UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BULLETIN 166

HANDLING FARM MANURE

A load of fertility

COLUMBIA, MISSOURI
SEPTEMBER, 1919

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

OFFICERS OF THE STATION

A. ROSS HILL, PH. D., LL. D., PRESIDENT OF THE UNIVERSITY
F. B. MUMFORD, M. S., DIRECTOR

STATION STAFF

1919

AGRICULTURAL CHEMISTRY
C. R. MOULTON, Ph. D.
L. D. HAIGH, Ph. D.
W. S. RITCHIE, A. M.
S. B. SHIRKEY, A. M.
T. H. HOPPER, B. S.
EMORY M. ROLLER

AGRICULTURAL ENGINEERING
E. H. LEHMANN, B. S. in A. E.
MACK M. JONES

ANIMAL HUSBANDRY
F. B. MUMFORD, M. S.
E. A. TROWBRIDGE, B. S. A.
L. A. WEAVER, B. S. in Agr.
RAY E. MILLER, B. S. in Agr.
D. W. CHITTENDEN, B. S. in Agr.
J. H. LONGWELL, B. S. in Agr.

BOTANY
W. E. MANEVAL, Ph. D.
W. J. ROBBINS, Ph. D.

DAIRY HUSBANDRY
A. C. RAGSDALE, B. S. in Agr.
A. C. DAHLBERG, M. S.
W. W. SWETT, A. M.
PERCY WERNER, JR., A. M.
W. H. E. REED, B. S. in Agr.
C. W. TURNER, B. S. in Agr.

ENTOMOLOGY
LEONARD HASEMAN, Ph. D.
K. C. SULLIVAN, A. M.

FARM CROPS
W. C. ETHERIDGE, Ph. D.
E. M. MCDONALD, B. S.
C. A. HELM, A. M.
E. J. STADLER, A. M.

FARM MANAGEMENT
O. R. JOHNSON, A. M.
R. M. GREEN, B. S. in Agr.

FORESTRY
FREDERICK DUNLAP, F. E.
S. N. SPRING, M. F.

HORTICULTURE
V. R. GARDNER, M. S. A.
H. D. HOOKER, Ph. D.
H. F. MAJOR, B. S. A.
J. T. ROSA, JR., M. S. H.
H. G. SWARTWOUT, B. S. in Agr.

POULTRY HUSBANDRY
H. L. KEMPSTER, B. S.
G. W. HERVEY, B. S.

SOILS
M. F. MILLER, M. S. A.
R. R. HUDELSON, A. M.
W. A. ALBRECHT, Ph. D.
F. L. DULEY, A. M.
H. H. KRUSEKOPF, A. M.
WM. DEYOUNG, B. S. in Agr.

VETERINARY SCIENCE
J. W. CONNOWAY, D. V. M., M. D.
L. S. BACKUS, D. V. M.
O. S. CRISLER, D. V. M.
A. J. DURANT, A. M.
H. G. NEWMAN, B. S. in Agr.

OTHER OFFICERS
R. B. PRICE, M. S., Treasurer
J. G. BABB, A. M., Secretary
E. H. HUGHES, A. M., Asst. to Dean.
O. W. WEAVER, B. S., Agricultural Editor
GEORGE REEDER, Director Weather Bureau
MRS. NORMA W. CARDINELL,[1] Seed Testing Laboratory
J. F. BARHAM, Photographer

[1]In service of U. S. Department of Agriculture.

Handling Farm Manure

F. L. Duley

As prices of farm products have increased and as the average fertility of our soils has decreased, the saving of barnyard manure has become a matter of vital importance in our system of agriculture. From time immemorial manuring has been known to be the most logical and practicable method of maintaining a soil's productiveness. Its extensive use and careful handling, however, have always been delayed until the soil was materially reduced in fertility and the supply of plant food markedly depleted. Most cultivated soils in Missouri have lost fertility by long and continuous cropping, to such an extent that they give marked increases in yield where manure is applied. This fact is bringing about an increasing interest in the handling of this valuable product. Manure is no longer considered as something to be got out of the way, but rather the most valuable by-product of the farm. Much less manure is wasted than was the case ten years ago, yet there is still much room for improvement. Not many men deliberately neglect the manure, but the better known methods of handling it have not been adopted by the majority of farmers in Missouri. At a conservative estimate they lose at least twenty million dollars a year, an amount equal to sixty cents for each acre of cultivated land in the state, because of their failure to make use of the best known methods of handling and utilizing the fertility in manure.

HOW SOILS LOSE FERTILITY

Soils lose fertility by erosion, by leaching or underdrainage, by cultivation, and by the removal of crops. The amount lost by erosion and leaching will depend largely upon the slope of the land and the methods of cultivation and cropping. There is probably more fertility lost from Missouri farms by soil erosion than in any other way. The amount of organic matter and nitrogen lost due to cultivation is also variable, and it is difficult to make any close estimate as to what may be the loss of fertility due to these factors.

The loss of fertility thru the removal of crops can be determined quite accurately by a chemical analysis of the material removed from

the land. This loss is a very important one, especially when the crops are entirely removed and nothing in the way of crop residues or manure is returned to the soil. Table 1 shows the approximate amounts of plant food contained in one acre of the common farm crops. There is also included the amount contained in other forms of farm produce.

TABLE 1.—FERTILIZING CONSTITUENTS IN FARM PRODUCTS

Calculated on the basis of an acre of field products or 1000 pounds of animal products

Material	Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Fertility value (a)	Manurial value (b)
Corn, grain, 50 bu.	50.0	9.1	9.3	$11.64	$9.31
Corn, stover, 1.75 T.	28.0	3.5	30.3	7.83	6.26
Corn, total crop	78.0	12.6	39.6	19.47	15.57
Oats, grain, 40 bu.	24.0	4.0	4.6	5.55	4.44
Oats, straw, 1.2 T.....	14.2	1.8	24.0	4.49	3.59
Oats, total crop	38.2	5.8	28.6	10.04	8.03
Wheat, grain, 25 bu.	29.1	3.7	6.6	6.66	5.32
Wheat, straw, 1.1 T.	10.2	2.2	18.3	3.40	2.72
Wheat total crop	39.3	5.9	24.9	10.06	8.04
Clover hay, 2 T.	80.0 (c)	10.0	60.0	20.80	16.64
Cowpea hay, 2 T.	93.0 (c)	9.0	63.0	23.46	18.76
Timothy, 1.5 T.	36.0	4.5	35.0	9.84	7.87
Alfalfa, 4 T.	200.0 (c)	18.0	96.0	47.92	38.33
Fat cattle, 1000 lbs.	25.0	7.0	1.0	5.90	4.72
Fat hogs, 1000 lbs.....	18.0	3.0	1.0	4.02	3 21
Milk, 1000 lbs.....	5.1	1.9	1.8	1.34	1 07
Butter, 1000 lbs.....	1.2	0.4	0.4	.31	.25

(a) The amount of plant food has been calculated from results obtained from various sources. The fertility value of the crops has been determined by assuming a value of 20 cents a pound for nitrogen, 12 cents a pound for phosphorus, and 6 cents a pound for potassium.

(b) The manurial value is obtained by taking 80% of the fertility value. It is assumed that about that amount of plant food can be returned in the manure if proper care is taken.

(c) It should be understood that much of the nitrogen in legume hay is derived from the air rather than from the soil.

It will be seen from Table 1 that the value of fertility contained in certain crops when calculated at fertilizer prices of plant foods is a large proportion of the value of the crop. If crops are continually sold from the land they act as a constant drain upon the stores of available plant food, which process may easily be continued to a point where one of the important fertilizing elements becomes a limiting factor in production. That is exactly what has happened on most of the worn soils of Missouri which will no longer yield as abundant crops as they once did.

Table 1 also shows that a large part of the fertility contained in crops will be found in the manure if these crops are fed to farm animals. If this is returned to the land most of the nitrogen, phosphorus and potassium will be restored to the soil. Manure also contains a large amount of organic matter which may have a very beneficial effect when used on certain types of soil.

THE COMPOSITION OF VARIOUS MANURES

Table 2 gives an idea of the approximate amount of plant-food elements, which are returned to the soil by one ton of various forms

TABLE 2.—PLANT FOOD AND TOTAL VALUE OF A TON OF THE COMMON KINDS OF MANURE

Animal	Wt. Manure, pounds	Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Value pre-war prices	Value per ton 1918 prices
Horse Solid	1632.2	8.06	2.12	3.26	$2.06	$4.68
Liquid	367.8	4.41	trace	4.56	1.15	3.36
Total	2000.0	12.47	2.12	7.82	3.21	8.04
Cow Solid	1456.5	4.71	1.31	1.80	1.20	2.70
Liquid	543.5	5.16	.06	4.29	1.29	3.57
Total	2000.0	9.87	1.37	6.09	2.50	6.27
Sheep Solid	1200.0	7.80	2.40	2.28	1.98	4.27
Liquid	800.0	13.44	.10	14.08	3.54	10.31
Total	2000.0	21.24	2.50	16.36	5.52	14.58
Hog Solid	1290.3	7.74	2.58	4.77	2.14	5.15
Liquid	709.7	2.12	.39	5.89	.82	2.96
Total	2000.0	9.86	2.97	10.66	2.96	8.11
Hen	2000.0	23.00	8.10	7.46	6.01	13.02

Note: This table was computed from data compiled from various sources. The value of plant food was taken on the pre-war basis of fertilizing materials, that is 20 cents a pound for nitrogen, 12 cents for phosphorus and 6 cents for potassium. The 1918 prices assume 40 cents for nitrogen, 15 cents for phosphorus, and 35 cents for potassium.

of manure. The table shows that there is a wide variation in the value of manure from different animals. The high value per ton of sheep and chicken manure is largely due to the high nitrogen and potash content of these materials. Cattle usually consume large quantities of coarse feeds which are low in plant food, and they also produce manure with a very high moisture content. These two factors tend to make the ton value of cattle manure less than that from other animals, but the total value of manure produced by cattle is more than that from other animals because of the greater quantity.

A study of the analyses of manure from different animals shows that there is considerable difference in the percentage composition

of both the solid and liquid excrements from different species. Manure low in moisture content produced by such animals as sheep has a higher plant-food value per ton than that from other livestock.

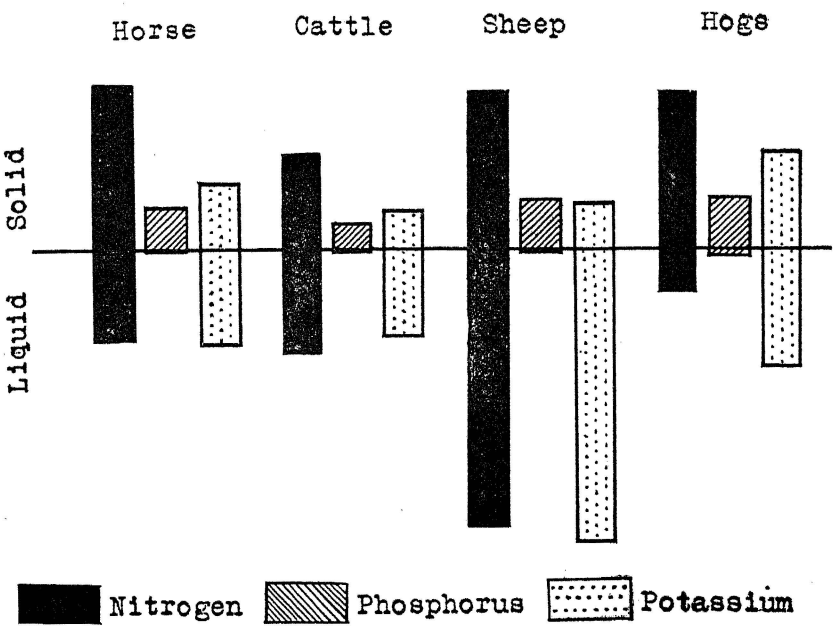

Fig. 1.—Diagram showing the relative amounts of plant food in pounds from one ton of solid and liquid manure from different animals as shown in Table 2.

Usually, about 35 per cent of the nitrogen and 55 per cent of the potassium is found in the liquid manure. There is, however, very little phosphorus in this part. It may be seen from Table 2 that the liquid manure is worth considerably more than half as much as is the solid portion. Unless great care is taken to save the liquid by absorbing in the bedding or collecting in some other way there are sure to be great losses of nitrogen and potash that should be returned to the soil with manure.

The urine from sheep contains a higher percentage of nitrogen and potassium than that from other animals, while the hog is the only animal excreting any considerable amount of phosphorus in the liquid manure. The total amount and value of manure produced in a year is indeed variable and depends upon a number of conditions, but a general idea may be had from Table 3. These figures were compiled from various sources and probably represent about average compositions.

TABLE 3.—AMOUNT AND VALUE OF MANURE PRODUCED ANNUALLY BY DIFFERENT ANIMALS AS CALCULATED FROM THE DATA OF VARIOUS INVESTIGATORS

Animal	Tons per year	Value per year
Horse	7.9	$25.36
Cow	13.0	32.50
Sheep	.6	3.31
Hog	1.7	5.03
100 Hens	1.6	9.62

It must be understood that the composition of manure even from the same animals is subject to great variation. It depends very largely upon (1) the quality of feed, (2) the age of the animals, and (3) the kind of bedding.

KIND OF FEED

If animals receive feeds which are high in nitrogen, phosphorus, or potassium, the manure will likewise be relatively high in these elements. When calculated upon the same valuations per unit as commercial plant foods, the manurial value of a ton of clover or timothy hay would be about as follows:

PLANT FOOD VALUE OF MANURE

Hay	*Normal prices*	*1918 prices*
Clover	$8.32	$21.80
Timothy	5.24	14.58
Excess manurial value of clover hay	$3.08	$ 7.22

It will be seen that clover has quite a distinct advantage over timothy when the value of manure is considered, especially since the two hays usually sell at about the same price. In the purchase of feeds this factor should always be taken into consideration, for as the quality of manure is improved the farmer will be able to produce a larger amount of his own feed.

Where a farmer buys nitrogenous concentrates, such as wheat bran, linseed or cottonseed meal, for feed he can very greatly improve the quality of manure. The manurial value of a ton of cottonseed meal at pre-war prices is about $29.44 while the plant food in the manure from one ton of shelled corn is only $6.90. It is often possible in this way to increase the value of the manure per ton and at

the same time to use the most economical system of feeding. This system is, however, merely a transfer of the fertility from the farm that produced the concentrates to the farm where these are fed to livestock.

AGE OF ANIMALS

The age of the animal also affects the quality of manure. In the mature animal which is making no growth except laying on fat, such as a steer or horse, practically all the fertilizing elements taken in the feed are returned in the solid and liquid manures. In the case of cows considerable quantities of nitrogen and mineral elements are found in the milk. The young growing animal, such as a calf or pig, retains much of the nitrogen and potash in its tissues while a considerable amount of the phosphorus goes to build up the bones. In general then it can be said that older animals produce a richer manure than young animals. While it is true that most of the fertilizing elements in the feed are returned in the manure of mature animals it is seldom possible except where crops are pastured to get more than three-fourths of this back to the soil. Approximately two-thirds of the organic material is broken down in the animal's body and passes off as gases and liquids. This means that only one-third of the organic matter in the feed can be returned in the manure.

USE OF BEDDING

The amount and kind of bedding used may materially affect the composition of any manure. Materials used for bedding are in most cases coarse substances, having a large proportion of crude fiber, and the fertilizing elements are in much less available form than in the manure itself.

When not too valuable for feed, oat straw makes an excellent bedding material, as it is a good absorbent for the liquid manure and gives a higher percentage of nitrogen than wheat straw or almost any other bedding material. Owing to the increased value of straw for roughage it is not always desirable to use it as bedding. The only excuse, however, for not using it in this way is that it shall be fed on the farm where produced. It is rarely good practice to sell straw from the farm. It is worth more when fed or used as bedding and as an absorbent for the liquid manure. Every year hundreds of straw stacks in Missouri are allowed to rot in the field and lose much of their organic material, while still others are burned with the loss of both organic matter and nitrogen.

When straw is not available, other materials may be substituted for the purpose of absorbing the liquid manure. Sawdust, shavings, leaves, or other coarse organic material may be used. Farmers as a rule use too little bedding. Bedding not only affords comfort for the animals but is the easiest and most practicable means of conserving liquid manure. All straw or other coarse materials which cannot be fed should be worked thru the barns and returned to the soil as manure. Substances of this sort do not decay as rapidly as the manure itself and therefore tend to keep up the organic matter content of the soil, afterward releasing their own plant food thru slow decay.

The value and composition of manure are further affected by the methods of storage employed and the conditions under which manure is kept before being hauled to the field. Manure is subject to three principal sources of loss: (1) Fermentation, (2) leaching, and (3) scattering about barns and lots.

FERMENTATION OF MANURE

Manure in a moderately loose and moist condition decays or ferments very rapidly. This is because the bacteria have a good supply of moisture, air, and usually a suitable temperature for growth. The bacteria which attack manure in this condition are air-loving (aerobic) and cause the manure to lose nitrogen in the form of ammonia. The odor of this substance can often be detected when a closed stable is opened in the morning. It is mainly the breaking down of the nitrogen compounds in the liquid portions of the manure, which causes this loss of ammonia. Much of the organic matter of the manure is also lost thru the action of bacteria and molds. This is caused by their power to oxidize organic materials and it may often be observed in the heating or "fire-fanging" of manure when loosely piled. In this process one-third of the total organic matter may be lost within three or four months. This power of bacteria to oxidize the organic matter of manure is often utilized in making hotbeds for plants.

Losses in nitrogen from manure due to the action of these aerobic bacteria may be reduced to a minimum by compacting the manure and keeping the heap thoroly wet so as to check free passage of air thru the pile. Manure in a perfectly dry condition or in a thoroly wet condition ferments slowly, but when it is only moderately moist the action of the ferments is rapid. Horse manure

ferments much more rapidly than cattle manure because of its loose and moderately moist condition. Hog manure is moist and compact and ferments more slowly even than sheep manure, where these manures accumulate in quantities large enough to cause fermentation.

Anaerobic bacteria, or those which do not need a large supply of air, work in manure which is too wet for the aerobic organisms. The organic matter under these conditions is slowly decomposed without a marked liberation of heat. This process usually leaves the manure in good physical condition for applying and comparatively little plant food is lost. Anaerobic bacteria may, however, reduce part of the nitrates and liberate certain quantities of free nitrogen into the air. It may be said, however, that the ordinary manure pile is seldom wet enough for much anaerobic bacterial action.

LOSS TO MANURE THRU WEATHERING

In addition to fermentation of manure there may also be a very marked loss of plant food due to leaching when the material is exposed to rains. In the fermentation, only the nitrogen is lost, while considerable amounts of all three of the fertilizing elements may be carried away by leaching. The principal loss, however, is that of potash. The plant foods contained in the liquid manure are all in soluble form and are easily lost thru leaching. It must also be remembered that when manure is exposed to leaching, conditions are usually favorable for fermentation. The total loss due to weathering may be seen from the following extracts from a table showing the results of work done in Ohio, and reported in Bulletin 246 from that experiment station. Table 4 shows that manure left exposed to the weather during three winter months, the time when manure is most often left outside, lost about one-third of its organic

TABLE 4.—COMPOSITION OF UNTREATED STEER MANURE BEFORE AND AFTER EXPOSURE TO THE WEATHER FOR THREE MONTHS, FROM JANUARY TO APRIL

Manure at beginning, 2000 lbs.	Organic matter, lbs.	Total nitrogen, lbs.	Total phosphorus, lbs.	Total potassium, lbs.	Value per ton as determined by:	
					Analysis	Crop production
Fresh manure.....	445.40	13.53	2.36	11.19	$2.92	$3.73
Weathered manure	287.41	8.71	1.83	5.48	1.80	2.93
Pounds lost.....	157.99	4.82	0.53	5.71	1.12	0.80
Per cent lost.....	35.47	35.63	22.46	51.02	38.35	21.45

matter and nitrogen, one-fourth of its phosphorus and one-half of its potassium. The great loss of potash is due to the fact that manure contains large quantities of this material which are soluble in water and easily leached away. Some nitrogen is lost thru leaching, but a much greater portion is lost thru fermentation. The phosphorus is more firmly fixed and its compounds less soluble, therefore a much smaller proportion of this element disappears during weathering.

Fig. 2.—Losing fertility by feeding in waste places where the manure will probably not be collected and where most of the fertility will be washed away.

Some work on the loss of plant food from manure due to weathering is being conducted at the Missouri Experiment Station. In this experiment one ton of mule manure taken from a barn where it had been trampled all winter, was placed in a flat iron pan ten feet square with a water tight bottom. A similar ton was placed in a pan with a drain to carry off the leachings. Still another ton of the same manure was placed in a conical pile on the ground. This being piled deeper than the material in the iron pans made it subject to less fermentation because the moisture content remained more uniform. Table 5 shows the effect of exposure during five summer months, May to October.

TABLE 5.—THE LOSSES FROM MULE MANURE DUE TO FIVE MONTHS' EXPOSURE TO THE WEATHER, MAY 23 TO OCTOBER 23, 1918

Method of Storage	Per cent dry matter lost	Per cent nitrogen lost	Per cent phosphorus lost	Per cent potassium lost
Undrained pan	34.38	29.09	9.39	7.25
Drained pan	44.91	35.28	15.38	47.03
Pile on ground	33.16	26.00	19.15	34.89
Average loss	37.48	30.12	14.64	29.72

It will be seen from this table that during the exposure for five months approximately one-third of the dry matter was lost under the conditions of a shallow undrained pan and pile, while in the drained pit nearly forty-five per cent of loss was recorded.

Altho the organic matter is usually not considered in calculating the fertility value of manure, it does have a marked effect upon the physical properties of certain soils and such a loss as is shown in the drained pan may be a serious decrease in the actual worth of manure.

Of the three principal elements of plant food there was an average loss under the three methods of exposure of 3.88 pounds of nitrogen, which when considered at pre-war prices of 20 cents a pound would be worth 78 cents. The average loss of phosphorus was 0.435 pounds, worth 5 cents at twelve cents a pound. The potassium lost amounted to 4.76 pounds, worth 28 cents at six cents a pound. Or, the average loss from the three methods of storage was $1.11 which was 28.5 per cent of the total value of the manure.

FRESH VERSUS ROTTED MANURE

As shown in Table 5, manure loses much of its plant food in the process of rotting. Its mechanical condition, however, is much improved, because there is a great deal of the coarse organic matter broken down. Much of this will be lost thru decay, and the percentage of mineral plant food remaining may be greater per ton of manure in the rotted, than in the fresh condition. These facts make rotted manure preferable for truck crops where quick results are desired and where a large amount of manure is used. Too heavy applications of fresh manure may often burn plants, especially during dry seasons. The coarse organic material keeps the soil open and reduces its capacity to retain moisture. On the general farm, however, there is too much loss of plant food in the rotting process and

a careful study of Tables 4 and 5 will show that it is always advisable to apply the manure to the land as soon as possible.

LOSS OF MANURE BY SCATTERING

The third source of loss to manure is that caused by its being dropped in roads, waste places and small lots where it cannot be picked up and returned to the cultivated land. Some of this loss can-

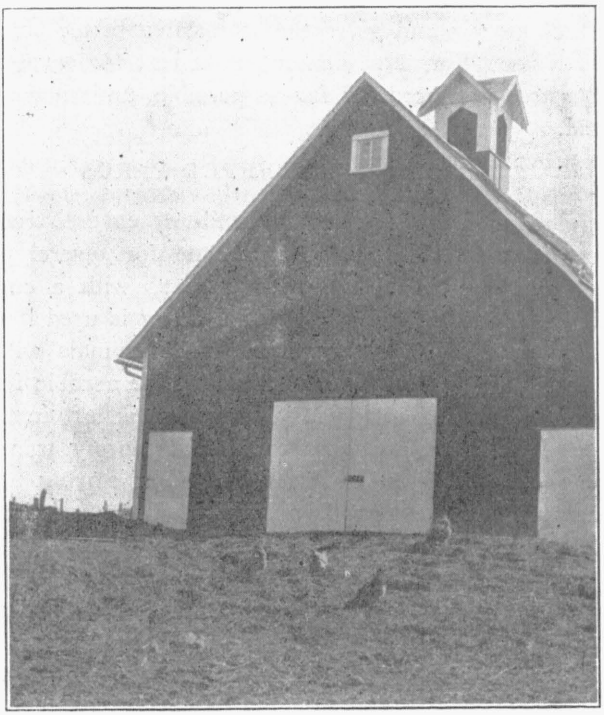

Fig. 3.—Manure scattered about the lots. A large portion of the plant food is lost by leaching and fermentation.

not be prevented; a great part of it, however, might be avoided by confining animals in lots small enough that the manure will accumulate in sufficient quantities to be hauled off. Another plan is to allow the stock needed each day to have the run of a few acres of pasture, so that the manure may serve to stimulate the growth of grass or enrich the soil for future crops. Hog manure is greatly wasted by being dropped about the feed lots and in waste places where it cannot be hauled to the cultivated land.

STORING MANURE

It has already been noted that the principal sources of loss in plant food from manure are thru leaching, fermentation and scattering, and if manure is to be stored, all practical precautions should be taken to keep down loss from any of these agencies. Another important point to consider in storing manure is the cost of handling. Handling manure increases the expense and at the same time lowers the value of the manure since the forking over of compacted manure exposes it to the air and gives the material a better chance to ferment and decay. For these reasons it is best to leave manure undisturbed where produced, so far as possible, until it can be hauled to the field.

STALLS AND COVERED YARDS

Where animals are confined in stalls or covered feeding yards the manure may be allowed to accumulate for several months and be hauled out only once or twice a year, with a comparatively small loss of plant food. If plenty of bedding is used it will absorb the liquid manure and the trampling of the animals will keep this compact and moist so as to prevent much of the aerobic fermentation and consequent loss of nitrogen. If manure is left in the stall or feed yard where it will be kept moist and thoroly tramped, so as to exclude the air, there is no better method of storing. Since there is no leaching under these conditions there will be practically no loss of phosphorus or potash. The covered feed yard is extensively used in some parts of the country and deserves more attention in Missouri.

This method of handling manure is advisable mainly where well-bedded stalls are provided for horses, and in cattle sheds or mule barns where the animals run loose and the trampling is very thoro.

HAULING DIRECT TO THE FIELDS

In dairy barns and in those horse stables where the best sanitary conditions are desirable, the manure cannot be left to be trampled but must be removed at regular intervals. In such cases it is far better to haul the manure directly to the field, and scatter. Any leaching that may occur after scattering will carry the plant food directly into the soil. Where manure is spread in a thin layer in the field, it dries out quickly and the loss from fermentation is reduced to a minimum. This is in fact the ideal way to handle manure, since the manure gets quickly on to the soil with the minimum of

loss. It is economical of labor because it entails no extra handling.

On steep hillsides it is not advisable to spread manure until just before the time for plowing, as the rains may carry much of the soluble plant food off in the surface drainage, or even wash a considerable amount of the manure down the slope. There is much more danger of this during winter rains when the ground is frozen. Manure spread on the snow is subject to this sort of loss. The loss is much less on level land or fall-plowed land, where there is but little drainage when the snow melts.

Experiments at various places have shown a decided advantage in the crop producing power of manure when it is hauled directly to the field. Another very great reason for hauling at once to the field is that manure left or stored about the barn usually forms an ideal breeding place for flies. It will help greatly in combating the housefly pest if every farmer will remove the manure to the field as soon as possible.

PILING MANURE

Owing to the pressing importance of other farm operations during certain seasons of the year, it is often impossible to haul the manure as it is produced. This makes it necessary on most farms to store considerable manure, especially that from work stock, during the busy season. Several methods of storage are used, but piling manure is by far the more common practice in Missouri. While this method usually results in a great loss of plant food, the wastage may be reduced if the manure is properly piled. Leaching and fermentation must be guarded against. To reduce the loss from leaching the pile should be built with nearly perpendicular sides, and a flat top. This sort of rick will absorb most of the rainfall and little liquid will drain away, except during very heavy rains. The dark brown liquid from a manure heap carries away the readily soluble plant food, especially the potash. To prevent excessive drainage, the ground under the heap may be compacted and slightly hollowed, or lined with cement to prevent leaching. The large amount of water absorbed from rains, when the pile is properly built, tends to keep the manure moist and also helps to compact it thru settling. An idea of the proper way to build a manure heap to reduce the loss from weathering may be gained by noting Figure 4. The other side of the story is shown in Figure 5.

Manure left in an open lot without being piled will lose much more than when in a heap, because practically all the manure is exposed to the weather. Losses under these conditions are likely to reach one-third to one-half the value of the manure within three or

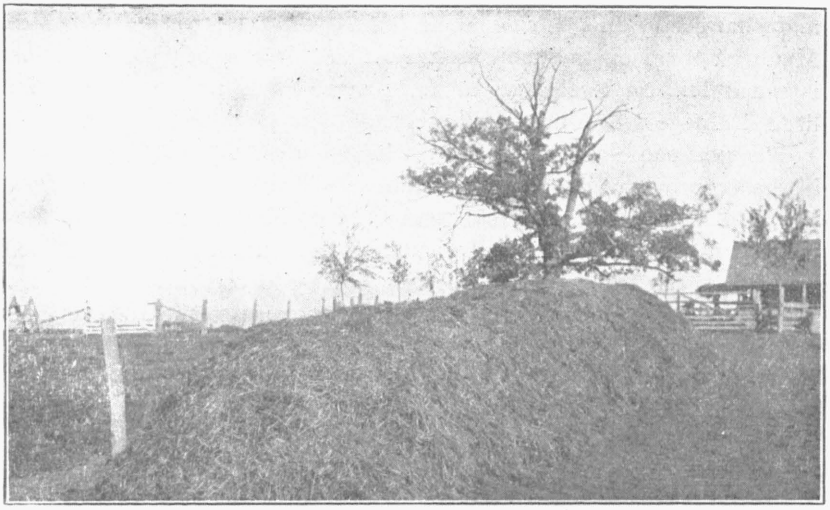

Fig. 4.—A well-built pile of manure. Notice the almost vertical sides and flat top. This pile could be improved by increasing the width.

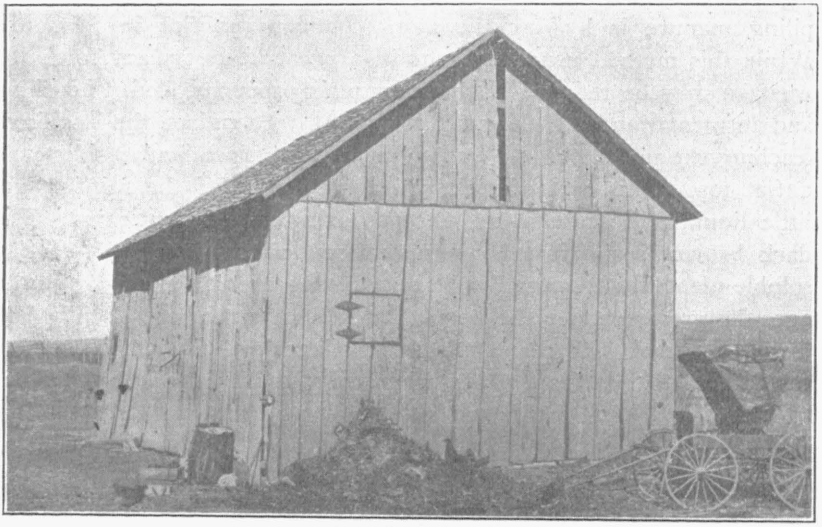

Fig. 5.—The wrong way to pile manure. It means loss of much nitrogen, potassium and organic matter

four months' time. It is subjected to losses thru leaching, fermentation, decay, and thru scattering about the lots or by being trampled into the mud. Even when properly piled, care must be taken that the manure does not become scattered. Hogs and chickens scatter manure badly and the heap should be protected from this sort of loss as far as possible.

MANURE PITS

Manure pits have been found very satisfactory in many places, but so far have been used very little in Missouri. If, in addition to proper ricking and compacting, the manure heap is built in a concrete pit, the loss of plant food will be still further reduced. The pit will retain not only all the liquid manure, but also the moisture coming from rain water. The manure in the pit should be kept flat on top so that it will absorb all the rainfall. This moist condition tends to keep down unfavorable bacterial action. If the sides of the pit are high enough to prevent scattering it is well to let stock trample over the manure to aid in keeping it compact.

The pit should be located near the barn so as to be convenient for filling. If possible, it is well to have it so located that it will receive manure from both the horse stable and dairy barn. Cattle manure, being more moist and compact, tends to keep down the fermentation of the drier and more open horse manure.

A manure pit can be constructed on any farm at small cost, and where much manure is stored it will usually pay for itself in a comparatively short time. The pit is valuable not only for preventing loss of plant food from the manure, but it serves as a specific place for piling manure and in that way encourages the farmer to take better care of this important product and to see that there is less waste.

Some dairymen use a cistern or tank for collecting the liquid manure, which is then hauled in a wagon tank and spread on the field. Altho by this method most of the liquid can be saved, it is probably somewhat more troublesome than absorbing the liquid with bedding and handling it with the solid manure.

In some sections of the country it is often considered good practice to construct a shed in which to pile the manure that must be removed from the barn each day. A shed is useful chiefly for maintaining more uniform moisture conditions and to prevent leaching. When possible the manure shed should be used for housing stock so that trampling will compact the manure and keep down fermentation.

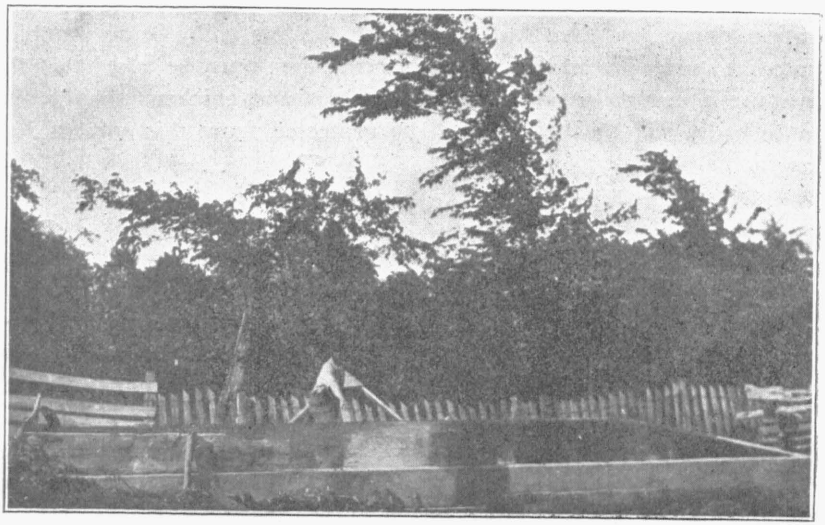

Fig. 6.—Liquid manure tank. A pipe carries the liquid manure from the gutters in the dairy barn to this tank. A drain pipe carries the liquid from the tank to a wagon sprinkler in which it is hauled to the field.

The shed may be used for animals continuously during severe weather, and this tends to reduce the cost of protecting the manure.

Experiments in England have shown that the plant food in manure stored under a shed is slightly more efficient in crop producing power than manure kept outside.

CEMENT FLOORS FOR BARNS

Where cattle or other animals are fed in stables it is economical of manure to provide concrete floors. When earth floors are used there is some loss from the manure due to a slow draining away of the liquid. The Ohio experiment station conducted a series of experiments in which steers were fed upon cement and earth floors and the manure carefully collected from each. The value of manure saved from those on the cement floor exceeded that from steers on earth floors by $4.48 a year for every 1000 pounds live weight. The Ohio people conclude that when cattle are fed for two six-months' feeding periods on cement floors there would be sufficient increase in the value of manure to pay the cost of installing the concrete floors. The results of these experiments are shown in Table 6.

TABLE 6.—COMPARISON OF STEER MANURE RECOVERED FROM EARTH AND CEMENT FLOORS

	Pounds recovered per 1000 pounds live weight		Per cent of plant food recovered in manure				
	Per Day	Per Year	Nitrogen	Phosphorus	Potassium	Value per ton	Value per year
Cement floors.....	47.5	17326	75	78	88	$2.96	$25.66
Earth floors.....	41.3	15052	62	78	78	2.81	21.18
Difference in favor of cement floors	6.2	2274	13	00	10	$0.15	$4.48

These figures were secured several years ago when the value of plant food in manure was much less than it is now. The cement floor has a greater advantage at the present time than when these tests were made.

SPREADING MANURE

In applying manure to the soil it is important to get an even distribution over the field. This can be done most satisfactorily by means of a manure spreader. A spreader is not absolutely essential, however, and if care is taken a fairly good job can be done by hand. That is, if a man cannot afford a spreader he should be all the more diligent about applying manure. The all-important thing is to get the manure back on to the land with the least possible loss. However, most farmers will succeed in getting more manure on the land when they have a spreader, since it can be kept where it can be loaded as the manure is produced and unloaded whenever a team is available for a few minutes' time. The labor and time saved will soon pay for the spreader. The advantage in using a spreader is not due so much to the saving of labor as to the fact that the manure is spread evenly and in a thin layer so that it will go further. Where manure is scarce it is advisable to make it cover as much land as possible. The spreader also serves to tear the coarse material to pieces so that it may be readily worked into the soil.

There are also machines on the market for loading manure into the wagon or spreader. These may be used to good advantage where a farmer has a large supply of manure to be hauled out at one time, especially if it is in an open lot or large shed where a team can be used in loading. While loaders are quite satisfactory for certain conditions of this kind, their usefulness is somewhat limited, and they are hardly adapted to the small farm.

For dairymen or horsemen who have large amounts of manure to remove each day, an overhead litter carrier such as is shown in Figure 7 will be found very useful. The spreader may be left under the carrier until filled. This greatly reduces the amount of handling, while the carrier makes the cleaning of the barns a much lighter task.

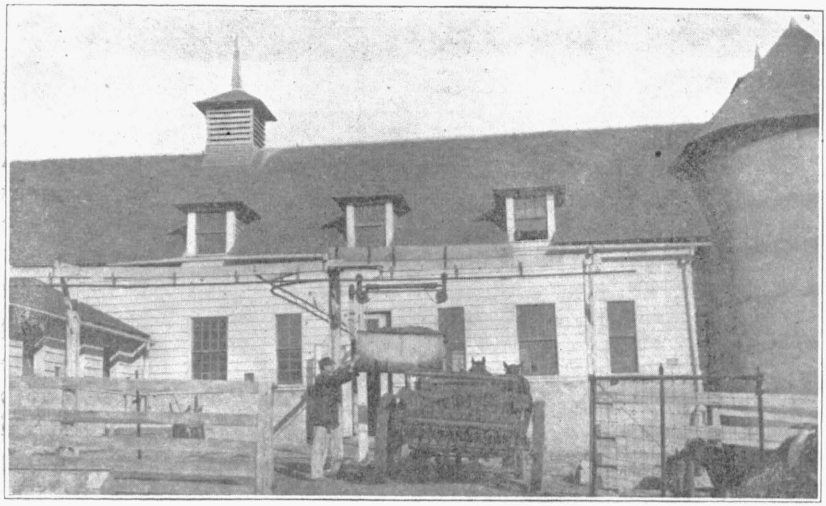

Fig. 7.—Litter carrier for dairy farm. The manure is collected in the carrier and dumped directly into the spreader.

FEEDING CROPS ON THE LAND

From ten to forty per cent more of the fertility contained in crops can be left on the land by pasturing or feeding in the field than by feeding around the barns, even where the most careful methods of saving manure are employed. Various experiments have shown it to be economical to produce pork and mutton by pasturing corn and by feeding grain in connection with the pasturing of forage crops. The manure from hogs and sheep is very difficult to collect and haul back to the land. Moreover, these animals are usually the better types to use for pasturing crops in the field. When pastured, about eighty per cent of the plant food in crops will be directly returned to the soil. This is usually accomplished with a much smaller amount of labor and loss of time than would be necessary to collect and haul the manure to the field. In fact careful observation of farm practices in all parts of the state where hogs are fed in pens indicates that the large majority of men actually return to the land

very little of the solid manure from hogs, and practically none of the liquid. A very good practice used by many farmers for saving manure from these animals as well as from beef cattle is to establish temporary feed yards on the thinner spots in the fields. This tends

Fig. 8.—A self-feeder and manure spreader combined. Hogs fed in this way make more economical use of the corn crop, save the labor of gathering and feeding the corn, and at the same time leave all the liquid and solid manure on the land where it belongs.

to make the fertility of a field more uniform and conserves a much greater percentage of the manure than can be hauled back to the land after feeding around the barn.

RATE OF APPLYING MANURE

The rate at which manure should be spread will usually depend upon the amount produced on the farm. As much of the cultivated land should be covered as possible. It is usually better to cover a whole field with a light application than to give only a part of the field a heavy coating. The effect of light and heavy applications is well shown by some results obtained at the Ohio experiment station with a rotation of potatoes, wheat and clover.

TABLE 7.—VALUE OF INCREASED PRODUCTION OF CROPS GROWN IN ROTATION WITH MANURE IN VARIOUS AMOUNTS FOR 17 YEARS

Potato, wheat, clover rotation	Tons of manure applied per A.	Average value of increase	
		Per acre	Per ton of manure
Yard manure on wheat	4	$4.84	$3.63
Yard manure on wheat	8	7.07	2.65
Yard manure on wheat	16	11.97	2.24

It may be seen from Table 7 that where the supply of manure is limited a greater return per ton is obtained if this amount of manure is spread lightly over considerable ground. Of course, where manure is abundant a greater return per acre is obtained where the application is heavier. In this experiment an application of sixteen tons per acre gave a very good increase, but the value per ton was so greatly cut down that the net profit for the last eight tons would not be very great. For this reason moderate applications over large areas bring best total returns and are always advisable if manure is scarce. Heavy applications are usually limited to truck farms or to special conditions.

On the whole these results indicate that applications up to sixteen tons once in three years may be considered profitable, if the manure is available. Lighter applications than three or four tons per acre are seldom advisable, because of the increased cost and trouble of applying such a thin coating. An application of six tons once in a three-year rotation, or eight tons during a four-year rotation, are very satisfactory rates for Missouri conditions, and are not out of reach of the farmer who will take good care of the manure produced on his farm.

QUANTITY OF MANURE PRODUCED

On the average farm where a considerable amount of livestock is kept, about two tons of manure should be produced annually for each acre of cultivated land. It is not an easy matter to save this amount and only the most careful farmers are doing it at present. In addition to saving all the solid portion, very careful methods must be adopted for taking up the liquid manure with a good supply of bedding. All straw and other suitable material should be worked thru the barns for this purpose. Where straw piles are sold, burned or left to rot, it is impossible to return this amount of manure. On dairy-farms or on other farms where large quantities of feed are

bought and fed even more than this amount should be produced. The use of concentrates such as oil meal, bran, legume hays, and the like greatly improve the quality of manure.

TIME TO SPREAD MANURE

A system of cropping should be arranged, so that a place to scatter manure will be available during much of the year. This will avoid the necessity for storing any great amount of manure about the farm. Thus, in a rotation of corn, oats, wheat, and clover, the manure would usually be applied to the clover sod and plowed under for corn. This sod land furnishes a place all fall and winter for scattering the manure. When manure is spread on sod land there will be very little fertility carried away by erosion or leaching during the winter and spring rains. Or, if it is desirable to plow some of the clover sod in the fall, the manure may be applied to the plowed land and thoroly disked in before corn. Coarse manure used in this way, however, may sometimes have a tendency to burn the crop during very dry seasons. Therefore, it is often thought more practicable to use this winter manure for wheat. Top dressing wheat protects it from severe winter killing, gives it an early start in the spring and very materially increases the yield. The manure is also of great benefit in obtaining a stand of clover or grass sown with the wheat. Manure collected in the summer may often be applied to grass land. A poor stand of bluegrass or timothy may be improved and the growth materially increased by applying manure as a top dressing. If it is not desirable to spread manure on grass it should be stored in a pit or well-built rick for use on fall wheat or for applying to corn land in the fall or winter.

RETURNS FROM MANURE

It is a matter of common observation that manure gives good returns on practically any soil and with nearly every crop. It is not always known, however, just what these increases are worth or how much profit the manure is giving above cost of application. This point has been studied during the last fourteen years on the soil experiment fields located in nearly every section of Missouri. Manure has proved profitable on every type of soil, yet some have given far greater increases in crop yields than others. The thinner and more worn soils usually give the greatest return. As an example, at

normal crop values, manure on the Ozark upland soil at the St. James experiment field increased the acre value of crops $3.54 for each ton of manure applied. On the very fertile Marshall silt loam at the Maryville experiment field the return was only $1.28 a ton. This means that a ton of manure is worth more on land of low fertility than on land of high fertility. To offset this, however, is the fact that the farmer on fertile land can produce more tons than can the man on thin land.

Fig. 9.—Effect of manure on spring growth of wheat on thin Ozark upland. The plot on left received 8 tons manure per acre and yielded 16.1 bushels of wheat. The plot on right was not treated and the yield was only 1.4 bushels, or only slightly more than was used in seeding.

TABLE 8.—AVERAGE RETURN FROM MANURE ON SOIL EXPERIMENT FIELDS, MISSOURI EXPERIMENT STATION

Crop	Number of trials	Increase from manure	Value at 1918 prices	Value at normal prices
Corn	61	10.50 bu.	$13.12	$6.30
Oats	35	5.17 bu.	3.36	2.07
Wheat	57	5.24 bu.	10.48	5.24
Clover	13	937 lbs.	11.71	5.62
Total value of increase in 4 year rotation			38.67	19.23
Increase for each ton of manure			4.83	2.40

Prices used in calculating the above crop values:

	1918 prices	Normal prices
Corn	$ 1.25 per bu.	$ 0.60 per bu.
Oats	.65 " "	.40 " "
Wheat	2.00 " "	1.00 " "
Clover	25.00 " ton	12.00 " ton

An average of all results from representative experiment fields in Missouri where manure has been tested shows the increases given in Table 8.

Fig. 10.—Soybeans grown on Ozark upland with no treatment. Yield, 7.55 bu. of seed and 1040 lbs. bean straw per acre.

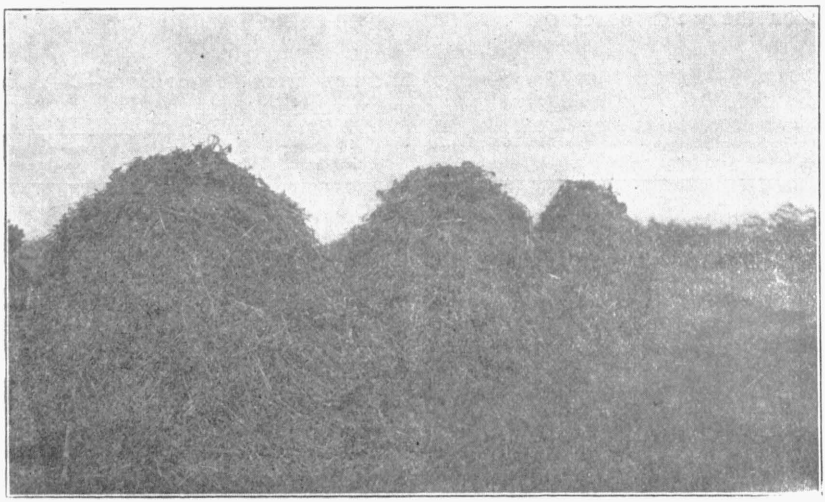

Fig. 11.—Soybeans on same land as above with manure. Yield, 16.25 bu. seed and 2075 lbs. bean straw. With soybeans at $4 a bushel the value of the seed alone on the manured land would have been $34.80 an acre more than from the untreated soil.

In the experiments reported in this table eight tons of manure per acre were applied before corn once in the rotation. It will be noted that at 1918 prices the increased yields would have been worth $4.83, and at pre-war prices $2.40, for each ton of manure applied. It should cost a farmer not more than one dollar a ton to collect the manure and haul it to the field. This would leave a net profit of $3.83 at present prices and $1.40 at pre-war prices. It may be said also that the full value of the manure is not usually obtained during the first four years, for it leaves the soil in better condition and its effect upon later crops is often quite significant. This effect becomes more noticeable after the first two or three applications.

REINFORCING MANURE WITH PHOSPHATES

The practice of adding some form of phosphate to manure is not yet very common in Missouri. It should be remembered that manure in itself is not a well-balanced fertilizer, since it is low in available phosphorus. It is also true that for most soils of the state the addition of phosphorus gives better crop returns than any other element. These two factors combined make the addition of phosphorus to manure highly important. In some states the practice is an old one, and the Ohio experiment station presents data (Table 9) showing the effects of acid phosphate and of raw rock phosphate upon the yields of crops.

TABLE 9.—EFFECTS OF REINFORCING MANURE WITH PHOSPHATES—21-YEAR AVERAGE (Ohio Experiment Station)

Treatment	Yield corn bushels	Yield wheat bushels	Yield hay pounds	Annual value of produce
No treatment	35.73	13.72	2815	$17.34
Untreated manure, 8 tons per acre	57.01	23.57	3916	27.09
Similar manure and 320 lbs. rock phosphate	63.70	26.49	4551	30.67
Manure and 320 lbs. acid phosphate	68.77	29.11	4958	33.37

When the values of these crops are figured at the prices in Table 8 it will be seen that an application of eight tons of manure once in three years has given an average annual increase of $9.75 over the untreated plot. This is equivalent to an increase of $3.65 for each ton of manure applied. By applying 320 pounds of rock

phosphate with the manure (worth $1.92 at $12 a ton, or 64 cents annually), the increase in crop values over the untreated manure was $3.58 a year, due to the rock phosphate. Acid phosphate used to reinforce the manure increased the value of crops by $6.28 over the manure alone. This phosphate would cost $3.20 at $20 a ton or the annual cost of application would be $1.07, leaving a net annual increase of $5.21 due to the acid phosphate. This would mean a yearly increase on the money invested of 486 per cent. At crop prices during 1919 the increase would be even much greater than this.

Under conditions prevailing in Missouri the return from the use of rock phosphate has not been so satisfactory as in Ohio. In some places, especially on the soils very low in phosphorus, the raw material has given fair results, but on the better soils it has often failed to pay the cost of application. It is quite probable, however, that if the soil is thoroly limed and the supply of organic matter kept up, raw rock phosphate may be used as a practical source of phosphate for reinforcing manure.

Acid phosphate is now being used on several of the Missouri soil experiment fields as a reinforcing material for manure. While it has been used in this manner only a short time the results are encouraging. A summary of the results obtained to date on the Willow Springs field (Table 10) will show the effect when used upon typical Ozark upland.

TABLE 10.—EFFECT OF ACID PHOSPHATE AT WILLOW SPRINGS WHEN USED TO REINFORCE MANURE

Crop	Trials	Yield no treatment, per acre	Manure, yield per acre	Manure, acid phosphate yield per A.	Return for acid phosphate	Value of increase from phosphorus at normal crop prices
Corn	2	10.13 bu.	27.56 bu.	31.29 bu.	3.73 bu.	$2.24
Soybeans....	3	704 lbs.	1016 lbs.	1493 lbs.	477 lbs.	2.86
Wheat	3	3.95 bu.	12.21 bu.	17.13 bu.	4.92 bu.	4.92
Red clover	2	876 lbs.	2181 lbs.	3258 lbs.	1077 lbs.	6.46
Value of total increase for one rotation						$16.48

From the work done so far on this and other experiment fields in Missouri, together with numerous observations of work being

done by farmers, it seems that acid phosphate is more desirable for reinforcing manure than is rock phosphate. It will be noted (Table 10) that the increased value at normal prices for farm crops, from the use of 400 pounds of acid phosphate, has been $16.48. This should, under normal conditions, leave a net increase of nearly $13 per acre from the use of this material. With either form of phosphorus care should be taken to sweeten the soil so as to insure the growth of legumes to help maintain the nitrogen supply.

Fig.12.—Effect of reinforcing manure with phosphates, St. James Experiment Field. The plot on right received manure and produced 23.08 bushels of wheat. The plot on left was treated with manure and phosphate and the yield was 33.33 bushels.

The acid phosphate may be scattered with the manure if desired, but on most farms a more practical method is to apply the manure before the corn crop and then drill in at least a part of the acid phosphate with wheat. This method distributes the fertilizer and manure over the rotation and will give more profitable returns on most soils of the state than where the two are applied together.

SUMMARY

1. Manure should be spread while fresh if possible.
2. Plenty of bedding should be used to absorb the liquid manure, for this portion contains about two-fifths of the plant food in the total manure.

3. Feeds should be selected in a way designed to improve the quality of manure. Concentrates or other feeds rich in protein produce manure rich in nitrogen.

4. Manure exposed to the weather four or five months may lose from one-third to one-half of its plant food.

5. Reduce fermentation during storage by keeping the manure compact and moist, or allow it to be trampled in the stalls or covered feed yard.

6. Prevent loss of plant food thru leaching, by storing in concrete pits or under cover.

7. For the average farm, applications of 6 to 8 tons of manure once in the rotation should give satisfactory returns.

8. The careful farmer should be able to return manure at the rate of about two tons per acre annually to his cultivated land.

9. Manure is usually best applied before corn and plowed under, or used as a top dressing for wheat. It may often be applied with profit to hay or grass lands.

10. According to the Missouri Experiments and at present prices for farm products manure is worth more than four dollars a ton when spread on the land. At normal prices it is worth approximately two and one-half dollars a ton.

11. To get the most profit from manure and at the same time most nearly maintain a well-balanced condition of soil fertility, it is good practice to reinforce each ton of manure with 25 to 40 pounds of acid phosphate or 40 to 80 pounds of rock phosphate. When acid phosphate is used it may be applied with the manure or it may be drilled when seeding some small grain crop in the rotation.