contains grain, bran, oil meal, etc., make manure of very much higher value per ton.

Quantity and Quality of Bedding. The most common substances used for bedding are straw, sawdust, and shavings. These substances are poorer in fertilizing constituents than animal excrements; hence their use in large quantities tends to decrease the value of the manure. But there is another important consideration. Bedding absorbs the liquid excrements, and if no bedding is used, it is more than probable that much of the liquid excrement will be lost; therefore, the use of sufficient bedding to absorb this important liquid and prevent its waste, adds very materially to the value of the manure. Straw is of course the usual and, excepting peat, the most valuable absorbent. Sawdust and shavings are regarded unfavorably by some farmers. When applied in large quantity on light land, they appear to be injurious, probably by making the land too open and thus lessening its already limited water holding power. There is need of further investigation in this connection; but where sawdust and shavings are used in moderation in the stables and applied to the land judiciously, there is little danger of injurious results. Peat is used for bedding in some districts, and is an excellent substance for the purpose. It absorbs and holds a large amount of liquid; it has considerable value as a fertilizer in itself; and it improves the mechanical condition of the soil to which it is applied.

Treatment. No one needs to be told that the treatment manure receives affects its value very materially. Excessive fermentation, washing by rain, keeping in badly constructed yards, etc., all have their influence in reducing the value of manure. As this part of the subject is dealt with more fully in another place, no more need be said under this heading.

V. CARE OF FARMYARD MANURE.

Liquid Manure Tank and Absorbents. While it is true that some loss is sure to occur in the management of manure, still, by using a little forethought the most serious losses may be prevented. What has been said regarding liquid manure is sufficient to illustrate its importance, for it has been pointed out that the greater part of the nitrogen and a large proportion of the potash which an animal consumes in its food appear in the liquid excrement. The first step in saving this important liquid is to have perfectly water tight floors. In this respect, a cement floor excels all others. This loss being stopped, it is in order to consider how to prevent loss of liquid outside of the stable. In some cases, liquid manure tanks have been built at considerable cost, but the tank has its objectionable features. To begin with, there is the cost of construction, including a portable tank for carrying the liquid to the field. Then, in warm weather, liquid manure ferments very rapidly, and in fermenting it loses much of its nitrogen which escapes into the air in the form of a gas (ammonia). If the tank is emptied frequently, much of this loss is prevented, but the liquid in the tank is out of sight and too frequently out of mind when other work is pressing. There is also an objection to applying liquid manure to the land separately, for liquid manure is rich in soluble nitrogen and potash but contains very little phosphoric acid, while the solid manure contains most of the phosphoric acid but is comparatively poor in soluble nitrogen. As a result, the manuring is somewhat one-sided and less satisfactory than where the solid and liquid manure are incorporated and applied together. Moreover, in applying liquid manure alone, there is danger of applying more nitrogen than the crop can use, and soluble unused nitrogen is washed out of the soil before another crop can be grown. Sometimes the liquid manure is pumped from the tank and distributed over the manure heap; but where there is sufficient absorbent material in the heap to retain the liquid thus applied, it is difficult to see what advantage this method possesses over carrying the liquid directly from the stable to the heap. On the average farm, straw is usually abundant, and where straw is plentiful there is little need of a liquid manure tank. Cut straw is more satisfactory than long straw, and a little cut straw in the bottom of the gutter behind the cattle will facilitate cleaning the stables. If straw is somewhat scarce, sawdust is a valuable adjunct. Where sawdust has to be used, it is better to use it in conjunction with straw than to use all the straw first and then use sawdust alone, since the mixture makes a more satisfactory bed and a more uniform quality of manure. Sawdust is excellent for the bottom of gutters, owing to its great absorbent power. Peat is an extremely valuable absorbent of liquid manure, but it is available in comparatively few districts. It is needless to say that for the system just described the stable gutters should have no outlet, and they are all the better if at least sixteen inches wide and from six to eight inches deep. Taking everything into consideration, therefore, the liquid manure tank seems unnecessary on the average farm; but for those cases where absorbents are extremely limited or entirely out of the question, the liquid manure tank is certainly better than nothing, and may be employed to advantage.

Open yards. After the manure is removed from the stable, the most serious losses are likely to occur. When manure is kept in open yards there is danger of losing a great deal of the soluble, and hence the most valuable part of it, unless much care is exercised. Many farmyards seem specially constructed for the purpose of wasting manure. It is no uncommon thing to see a large, sloping yard with the manure scattered thinly over it. As a result, the thin layer of manure is unable to hold all the rain-water which falls upon it, and the slope in the yard gives this excessive water a chance to drain away, carrying with it a large part of the soluble plant food from the manure. Frequently, too, the buildings about the yard have no eave-troughs. In such cases the manure receives an additional supply of water from the roofs, and the waste of plant food is proportionately greater. Where manure is kept outside, the opposite of the conditions just described should exist. The yard should be lower in the centre than at the sides so as to hinder drainage from the manure heap, and the buildings about the yard should be furnished with eavetroughs. It must also be remembered that twice as much rain will fall upon one hundred square yards as upon fifty square yards; consequently in order that the manure heap may receive as little rain as possible, it should be spread over as little ground as possible and kept in a compact pile. Manure which contains considerable straw may be made to absorb nearly all the rain which falls upon it, if it is kept in a compact heap so as to expose as little surface as possible to the rain. Many otherwise good yards are spoiled by having too large a space graded so as to be lower in the centre than the surrounding yard. The part of the yard thus hollowed out should be no larger than is absolutely necessary for the manure pile, while the remainder of the yard should fall away from the pile. When a large yard is made to slope towards the centre, it collects a great amount of water which floods the lower portion, causing much inconvenience as well as injuring the manure.

Manure Sheds. Owing to the dangers of loss from the open yard, even after more than average precautions have been taken, the covered manure shed is generally regarded as more satisfactory. The manure shed has several important advantages over the open yard. The manure is protected from rain and snow, and if the shed has a water-tight bottom, and a fair amount of absorbents have been used in the stable, there can be little loss of liquid manure. The shed may be so constructed that it will serve as an exercise ground for the stock, where they can take exercise in comfort even in the most stormy weather. The manure does not freeze as it does outside, and is therefore more easily drawn to the field in winter, if desired. The manure contains less water than that from outside yards, and consequently requires less labor in drawing. When manure sheds are built so as to allow animals to take exercise in them, loss of the droppings of the animals when out of the stable is prevented. The greatest danger of loss in the manure shed is from excessive fermentation of the manure. The manure, being kept drier than in the open yards, ferments much more readily, and if it is not properly attended to, loses much of its nitrogen. Fermentation is much more active when the manure is loosely piled, so that loss from fermentation is greatest in sheds when the stock do not trample the manure. If the shed is arranged so that the stock thoroughly trample and compact the manure, there is very little danger of loss ; but when the shed does not admit of this, it must be cleaned out frequently.

Manure sheds are of numberless patterns, and their arrangement will depend entirely upon the construction of the stables and the requirements of the owner. Convenience, economy, and effectiveness must be considered. Sometimes the manure shed takes the form of a basement below the stables, the floor and walls being cemented. In some cases hogs are fed in this basement, to trample and compact the manure. Such an arrangement is certainly convenient and effective, but the cost of construction will probably prevent its general adoption. Generally speaking, the floor of a manure shed should be water-tight, and somewhat hollowed in the centre. A hard clay bottom covered with a layer of gravel will answer very well. The shed is all the better if set on a low stone foundation cemented on the inside, though one that will answer the purpose may be made by setting posts in the ground and boarding with rough lumber, care being taken to have the floor properly graded. It must be borne in mind, however, that the less care bestowed upon the construction of the manure shed the greater care will be necessary to prevent loss. If excessive heating is observed, or if liquid is seen escaping, it will be necessary to clean out the shed. When the manure is trampled and kept compact by the stock, there is not much danger of excessive heating, but trampling will not prevent the escape of liquid manure if the shed is not properly constructed. In sheds where trampling by stock is not practicable, sometimes the manure is kept from heating by frequent moistening with water. This plan can scarcely be commended. The effect of the water is only temporary, and heating soon commences again, calling for repeated applications. As a result, more water is added than the manure can retain, and the water which escapes from the heap carries with it much valuable plant food. Thus the object of the manure shed is defeated, and keeping the manure in an open yard would have saved, at any rate, the labor of carrying water.

Box Stalls. The practise of fattening cattle loose in box stalls is growing in favor. Whatever may be said of its value so far as the cattle are concerned, it is certainly conducive to the production of first-class manure, provided that the stalls are properly constructed and well bedded. The floor of the box stall or pen should be water-tight, cement being preferable. Sufficient straw should be used to absorb all the liquid, and the trampling of the manure by the animals prevents excessive fermenation. In such stalls practically no waste occurs, and they need not be cleaned out oftener than once in two weeks. If the manure can be taken directly from the stalls to the field, the danger of loss is comparatively slight.

Mixing Manure. When manure is stored in yards or sheds it is very important that, as far as practicable, the manure from different kinds of stock should be mixed. Horse and sheep manure is comparatively dry and, consequently, ferments very rapidly. The manure from cattle and swine is much more moist and ferments more slowly. Mixing different kinds of manure, therefore, tends to prevent excessive fermentation of the dry manure, while the dry manure absorbs some of the excessive moisture of the wet manure, and thus helps to prevent loss by leaching. Moreover, the mixing of manures gives a product of more uniform quality, and more satisfactory to apply.

Fermentation. The widest difference of opinion exists among both practical and scientific men as to whether farmyard manure should be applied to the soil in its fresh state, or whether it should first undergo fermentation, or decomposition, in the heap. The question is a very difficult one, and it is also very important. The changes which take place in a pile of fermenting manure are extremely varied and are not, as yet, fully understood. Anything like a full discussion of these changes would be out of place here, but the advisability of allowing farmyard manure to ferment gives rise to so much discussion that it seems as though some attempt should be made to explain a few of the more important changes which may occur before the subject can be intelligently considered.

Before taking up the question of changes in manure, it may be well to make a few preliminary explanations, the importance of which will appear later. To begin with, an attempt will be made to explain the terms *free oxygen* and *combined oxygen*, *free nitrogen* and *combined nitrogen*. Oxygen and hydrogen are both colorless gases. If they are mixed in a suitable vessel and allowed to stand for an indefinite time, no change will be observed. There is in the vessel simply a mixture of oxygen and hydrogen, the same as there might be a mixture of sand and clay. But if a match could be applied to the mixture, or an electric spark sent through it, there would be an explosion, and after the explosion (if the gases were mixed in proper proportions) not a trace of either gas would be found. Instead of the gases there would be merely a few small drops of water. Before the explosion the vessel contained two *gases*; after the explosion it contained a small quantity of *liquid* called water. Now, water is made up of oxygen and hydrogen, but it is very different from either of them, or from the mixture of the two before the heat was applied. Heat brought about a union of the two gases, resulting in what is called a chemical compound. Before the explosion the gases were *free*, that is, each had a separate existence; but after the explosion the gases were no longer *free*, each gas lost its identity and the two *combined* to form water. In other words, before the explosion the vessel contained *free* oxygen and hydrogen, but after the explosion it contained *combined* oxygen and hydrogen.

Take another example. The atmosphere is largely made up of the gases oxygen and nitrogen, but they are not combined, and though they are mixed, they still exist as two distinct gases. The atmosphere, therefore, is largely made up of *free* oxygen and nitrogen. Now, hydrogen might be mixed with oxygen and nitrogen, and under ordinary conditions, no change would occur, but there would simply be a mixture of three distinct gases, each possessing its own peculiar properties. But, under certain conditions, these three gases do combine and form the powerful acid known as nitric acid. Nitric acid is entirely different from any one of the gases or the mixture of gases before combination took place, yet it is composed of hydrogen, nitrogen, and oxygen, and nothing else. Nitric acid, therefore, is a chemical compound made up of *combined* hydrogen, nitrogen, and oxygen, and it is the *combining* of these substances that has changed their character and made them entirely different from the mixture of *free* hydrogen, nitrogen and oxygen.

When nitric acid comes in contact with certain other substances, another marked change takes place. For example, if it comes in contact with the element potassium, some of the potassium will take the place of the hydrogen of the acid, and the compound of hydrogen, nitrogen, and oxygen will be changed into a compound of potassium, nitrogen, and oxygen. The latter compound is known by the names *potassium nitrate*, *nitrate* of *potash*, and *saltpetre*, and possesses qualities entirely different from nitric acid. Similarly, had the nitric acid come in contact with the element sodium, the sodium would have taken the place of the hydrogen of the acid, and the resulting compound would then be composed of sodium, nitrogen and oxygen, and would be called *sodium nitrate* or *nitrate of soda*. In the same way calcium may take the place of hydrogen in the acid and form *calcium nitrate*, and ammonia will form *ammonium nitrate*. Potassium nitrate, sodium nitrate, calcium nitrate, and ammonium nitrate, are probably the most important nitrates from an agricultural standpoint.

Special attention has been given to the explanation of what nitrates are, on account of their great agricultural importance. The nitrogen contained in organic matter (vegetable or animal matter) exists in very complicated compounds, and cannot be used again by plants as food until these compounds have been changed into much simpler ones. The most common form, and in fact almost the only form in which plants can make use of nitrogen, is in the form of nitrates. Hence the nitrogen of farmyard manure is of no use to plants until it has been changed into nitrates. But the change of the vegetable compounds containing nitrogen into nitrates is not accomplished in a single step nor by a single agency. Manure contains many different kinds of minute organisms called *bacteria*, and each kind of bacteria has its own peculiar influence upon the manure. All the changes which occur in manure, whether in the heap or in the soil, are caused by bacteria, and it is now in order to consider a few of these changes.

Vegetable matter contains a large amount of carbon. Carbon is taken from the air by plants through their leaves, and hence it has no value as plant food when applied to the soil. Before the nitrogen of vegetable matter can be changed into nitrates, it is necessary to get rid of the carbon which exists in combination with the nitrogen. This first step is brought about by one kind of bacteria, and the process is called *fermentation*. Generally speaking, the bacteria which cause fermentation require the presence of free oxygen (air); and fermentation can be checked or hastened by regulating the supply of air. The carbon liberated by the bacteria, combines with the oxygen of the air and escapes in the form of a gas known as carbonic acid gas. The carbon being driven off, simpler compounds containing nitrogen are left, and other kinds of bacteria bring about further changes in these compounds. It would be out of place to attempt to follow these changes in detail, but ammonia and nitric acid are common products. Ammonia contains nitrogen, and as it very readily escapes into the air in the form of a gas when fermentation is rapid, the result may be a very serious loss of nitrogen. The smell of ammonia can be very plainly detected in the neighborhood of a rapidly fermenting manure heap. If fermentation goes on slowly, much of the ammonia is changed into nitric acid, or combines with nitric acid already formed, and if such substances as calcium, potassium, or sodium are present, they also combine with nitric acid to form the important nitrates, as previously explained. The process by which nitric acid is formed is called *nitrification*, and the bacteria which are instrumental in bringing about nitrification are called *nitrifying bacteria*. Nitrification requires the presence of free oxygen, and therefore cannot go on in the absence of air. Warmth and moisture are also necessary.

There is one more possible change which must not be overlooked. It has been stated that ordinarily the bacteria which cause fermentation require air. There are, however, some kinds of bacteria which can cause organic matter to ferment in the absence of free oxygen. Oxygen is necessary to fermentation, and in the absence of free oxygen, these bacteria obtain their supply by breaking up any nitrates that may be present, using the oxygen of the nitrate, and allowing the nitrogen of the nitrate to escape as a gas. These bacteria, therefore, are very injurious to manure, since they destroy the valuable nitrates and allow their nitrogen to escape. Their effect is directly opposite to nitrification, and hence it is called *denitrification*.

The conditions favoring denitrification, according to Prof. Warington, are: 1. The presence of denitrifying bacteria. 2. The presence of a nitrate and suitable organic matter. 3. Such a condition as to aeration that the supply of free oxygen shall be limited. 4. The usual essential conditions of bacterial growth, as plant food, moisture, and a suitable temperature. Of these conditions, Warington considers an abundant supply of organic matter as most important. On the other hand, nitrifying bacteria require organic matter containing nitrogen, an abundant supply of free oxygen, the presence of some element such as calcium, potassium, or sodium to combine with the nitric acid, together with a suitable temperature, degree of moisture, etc.

It will be seen therefore that fermentation may produce injurious as well as beneficial results. It must also be borne in mind that fermentation and nitrification must take place before the nitrogen of farmyard manure can be of any use to plants, and therefore the point to be considered is how to bring about fermentation with the least danger of loss.

A very common European practice which also has some advocates in this country, is to cause considerable fermentation of the manure while in the heap. In defence of this method, it is claimed that the fermented product contains more available plant food than unfermented manure. No doubt this claim is true, but it may be questioned whether the available plant food was not obtained at too great a cost. If air is freely admitted to the heap, fermentation is extremely rapid and a large quantity of ammonia is evolved, carrying away with it much of the valuable nitrogen. Manure that has fermented very rapidly, frequently presents a scorched appearance, and is said to be "fire-fanged." Such manure is practically worthless. If air is largely excluded by packing the manure so as to check fermentation, then conditions prevail which favor denitrification of some of the nitrates which may be formed. A careful study of the question leads to the conclusion that the conditions existing in the manure heap are rather more favorable to denitrification than to nitrification, and that attempts to bring about nitrification in the manure heap are almost certain to be accompanied by a great loss of nitrogen, principally in the form of ammonia.

It is true that fresh manure contains a large proportion of unavailable plant food, but if it has been properly cared for and contains all the liquid excrements of the animals, it will contain sufficient available plant food for the present requirements of the crop, while the remainder will gradually ferment in the soil and become available for succeeding crops. The conditions in the soil are entirely different from those in the manure heap. The manure is mixed with the soil, fermentation is gradual, air is freely admitted, and the mineral matter of the soil combines with the nitric acid as it forms. In a wet soil, however, where air is excluded by excessive water, or in cases where a very heavy dressing of manure has been applied, denitrification is very active, but the difficulty may be overcome by thorough drainage, or by light application of manure. In all soils there is always more or less loss of nitrates in the drainage water, but this loss will occur whether the manure has been fermented or not. As a result of investigations up to date the eminent authority, Prof. R. Warington, deduces the following conclusion: "The original voidings of the animal have a far greater manurial value than the final product of the manure heap which the farmer carries to his fields. In the whole progress from the stable to the field the loss of nitrogen is going on, this loss falling on the most valuable constituent of the manure, and resulting finally in a residue of comparatively inert matter." The subject of the preparation and preservation of farmyard manure is still under investigation, but up to the present time the bulk of evidence is in favor of applying manure in its fresh state so far as economy of plant food is concerned. Certain crops or conditions of soil may call for fermented manure, and sometimes the destruction of weed seeds may influence some farmers in their practice, but these are questions aside from the general issue.

Rotted or fermented manure is commonly believed to be more suitable for light, sandy or gravelly soils than fresh strawy manure. If the manure is very strawy no doubt some injury to the texture of such soils may result from its application, especially if applied and plowed under in the spring; but with manure of good quality applied judiciously, there is less need of rotting than is commonly believed, in fact, some excellent farmers prefer fresh manure for light soils. Just to what extent fermentation is effective in destroying weed seeds has never been clearly demonstrated. No doubt it has some influence, and may be justifiable under some conditions.

Fermentation of manure in the heap, therefore, is invariably accompanied by a loss of nitrogen, either as free nitrogen or as ammonia, but chiefly in the form of ammonia. Fermentation is accompanied by a rise in temperature, a high temperature indicating rapid fermentation, and the more rapid the fermentation the greater the loss of ammonia. If it is desired to ferment manure the temperature must be carefully watched, and some preservative should be used to retain the ammonia. Before deciding that fermented manure is necessary for any particular soil or crop, careful tests should be made with fresh manure applied in the most approved methods. But, in comparing the effects of rotted and fresh farmyard manure, great care is necessary. It will not do to apply equal weights of each to equal areas of land, and draw conclusions therefrom regarding their relative values. A ton of rotted manure represents a great deal more than a ton of fresh manure; consequently the rotted manure may have lost a large percentage of its original plant food and still contain more plant food per ton than the fresh manure. For example, at the Cornell Experiment Station 10,000 pounds of fresh cow manure, composed of 9,278 pounds of excrements mixed with 422 pounds of straw, were placed in a compact heap and exposed from April 25th to September 22nd. At the beginning of the experiment the manure contained forty-seven pounds of nitrogen, and at the end of the experiment it contained twenty-eight pounds of nitrogen, showing a loss of forty-one per cent. of the original nitrogen. But at the end of the experiment the manure weighed only 5,125 pounds. Therefore the 10,000 pounds of fresh manure contained forty-seven pounds of nitrogen, or 9.4 pounds per ton, while the resulting 5,125 pounds of rotted manure contained twenty-eight pounds of nitrogen, or 10.9 pounds per ton. Now, if the 5,125 pounds of rotted manure and 5,125 pounds of fresh manure were applied to equal areas of land, the results would naturally be in favor of the rotted manure. The unfairness of such a comparison may readily be seen. In order to get a fair comparison in this particular case 10,000 pounds of fresh manure should be used for every 5,125 pounds of rotted manure, when very different results may be expected. Since there are great variations in the shrinkage of manure during rotting, it is extremely difficult to obtain anything approaching fair comparisons of fresh and rotted manure when applied to the soil.

Preservatives. When it is necessary to store manure for a considerable length of time, especially if it is not well compacted, or when it is deemed advisable to ferment the manure, the question of preservatives becomes one of considerable importance. As already intimated, the greatest loss of nitrogen from the covered manure heap occurs in the form of ammonia, and considerable attention has been devoted to the prevention of this loss. Various substances have been tested, but the results so far have not been thoroughly satisfactory.

Gypsum, or land plaster as it is commonly called, is highly commended by some for use in the stables and on the manure heap, but, while it tends to preserve ammonia, its influence is comparatively slight.

Lime hastens ammonia fermentation, and therefore should never be applied to the manure heap.

Thomas slag, according to Holdefleiss, has the same effect as lime.

Sulphate of iron has some effect in preventing the escape of ammonia, but to be effective, would have to be applied in such large quantities as to injure the manure in other ways, not to mention the cost of the substance.

Kainit appears to have a little influence in preserving ammonia, but is of doubtful value. It has a tendency to prevent fermentation and is therefore recommended for use in stables.

Superphosphate is regarded by some German investigators as one of the most effective of the chemical nitrogen preservers. The phosphoric acid which it contains also adds to the value of the manure. Even with superphosphate it requires such large quantities of the substance to preserve all the ammonia that it can scarcely be called a success.

Dry earth containing a considerable amount of humus has given very fair results. Considering that it is to be had on practically every farm for the trouble of drawing, it is pretty safe to say that it is one of the best and safest preservatives that the farmer can use. The more humus it contains the better. Its free use both in the stables and on the manure heap will add to the value of the manure in no small degree.

VI. APPLICATION OF FARMYARD MANURE.

Rate of Application. A very common mistake in applying farmyard manure is to give a small part of the farm a very heavy coating and leave the remainder without any. There are several good reasons why such a practice should not be followed. If the manure has been properly cared for, there is no need of such heavy applications to supply sufficient plant food for the crops; and when heavy manuring is practised, a large part of the farm is neglected while a small part receives much more than it requires. The practice is similar to starving the greater number of a herd of cattle and giving the few remaining animals far more than they can eat. Very heavy manuring is wasteful. It is frequently claimed that if the first crop does not require the plant food applied, the next crop will be all the better off. It is true that the heavier the application, the greater the residue left over for succeeding crops; but it does not follow that there is no waste of plant food under heavy manuring. There are at least two important sources of loss of plant food in the soil under heavy manuring. In the first place, there is danger that some of the excessive plant food may be leached out of the soil and lost in the drainage water when the land is not under crop. In all fertile soils there is always a considerable loss of nitrates from the soil in the drainage water, and it is not difficult to understand that the greater the excess of soluble plant food in the soil, the greater the loss in the drainage water. Some loss is sure to occur, but an effort should be made to make the loss as small as possible; and moderation in applying manure is one step in this direction.

The other source of loss under heavy manuring is not so easy to understand, and may be best illustrated by reference to experiments conducted by Wagner and Maercker in Germany. After a long series of careful experiments in which farmyard manure was used with other fertilizers, notably with nitrate of soda, they were led to some remarkable conclusions, among which the following may be mentioned:

1. "The solid excrement of the horse and cow is practically without value as a manure for plants."

2. "When applied to the land, fresh horse or cow dung destroys the nitrates naturally contained in the soil, or added to it in the form of nitrate of sodium, and the crop which immediately follows is consequently less than if no dung had been applied."

The reason for these and other unfavorable conclusions is given in the second conclusion quoted above, viz., the farmyard manure brought about denitrification apparently of both the nitrates of the soil and the nitrate of sodium applied along with the farmyard manure; that is to say, it caused these valuable nitrates to be broken up, and the nitrogen which they contained to be liberated as free nitrogen which escaped into the atmosphere and was thus lost to the soil. Now, undoubtedly denitrification did occur in these experiments and very energetically too; and there is no room for doubt that in these experiments farmyard manure was a failure. But, as Warington points out, the experiments were conducted in zinc cylinders or pots from which there was probably no drainage. The amount of soil used in each pot was small, and the amount of manure used compared with the amount of soil was abnormally large, representing applications at the rate of from forty to one hundred tons per acre. In the field experiments at Rothamsted where moderate applications of manure were used along with nitrate of sodium, farmyard manure proved to be decidedly beneficial. In the discussion of fermentation of farmyard manure, the conditions favoring denitrification were described, and it will be seen that the German conditions were particularly suitable for denitrification. From the German results a useful practical lesson is to be derived. They show that it is possible to apply farmyard manure in such a manner that its effect is positively injurious ; and though it is extremely improbable that such conditions would exist in farm practice, it is more than probable that large losses of nitrogen through denitrification frequently occur when very heavy applications of farmyard manure are made. When the soil is not well drained, the danger of denitrification is increased.

It is a difficult matter to say what constitutes a light, moderate, or heavy application of farmyard manure. It has been shown that farmyard manure is subject to extreme variations in composition ; consequently a given number of tons per acre might be a heavy dressing of manure in one case and a light dressing in another, depending on the quality of the manure. The rate of application will also be influenced by the natural fertility of the soil and the kind of crop to be grown, so that recommendations as to quantity can be made only in the most general terms, and a good deal must be left to the judgment of the person applying it. Generally speaking, about fifteen tons per acre of good manure from an outside yard may be counted a fairly heavy dressing for average soils. Well managed manure from a covered yard or shed contains less water than that from outside yards, and consequently a smaller quantity would be equivalent to fifteen tons of outside manure. Now, mixed farmyard manure of fairly good quality may contain .6 per cent. of nitrogen, .3 per cent. of phosphoric acid, and .45 per cent. of potash, though of course these percentages are merely approximations. The following table shows the amount of nitrogen, phosphoric acid, and potash supplied by fifteen tons of farmyard manure according to the percentages given above, together with the amount of these constituents removed per acre by a crop of wheat and turnips, as estimated by Van Slyke :

—	Nitrogen.	Phosphoric Acid.	Potash.
15 tons farmyard manure contain	180 lbs.	90 lbs.	135 lbs.
Wheat crop (15 to 30 bushels) contains	31 to 62 lbs.	10 to 20 lbs.	13 to 26 lbs.
Turnip crop (350 to 700 bushels) contains	40 to 80 lbs.	26 to 52 lbs.	90 to 180 lbs.

According to the estimates just quoted, fifteen tons of farmyard manure supplies an excess of all the fertilizing constituents, except phosphoric acid for the largest crop of turnips. All of the plant food contained in the manure is not available, but it is not known what percentage of the plant food can be made use of by the crop under ordinary field conditions, and probably never will be known owing to the complexity of the problem. In a fertile, well cultivated soil, however, some allowance must be made for available plant food already in the soil, either as a residue from previous manuring or as natural fertility, so that it is not necessary to supply in an available form the full amount of plant food required by the crop. It is quite probable, too, that average farmyard manure would not contain so much plant food as is assumed in the table, and further allowances must be made if the manure is of inferior quality. Practical results seem to indicate that about fifteeen tons per acre of fair quality of manure may be regarded as the maximum quantity necessary on average soil for the heaviest feeding crops, such as roots and corn. For wheat, the requirements are considerably smaller, as may be seen by referring to the table, where wheat is compared with turnips. Probably ten tons per acre, or even less, may be regarded as a heavy application for wheat. No fixed rule can be given regarding the quantity of manure to apply for different crops. Each farmer must be guided largely by circumstances, and by an understanding of some general principles underlying the operation. It is a pretty safe conclusion that moderate applications of manure to a large area will give better ultimate returns than heavy applications to a small area ; and the smaller the supply of manure, the greater the necessity of restricting the amount applied per acre. The time has passed when it was thought necessary to apply from twenty to forty tons of manure per acre.

Depth of Covering. Farmyard manure should be kept as near the surface of the soil as possible. The rainwater as it percolates through the soil, has a tendency to carry the soluble plant food downward and out of the reach of plants ; consequently an attempt should be made to delay the downward progress of plant food instead of assisting it by plowing the manure in deeply. Then again, nitrification is most active near the surface of the soil. Therefore manure kept near the surface is under more favorable conditions for having its plant food made available and consequently gives quicker returns. When a heavy application of manure has been plowed under deeply, it is no uncommon thing to see lumps of manure brought to the surface by subsequent plowing, showing that it had never become properly incorporated with the soil. It is quite probable, too, that this deeply buried manure has lost considerable nitrogen through denitrification. Economical manuring consists in obtaining quick returns over as large an area of the farm as possible, and this is accomplished by moderate applications incorporated with the surface soil. Shallow covering of manure also increases the humus of the surface soil. As a result, the soil does not bake and crack in dry weather ; it absorbs and retains water much more satisfactorily, and works up into a fine tilth more easily.

Time of Application. Farmyard manure gives better results with spring sown crops if applied and incorporated with the soil during the preceding fall. This is the case especially with crops sown in the early spring, such as mangels or a grain crop. The reason is obvious, since mixing the manure with the soil in the fall gives more time for the preparation of the plant food which it contains. The quantity of manure available for fall application is usually limited, for keeping manure in the yard throughout the summer is open to some very grave objections. Extended experiments at various American experiment stations show that very serious losses may occur in the manure pile during the summer. Sheldon, of the Kansas Experiment Station, concludes that manure should be hauled to the field in the spring, otherwise the loss in six months may amount to nearly forty per cent. of the nitrogen it contains. Experiments at the Cornell Experiment Station tend to confirm this conclusion ; but in one case, where the manure was very firmly packed, the loss in value was less than ten per cent. When manure is carelessly scattered over badly constructed yards during the summer, the loss in value is extremely great. When kept in manure sheds during the summer there is danger of excessive fermentation. To say the least, it is an extremely difficult matter to keep manure over from spring until fall without incurring considerable loss.

To avoid this loss and to relieve the pressure of work in the spring, the practice of drawing manure as it is made and spreading it on the land during the winter is becoming popular in many districts. No doubt some loss occurs when this method is followed, but just how great the loss is it is impossible to ascertain. Steep hillsides or those parts of a field that are subject to the wash of surface water in the spring are entirely unsuitable for the winter application of manure; but on comparatively level land, where little washing occurs, it is probable that the loss of plant food is no greater than in the average yard or shed. At any rate the practice seems to be giving good results on many farms, and, so far as present knowledge goes, it seems to have many commendable features when judiciously followed, though no doubt it is frequently abused. Land which is inclined to be wet in the spring, or which is intended for early sown crops, should not be manured during the winter, because the manure tends to retard the thawing and drying of the soil.

The method practised on the College farm has given excellent results. In the regular course of rotation, roots, corn, and peas are sown on land that has been two years under clover and grass, either as meadow or pasture. The sod is plowed as early as possible the preceding fall and thoroughly cultivated, so as to have the sod fairly well rotted before the weather turns cold. In the fall all the manure that can be obtained about the place is drawn on the land intended for roots and corn and spread upon the surface. Then the land is ribbed or ridged up with the double mouldboard plow, as is commonly practised for roots, making the ribs or ridges about twenty-one inches apart. By this means the manure is incorporated with the soil in the ridges. In the spring these ridges are cultivated down and the land is in excellent condition for a root crop, or any other crop. This method not only ensures a thorough mixing of soil and manure, but it also tends to prevent loss of plant food in the drainage water, especially on rolling land. All the manure which accumulates during the summer, together with that which is made during the fall until the plow is stopped by frost, is treated in this way, the hilly or rolling ground receiving the first attention, so as to lessen the danger of waste. There is never enough manure to cover all the corn and root ground in the fall, so manure is applied to the remaining ground during the winter and early spring, and incorporated with the surface soil by means of the gang plow and cultivator after the early sown crops are in. It will be seen that by this method no manure is available for the fall wheat ground in the fall, but in the rotation fall wheat follows the peas, and before the peas are sown the land is given a coating of manure which is incorporated with the surface soil. The object is not to manure the pea crop, but to prepare a store of available plant food for the wheat which follows the peas. On fairly rich soil a very light application of manure is sufficient for this purpose. On soils which tend to produce too great a yield of straw, applying manure before sowing peas would be open to objection, since it would probably aggravate the evil. Where the plan is practicable it possesses several important advantages. It admits of the application of manure for roots in perhaps the most effective manner. It allows of applying fresh or coarse manure in the spring with a crop that has little need of it, consequently during the summer its plant food is being rendered available for the fall wheat which is to follow. It obviates the danger of having to apply manure for fall wheat at the time when the ground is very dry, the evil effects of which will be noted presently. It also admits of the application of coarse manure when the soil is moist, consequently the manure ferments readily and increases the humus of the soil, and when the pea crop is removed the ground is mellow, moist, and in good condition for wheat.

When manure is applied during the summer, it should be mixed with the soil as soon as possible to prevent drying. It is not likely that simply drying the manure would result in any very serious loss of plant food, but when day manure is mixed with a comparatively dry soil, the necessary fermentation cannot take place, since, as was previously explained, moisture is necessary for the development of nitrifying bacteria. As a result, the manure is apt to form masses of dry, inert material in the soil, which never seem to become properly mixed with the soil afterwards. For the same reasons, plowing under manure during dry weather may injure the water-holding power of the soil, since there is not sufficient moisture to ferment the manure and change it into humus, and the soil is rendered too open in texture. The fault is not in the manure, but lies in the time and method of applying it.

VII. VALUATION OF FERTILIZING CONSTITUENTS IN MANURE.

Few subjects present more real difficulties than the valuation of the fertilizing constituents of farmyard manure. Farmyard manure varies so in composition that it is impossible to estimate with any degree of accuracy how much plant food a given sample contains without first subjecting it to a chemical analysis. Even if the composition is known the difficulty is by no means overcome, for the next point to decide is what money value to attach to the different elements of plant food in the manure, a problem more difficult to solve than the first. A common method is to value each constituent at the price per pound which would have to be paid for it if purchased in the form of a commercial fertilizer. It is argued that were it not for farmyard manure the farmer would be forced to use commercial fertilizers; consequently the manure is worth whatever it saves him in expenditure for its equivalent in commercial fertilizers. From this point of view the argument is perfectly sound; but there is another way of looking at the question, and it may well be asked whether commercial fertilizers are always *worth* what they *cost.* For example, a pound of nitrogen in a good commercial fertilizer usually costs about fifteen cents in the United States, and this value is frequently employed in valuing the nitrogen in farmyard manure and in fodders. In valuing fodders in England, Lawes and Gilbert value nitrogen in the form of ammonia at four pence per pound, which is equivalent to about 9.8 cents per pound for nitrogen, or say ten cents per pound. Now, because nitrogen costs fifteen cents per pound in the United States and ten cents per pound in England, does it follow that nitrogen is worth more to the American farmer than to the English farmer? There is a difference between what a thing is worth and what it costs, as everyone knows, and therefore there are two ways of valuing the constituents of plant food in any manure or fertilizer. It is possible to ascertain, approximately, the value of a manure pile or of certain fodders in terms of commercial fertilizers; but if it is required to find just how much the manure and fodders are worth, so far as increased productivity of the soil or increased value of the land is concerned, probably a very different scale of values may be necessary. It is a comparatively simple matter to show, according to the first method, that plant food to the value of \$50 or \$100 per acre has been added to a certain farm, and to reason therefrom that the farmer's capital has been increased by that amount; but when it is attempted to show that the farmer's profits have been increased in like proportion, or that the selling price of his farm has been increased to the extent of $50 or $100 per acre, the real difficulties of the problem are fully appreciated. Soils, seasons, cultivation, and markets, all combine to complicate matters, so that it is impossible to say just what cash returns may be expected from the application of a given quantity of plant food. But plant food must be added to the soil; there is no option in the matter; and therefore all that is left for the farmer to do is to study how he can obtain sufficient plant food at the lowest possible cost. The importance of making the best possible use of animal excrements has already been pointed out. If animals can be so managed that their products pay for purchased fodders, certainly no cheaper fertilizer is available than the manure resulting from the use of these fodders. It will not do, however, to spend money recklessly in animals and feeding stuffs, believing that the loss sustained on the animals will be more than made up by increased fertility of the soil. It may be possible to justify this course of action by attaching money values to the plant food contained in the purchased fodders, but the bank account may tell a very different story. It is not intended to discredit the practice of valuing the manurial constituents of feeding stuffs—far from it. The practice is a very commendable one, and manurial value should always be considered in purchasing food for animals. It is intended, however, to sound a note of warning against the abuse of the practice, and to show that it is possible to attach values to fertilizing constituents which can never be realized when put to a practical test.

The composition of farmyard manure is so greatly influenced by the foods which animals consume, that it becomes of importance to know something of the relative values of feeding stuffs for furnishing plant food. Since the fertilizing constituents of fodders exist in insoluble forms and must undergo many changes before they become available for plants, it is customary to attach somewhat lower values to them than the market values of the same constituents in soluble commercial fertilizers. A common plan is to value the nitrogen of feeding stuffs at twelve cents per pound, phosphoric acid at four and a half cents per pound, and potash at four and a half cents per pound. Below is given a table, the first column of which shows the result of applying the values mentioned to the fertilizing constituents of some representative feeding stuffs, the composition of the fodders being obtained from American analyses. The second column shows the result of applying the same values to the fertilizing constituents contained in the fodders according to English analyses. The third column shows the same values applied to the remaining fertilizing constituents of the fodders after being fed to cows producing ten quarts of milk per head per day, data regarding the fertilizing constituents in the manure being obtained from the estimates of Lawes and Gilbert. American analyses are more satisfactory for this country than English analyses, as the difference in climate likely influences the composition of the fodders. The only reason for inserting the second column is to furnish a basis of comparison for the third column. The second and third columns are computed from English analyses; consequently, to obtain an idea of the probable shrinkage in manurial value of fodders as the result of being fed to cows, it will be necessary to compare the third column with the second.

TABLE I. Showing value of fertilizing constituents in one ton of various fodders according to American and English analyses; also value of fertilizing constituents returned in manure per ton of food consumed by cows producing ten quarts of milk per head per day; estimating nitrogen worth twelve cents, phosphoric acid, four and a half cents, and potash four and a half cents per pound.

Fodder.	Total value of fertilizing constituents per ton of different fodders.		Value of fertilizing constituents returned in manure per ton of food consumed by cows producing ten qrts. of milk per head per day.
	Computed from American analyses.	Computed from English analyses.	
Cotton seed meal	$19 70	$22 88	$19 96
Oil cake	16 77	16 19	13 04
Wheat bran	10 46	11 81	9 71
Peas	9 02	11 50	8 [illegible]
Wheat middlings	7 73	10 98	8 46
Oats	6 24	6 48	3 96
Wheat	6 65	6 22	3 60
Barley	4 77	5 74	3 11
Corn (maize)	5 36	5 54	2 91
Clover hay	7 29	8 53	7 18
Meadow hay (mixed)	5 02	6 04	4 78
Wheat straw	1 98	2 25	1 35
Potatoes	1 22	1 37	1 06
Mangels	87	1 06	86

The method of valuation shown in the first column is very commonly adopted in estimating the manurial value of fodders, but no allowance is made for what the animals remove from the food. A comparison of the second and third columns shows that the reduction in value when fed to cows giving a fair average flow of milk, amounts to a considerable percentage of the original value. Allowance must also be made for losses which are almost certain to occur before the manure reaches the field. Then, too, there are losses in the drainage water, and under some conditions there may be losses due to denitrification. Therefore, even if it be granted that the values attached to the different fertilizing constituents are not too high, it is quite apparent that considerable deductions must be made from the figures given in the table before they represent the actual worth of the fodders as fertilizers. It is also apparent that valuations of the fertilizing constituents of fodders are sometimes very misleading. The table is not without value, however, for if it does not show the actual manurial values of the fodders, it gives an intelligent idea of their approximate relative values, a very important consideration in buying fodders.

It has been already intimated that Lawes and Gilbert employ lower values than those commonly used in America in estimating the manurial value of fodders. In their most recent publications they value nitrogen as ammonia at 4 d., phosphoric acid at 2 d., and potash at $1\frac{1}{2}$ d. per pound. The following table shows the effect of applying these values to the fertilizing constituents of the fodders under consideration, estimating £1=$4 86:

TABLE II. Showing manurial value per ton of food consumed, after deducting the fertilizing constituents in fattening increase and in milk. Adapted from estimates of Lawes and Gilbert. Nitrogen (as ammonia), 4 d.; phosphoric acid, 2 d.; and potash $1\frac{1}{2}$ d. per lb.

Fodder.	Manurial value per ton of food consumed, deducting the constituents in fattening increase and in milk.	
	For the production of fattening increase.	For the production of milk, supposing the yield per head per day to be 10 quarts.
Cotton seed meal	$18 16	$16 36
Oil cake	12 62	10 65
Wheat bran	9 35	8 04
Peas	8 85	7 17
Wheat middlings	8 54	6 97
Oats	4 79	3 24
Wheat	4 60	2 93
Barley	4 17	2 55
Corn (maize)	4 03	2 41
Clover hay	6 56	5 73
Meadow hay (mixed)	4 51	3 75
Wheat straw	1 58	1 01
Potatoes	99	79
Mangels	77	67

Table II. is of interest as a means of comparing the relative influence of fattening and milk production upon the manurial value of feeding stuffs. As in the preceding table, no allowance is made for other losses which may occur. The third column of Table I. is obtained from exactly the same data as the second column of Table II., except that different values are applied to the manurial constituents. It is interesting, therefore, to compare these two columns, because they show the difference between American and English valuations of fertilizing constituents, and afford another illustration of the need of care in applying money values to manure.

The whole subject of valuing fertilizing constituents in any form, is full of difficulty. An attempt has been made to show the importance of distinguishing between market value and actual value as shown by increased productivity, and to show that it is impossible to affix money values to fertilizing constituents, which would represent their true worth in increasing the profits of the farmer. The whole question is largely a matter of judgment. But understanding is necessary to sound judgment, and therefore an attempt has been made to assist in understanding this complex subject.