UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BULLETIN 157

FERTILIZER TRIALS—WENTZVILLE EXPERIMENT FIELD

EFFECT OF SOIL TREATMENT ON WHEAT, 1917

The plot on left received acid phosphate and yielded 27.1 bushels per acre. The plot on right received no soil treatment, and produced only 15.3 bushels per acre.

COLUMBIA, MISSOURI
JULY, 1918

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

[1]In service of U. S. Department of Agriculture
[2]In U. S. Military Service
[3]On leave of absence

Fertilizer Trials — Wentzville Experiment Field

(PUTNAM SILT LOAM)

M. F. MILLER and F. L. DULEY

The Missouri Experiment Station has in operation several soil experiment fields which represent the more important soil types in Missouri. The experiments are conducted to determine the most profitable systems of soil treatment and management for each of these soil types. Usually these experiment fields are selected without reference to county lines since the object is to keep them well distributed thruout the state and on land which represents the more important soil types in Missouri. In some cases, however, counties have become interested in such fields, and experiments have been conducted in cooperation with the county court. The Wentzville experiment field was established in 1913 thru such a cooperative arrangement between the Experiment Station and the St. Charles County Court. This cooperation continued until the fall of 1915 when the court decided to provide for a county agricultural agent. The field was then conducted until the fall of 1917 as one of the regular outlying soil experiment fields of the Station. The farm on which the field was located belonged to Richard King and was about a half mile east of Wentzville in the western part of St. Charles County. M. Kelly, a farmer living on an adjoining farm, was in direct charge of the work during the experiment.

The soil on which this field was located is classed as the Putnam silt loam. It differs slightly, however, in topography from the typical level Putnam silt loam as it is somewhat more rolling and better drained. It is, however, typical of the prairie land of St. Charles County and of the greater part of the Northeast Missouri prairie. It is a soil of medium fertility and consists of a dark gray to brownish gray silt loam, which is nine or ten inches deep. Immediately beneath the surface soil and extending from about nine to sixteen inches there is a light colored layer faintly mottled with brown. This so-called "ashy" layer is typical of the Putnam silt loam found in Northeast Missouri. A grayish brown, very heavy, silty clay

NOTE.—The material presented in this bulletin has to do merely with the immediate effects of different fertilizing materials on corn, oats and wheat, when the crops are considered individually. The man who is interested in the general management of the Putnam silt loam from the standpoint of fertility improvement and maintenance should obtain Bulletin 126 of the Missouri Experiment Station.

layer, plastic and tenacious, extends from about sixteen to twenty-four inches, below which the material is somewhat coarser and more friable.

The object of this report is to place the results of the experiments before the farmers of St. Charles County, but since the soil of this field is fairly typical of the Putnam silt loam the results should apply to practically all the average prairie land of Northeast Missouri.

COMPOSITION OF THE PUTNAM SILT LOAM

Many samples of the Putnam silt loam have been analyzed and the content of nitrogen, phosphorus and potassium determined. These three elements concern the farmer most in fertilizing a soil or in maintaining soil fertility, since they are the ones which are likely to be lowest in quantity with reference to crop needs. The supply of lime, however, is often so low that the land becomes sour. In such cases lime must be applied before clover or alfalfa can be grown successfully and before most other crops can be produced to best advantage. Consequently, in reporting on the composition of the soil the so-called "lime requirement" or "lime need" of the soil is given. The following table shows the average content of nitrogen, phosphorus and potassium found in Putnam silt loam as compared with what might be termed very fertile soil. It also shows the "lime requirement" or the amount of ground limestone needed to sweeten a seven-inch layer of surface soil covering one acre.

POUNDS IN SEVEN-INCH LAYER OF AN ACRE OF SURFACE SOIL

	Nitrogen	Phosphorus	Potassium	Limestone needed
Very fertile soil	6000	2000	30,000	0
Putnam silt loam	2335	950	29,840	2300

It will be seen from the foregoing table that this soil is particularly deficient in nitrogen and phosphorus, and that it needs more than a ton of ground limestone per acre to sweeten the plowed soil. The supply of potassium is practically equal to that of a very fertile soil, but because of the rather wet nature of this land it is often deficient in available potassium.

PLAN OF THE EXPERIMENTS

Since this county experiment field was designed to give early and concrete results, the experiments were confined to different kinds and amounts of fertilizing materials on different crops. The fertilizers used were steamed bone meal, acid phosphate, and two grades of mixed fertilizers. The steamed bone meal was chosen because it has been commonly used in Missouri for several years. The acid phosphate was selected because it is gradually replacing the bone meal, due to the limited supplies of the latter. One of the mixed fertilizers was a so-called 2-8-2, that is a fertilizer which contains two per cent ammonia, eight per cent available phosphoric acid and two per cent potash. It is a medium grade fertilizer which is commonly used in Missouri. The second was a so-called 3-8-5, which is known as a rather high grade fertilizer, used to some extent in Missouri. These four were selected because they represent the important phosphates used in the state as well as one medium grade and one high grade mixed fertilizer. It is obviously impossible, as well as unnecessary, in experiments of this kind to try all the mixtures found on the market. Only representative types of fertilizers can be used. The values of these fertilizers for 1913 and for 1918 are given below.

	Value per ton 1913	Value per ton 1918
Steamed bone meal	$28.00	$45.00
Acid phosphate (14 per cent)	16.00	27.00
2-8-2	22.00	50.50
3-8-5	28.00	78.00

The experiment field was divided into four series of plots. Three series (A, B, C) were rotated in a four year rotation of corn, oats, wheat and clover, cowpeas being substituted for clover when the latter failed. The fourth series (D) was sown to wheat continuously thruout the experiment. The results, therefore, show the effect of fertilizer on corn, oats and wheat in rotation, as well as a comparison of fertilizers on wheat grown continuously on the same land with wheat grown in rotation with other crops.

The rates of application of these fertilizers were based principally upon the money value. In other words, an effort was made to apply quantities which cost the same on the market. Two rates of application were chosen, one which might be called a medium or low rate and the other a rather high rate for the fertilizer concerned.

The 1913 values of the various fertilizers were used thruout in determining the applications, altho owing to war conditions there was a marked change in these values during the latter part of the period. The kinds and amounts of fertilizers used on the various plots and the costs of these applications at 1913 prices are shown in Table 1.

TABLE 1.—FERTILIZER APPLICATIONS AND VALUES AT 1913 PRICES
Series A, B, C (Under crop rotation)

Plot	Treatment	Lbs. per acre for corn and oats	Cost of treatment per acre	Lbs. per acre for wheat	Cost of treatment per acre
1	Bone meal	100	$1.40	125	$1.75
2	Bone meal	200	2.80	250	3.50
3	No treatment....	......	......	......	......
4	Acid phosphate	175	1.40	262	2.10
5	Acid phosphate	350	2.80	524	4.20
6	2-8-2	127	1.40	190	2.09
7	2-8-2	254	2.80	380	4.18
8	No treatment....	......	......	......	......
9	3-8-5	100	1.40	150	2.10
10	3-8-5	200	2.80	300[1]	4.20

Series D (In continuous wheat)

Plot	Treatment	Lbs. per acre for corn and oats	Cost of treatment per acre	Lbs. per acre for wheat	Cost of treatment per acre
1	Bone meal	......	......	100	1.40
2	Bone meal	......	......	150	2.10
3	No treatment....	......	......	......	......
4	Bonemeal	......	......	200	2.80
5	Bonemeal	......	......	250	3.50
6	3-8-5	......	......	100	1.40
7	3-8-5	......	......	150	2.10
8	No treatment....	......	......	......	......
9	3-8-5	......	......	200	2.80
10	3-8-5	......	......	250	3.50

[1]In 1913 only 250 pounds were applied.

BASIS OF CALCULATION

In calculating the net return received from the various crops with different fertilizer treatments, the cost of the fertilizer has in each case been charged directly to the crop to which it was applied. Since a fertilizer was not applied to the hay crop on the rotated plots, no charge has been made against this crop. The value of the crops has been computed for both 1913 pre-war prices and 1918 prices. The cost of the fertilizers has been figured in a similar manner. The assumed crop prices are as follows.

Crop	Pre-war prices	1918 prices
Corn	$ .60 per bushel	$ 1.00 per bushel
Oats	.40 " "	.60 " "
Wheat	.90 " "	2.00 " "
Cowpea hay	11.00 " ton	18.00 " ton

Net returns are determined by deducting the cost of treatment from the value of the increase in crop obtained. In the case of the grain crops no charge is made for either the work of harvesting the increased crops due to treatment or for increased cost of production; but, on the other hand, no value is allowed for the increase in straw and stover or for the improved quality of the grain resulting from the fertilizer. It is assumed that one of these sets of factors will approximately offset the other. Where no net return is obtained the losses are indicated by minus signs.

THE USE OF FERTILIZERS WITH CORN

The results of the experiments with corn are given in Table 2.

TABLE 2.—NET RETURN FROM FERTILIZERS APPLIED TO CORN GROWN IN ROTATION.

(Average of four crops)

	At 1913 prices					At 1918 prices		
Treatment Pounds per acre	Average yield bushels per acre	Increase over no treat-ment bu. per acre	Value of in-crease per acre	Cost of treat-ment per acre	Net return per acre	Value of in-crease per acre	Cost of treat-ment per acre	Net return per acre
Bone meal 100	18.24	2.36	$1.42	$1.40	$0.02	$2.36	$2.25	$0.11
Bone meal 200	19.45	3.57	2.14	2.80	—0.66	3.57	4.50	—0.93
Check	15.88	......	......	......	......	......	......	......
Ac. phos. 175	20.09	4.21	2.53	1.40	1.13	4.21	2.36	1.85
Ac. phos. 350	17.84	1.96	1.18	2.80	—1.62	1.96	4.72	—2.76
2-8-2, 127	17.75	—0.98	—0.59	1.40	—1.99	—0.98	3.22	—4.20
2-8-2, 254	19.44	0.71	0.43	2.80	—2.37	0.71	6.44	—5.73
Check	18.73	......	......	......	......	......	......	......
3-8-5, 100	20.51	1.78	1.07	1.40	—0.33	1.78	3.90	—2.12
3-8-5, 200	19.76	1.03	0.62	2.80	—2.18	1.03	7.80	—6.77

In interpreting the results of these experiments it should be said that of the four trials two were in dry seasons and one in a season so wet that the series in corn was very deficient in drainage which resulted in practically a crop failure. The one season of reasonable rainfall (1917) gave fair results for the medium applications. The results for the four years confirm the findings on other experiment fields of this soil type, that medium amounts of phosphatic fertilizers applied in advance of the planter with a fertilizer drill will pay a small profit on corn, particularly when the season is neither exceptionally dry nor exceptionally wet. It must be understood that part of the return from the fertilizer, particularly from bone, will be felt on the crops following; but in the Wentzville experiments the entire charge has been made to the crops on which the fertilizer was applied.

Unfortunately no opportunity was offered on this field to test the effect of applying the fertilizer to corn in the row. At the High Hill experiment field, on this same soil type, experiments with fertilizing corn in the row were carried on for three years (1909-12). The results are shown in the Table 3.[1]

TABLE 3.—DIFFERENT KINDS AND AMOUNTS OF FERTILIZERS IN THE HILL WITH CORN AT THE HIGH HILL EXPERIMENT FIELD

Soil treatment	Annual cost per treatment per acre	Yield of corn in bushels per acre					Results per acre. Ave. of two years 1910 and 1912		
		1910	1909	1912	Average 3 yrs.'09, '10, '12	Average 2 yrs. '10, '12	Increase bu.per acre	Value of increase	Net return
None	......	36.4	45.0	26.3	35.9	35.7	....	......	......
Bone meal, 50 lbs.	$ .70	36.9	56.0	31.8	41.6	43.9	9.6	$5.28	$4.58
Bone meal, 75 lbs.	1.05	39.7	59.0	26.9	41.8	43.0	8.7	4.78	3.73
Bone meal, 100 lbs.	1.40	37.1	57.0	25.1	39.7	41.0	6.7	3.68	2.28
None	......	32.5	42.0	29.3	34.6	35.7	....	......	......
2-8-2, 50 lbs.	.60	*34.7	46.0	34.7	38.5	40.3	6.0	3.30	2.70
2-8-2, 75 lbs.	.90	*36.7	49.5	27.7	38.0	38.6	4.3	2.36	1.46
2-8-2, 100 lbs.	1.20	*38.3	50.5	28.7	39.2	39.6	5.3	2.91	1.71
None	......	*34.2	40.5	24.8	33.2	32.7	....	......	......
3-8-6, 50 lbs.	.80	......	50.0	31.0	......	40.5	6.2	3.41	2.61
3-8-6, 75 lbs.	1.20	......	47.0	30.2	......	38.6	4.3	2.36	1.16
3-8-6, 100 lbs.	1.60	......	50.0	32.9	......	41.4	7.1	3.90	2.30
None	......	......	39.5	26.6	......	33.0	....	......	......

*Average of two plots.

As a result of the various experiments on the Northeast Missouri prairie it can be said that the proper use of commercial fertil-

[1]Mo. Exp. Sta. Bul. 126, p. 332.

izers on the corn crop will usually give returns. The net return on corn, however, is not so certain as in the case of wheat, due to the fact that corn is more subject to injury by abnormal weather conditions.

The applications best to use are (1) 150 to 200 pounds per acre of bone meal, acid phosphate, or, at normal prices, one of the highly phosphatic mixed fertilizers, applied with a fertilizer grain drill in advance of the corn planter; or (2) 60 to 90 pounds per acre of the same fertilizer applied in the row by means of a fertilizer attachment on the corn planter. If there is any choice of these fertilizers it is given probably to acid phosphate or bonemeal from the standpoint of net return. At normal prices, however, medium grade mixed fertilizers, such as those which contain from two to three per cent nitrogen, ten to twelve per cent available phosphoric acid and two to three per cent potash, will probably give as good and sometimes better net return. The unfavorable seasons encountered in the Wentzville experiments have doubtless caused the mixed fertilizers to show at a somewhat greater disadvantage than normally. At present prices of potash these mixed fertilizers are certainly less to be preferred than the acid phosphate and bone meal, if the latter can be obtained.

In relation to the effect of the weather upon the fertilizers applied to corn it can be said that in seasons which have dry periods during July and August little return can be expected from their use. This seems to be particularly true in the case of fertilizers applied in the row, since such corn seems more subject to "firing" than unfertilized corn and the yield may sometimes be reduced. Doubtless this is due to the fact that fertilizers applied directly in the row cause a rapid, early growth of the corn with a large leaf development, and such corn requires much water to maintain it after it has reached the laying-by stage. It is, therefore, less able to withstand dry weather at that time than is corn which has not made such rapid growth. Furthermore, the larger the application of fertilizer in the row the more marked the early growth, and the greater the danger seems to be from the July and August drouths. If, however, the late growing season is one of abundant rainfall, the larger applications will give better returns than the smaller ones. When the frequent summer drouths in Missouri are considered it is doubtless safer, where row fertilization is practiced, to limit the application to a maximum of about 100 pounds, or to an average of about 75 pounds per acre.

No definite statements can be made as to the best means of applying fertilizer along the row, since no conclusive experiments of this nature have been carried out. Where corn is checked, the fertilizer may either be placed in the hill or distributed continuously in the row. Some men prefer the latter method. Experiments in progress at the Station, while as yet inconclusive, indicate that it may be preferable to delay the fertilizer application until the second or third cultivation and then apply it along the row, in either drilled or checked corn, with a fertilizer attachment on the cultivator. Such a plan would largely overcome the danger of drouth on early stimulated corn and would supply the fertilizer at the time when the crop needs the largest amounts of plant food. The plan seems to have possibilities but unfortunately the experimental results are not sufficient to warrant recommending it.

A final word should be said from the standpoint of maintaining soil fertility with reference to the advisability of fertilizing corn in the row. This practice is already common on the Northeast Missouri prairies and there is grave danger that it may be followed to the ultimate injury of the land. The fertilizer in itself is not harmful, but such a use of it may be abused, since with fertilizer it is possible to grow corn longer on the same land than could be done otherwise. Where such a practice is followed and no particular attention is given to manuring and crop rotation the final results will be marked soil depletion. It must, of course, be admitted that in normal seasons money invested in fertilizer, which is applied in small quantities in the row will give good returns. However, the average yield of corn thru a series of years will be greater where a crop rotation is practiced, where manure is saved and returned to the land, and where other rational methods of soil management are adopted. The practice of row fertilization is, therefore, one which is adapted to the renter and to the man who must have immediate returns regardless of the effect upon the soil. Fertilizer, however, can be used as an adjunct to proper systems of fertility maintenance with good returns and with no final injury to the land.

As to the practice of using medium to large amounts of fertilizer applied over the entire soil surface with a grain drill in advance of the planter, it can be said that such a practice used without well balanced systems of maintaining fertility also tends toward soil depletion. This practice, however, leaves a larger amount of plant food in the soil, particularly phosphorus, than does row fertilization. While the danger of continuous use of fertilizer in this way without systems of fertility maintenance is not so great as that from the use of fertilizers in the row, it should be understood clearly that in most cases the practice should go hand in hand with systems of crop rotation and the use of barnyard manure or green manures.

For the livestock farmer on Northeast Missouri prairie land probably the best system of fertilizing corn, everything considered, is to apply before the corn crop all available barnyard manure, which is supplemented with acid phosphate at the rate of thirty to forty pounds per ton of manure and applied directly on the manure in the spreader. Instead of acid phosphate the raw rock phosphate may be used, altho the experiments on the various fields in Northeast Missouri indicate that raw rock phosphate used in this way has not given very satisfactory returns. Where such a system of applying phosphates with the manure is followed it may often be profitable to apply some fertilizer in the row. In case animals are fed largely on the fields so that insufficient manure is available to cover the corn land, acid phosphate, bone meal or a highly phosphatic mixed fertilizer may be applied with a fertilizer drill in advance of the planter as previously indicated, or a small amount of fertilizer can be applied economically in the row.

One of the important considerations in using fertilizer with corn, either in the row or otherwise, is the time of planting. It has been observed that corn planted as soon as the ground has become thoroly warmed usually withstands the drouth better and yields more than that which is planted later. Since the effect of the fertilizer is also greatly interfered with by drouth, it follows that the early planted corn will give a better response from the fertilizer than will late planted corn. This may mean the difference between success and failure in the use of fertilizer with this crop.

THE USE OF FERTILIZERS WITH OATS

The fertilization of land for oats is not a common practice in Northeast Missouri. It is, however, being tried by some farmers in that section and it was deemed wise by the Station to carry out some experiments along this line. Tables 4 and 5 show the results obtained.

TABLE 4.—NET RETURN FROM FERTILIZERS APPLIED TO OATS GROWN IN ROTATION (Average of three crops)

Treatment pounds per acre	At 1913 prices: Average yield bushels per acre	Increase over no treatment bu. per acre	Value of increase per acre	Cost of treatment per acre	Net return per acre	At 1918 prices: Value of increase per acre	Cost of treatment per acre	Net return per acre
Bone meal 100	23.75	6.07	$2.43	$1.40	$1.03	$3.64	$2.25	$1.39
Bone meal 200	23.46	5.78	2.31	2.80	—0.49	3.47	4.50	—1.03
No treatment	17.68	......	......	......	......	......	......	......
Ac. phos. 175	23.30	5.62	2.25	1.40	0.85	3.37	2.36	1.01
Ac. phos. 350	22.75	5.07	2.03	2.80	—0.77	3.04	4.72	—1.68
2-8-2, 127	23.61	3.01	1.20	1.40	—0.20	1.81	3.22	—1.41
2-8-2, 254	26.23	5.63	2.25	2.80	—0.55	3.37	6.44	—3.07
No treatment	20.60	......	......	......	......	......	......	......
3-8-5, 100	26.87	6.27	2.51	1.40	1.11	3.76	3.90	—0.14
3-8-5, 200	28.71	8.11	3.24	2.80	0.44	4.87	7.80	—2.93

TABLE 5.—NET RETURNS FROM FERTILIZERS APPLIED TO 1917 OATS CROP

Treatment Pounds per acre	At 1913 prices: Yield bushels per acre	Increase over no treatment bu. per acre	Value of increase per acre	Cost of treatment per acre	Net return per acre	At 1918 prices: Value of increase per acre	Cost of treatment per acre	Net return per acre
Bone meal 100	51.5	14.9	$5.96	$1.40	$4.56	$8.94	$2.25	$6.69
Bone meal 200	52.1	15.5	6.20	2.80	3.40	9.30	4.50	4.80
No treatment	36.6	......	......	......	......	......	......	......
Ac. phos. 175	53.1	16.5	6.60	1.40	5.20	9.90	2.36	7.54
Ac. phos. 350	51.5	14.9	5.96	2.80	3.16	8.94	4.72	4.22
2-8-2, 127	52.0	6.4	2.56	1.40	1.16	3.84	3.22	0.62
2-8-2, 254	60.3	14.7	5.88	2.80	3.08	8.82	6.44	2.38
No treatment	45.6	......	......	......	......	......	......	......
3-8-5, 100	61.6	16.0	6.40	1.40	5.00	9.60	3.90	5.70
3-8-5, 200	64.0	18.4	7.36	2.80	4.56	11.04	7.80	3.24

Of the three crops grown, only that of 1917 made a satisfactory yield. The other crops were injured by unfavorable weather conditions. It was only on this 1917 crop that the fertilizers gave a paying return. For this season all treatments returned a profit. In general, however, the increases due to the heavier applications were not sufficiently greater than those from the lighter applications to pay the extra cost. The averages of all three years, given in Table

5, show little economic return from the treatments. The effect from nitrogen and potash is, however, more marked on the oats crop than on either the corn or wheat. The highest oats yields were obtained from 200 pounds per acre of the 3-8-5 mixture. At 1918 prices of fertilizers all those which contained potash were used at a loss, and even at normal potash prices the net return from the 3-8-5 mixture was only $1.11 per acre. From these experiments it seems very doubtful if oats can be fertilized on this soil with any very marked profit. The same general results have been obtained from other experiment fields on this soil type.

There are two factors which are primarily responsible for the questionable use of fertilizers on oats. The first is the rather low acre value of the crop. Experimental results and farm practice show that the use of fertilizer is always more profitable on those crops which have a high acre value. Even the increased value of the oats crop, due to the war, has not been sufficient in these experiments to offset the increased price of the fertilizer. The second factor contributing to the low return from fertilizer is the season. The average season in Northeast Missouri is not ideal for oats production. It is only in seasons of abundant rainfall and of moderate spring and early summer temperatures that the oats crop is at its best, and there is no doubt that the fertilization in such a season will pay well. A marked economic return, however, is very doubtful for average seasons.

One consideration which must not be overlooked in the fertilizing of oats is the effect which the fertilizer usually shows on clover and grass crops following the oats. In most parts of this region it is a common practice to use oats as a nurse crop for the hay crops. In such cases the net return from the fertilizer may be obtained entirely from the succeeding crops. There are cases, therefore, where the use of acid phosphate, bone meal or one of the highly phosphatic mixed fertilizers, or even a mixed fertilizer containing as much as three to five per cent of potash, at normal potash prices, may pay a good net return, when the oats and hay crops are considered together. It is doubtful if such fertilizers should contain any large percentage of nitrogen because of the tendency of this material to stimulate vegetative growth. Where oats are stimulated to a rank growth of straw the early development of the grass and clover growing in it would be somewhat retarded. Moreover, nitrogen is the most expensive element to apply and the oats crop has a comparatively low acre value. Consequently, it would seem wise to limit the choice of fertilizers to phosphates or, at normal prices, to those mixed fertilizers which contain a large amount of phosphate and a fair amount of potash, with little or no nitrogen.

EFFECT OF FERTILIZERS UPON OATS DURING A FAVORABLE SEASON (1917)

The plot on left received acid phosphate, 175 pounds per acre, and yielded 53.1 bushels. The plot on the right received no treatment and produced 36.5 bushels per acre.

The plot on the left received 3-8-5 fertilizer, 100 pounds per acre, and produced 61.6 bushels. The plot on the right received no soil treatment and the yield was 45.6 bushels per acre.

THE USE OF FERTILIZERS ON WHEAT

The results of these experiments show a much greater net return from the use of fertilizers on wheat than on either corn or oats. This is in accord with the findings on other experiment fields in Northeast Missouri and with the experience of farmers on this land. The great bulk of the fertilizer now used in this section is applied to wheat. The results of the experiments in fertilizing wheat grown in rotation with other crops are shown in Table 6.

TABLE 6.—RETURNS FROM FERTILIZERS APPLIED TO WHEAT GROWN IN ROTATION (Average of four crops)

	At 1913 prices					At 1918 prices		
Treatment pounds per acre	Average yield bushels per acre	Increase over no treatment bu. per acre	Value of increase per acre	Cost of treatment per acre	Net return per acre	Value of increase per acre	Cost of treatment per acre	Net return per acre
Bone meal 125	24.27	6.03	$5.43	$1.75	$3.68	$12.06	$2.81	$9.25
Bone meal 250	24.50	6.26	5.63	3.50	2.13	12.52	5.62	6.90
No treatment	18.24	......	......	......	......	......	......	......
Ac. phos. 262	24.89	6.65	5.99	2.10	3.89	13.30	3.54	9.76
Ac. phos. 524	24.66	6.42	5.78	4.20	1.58	12.84	7.09	5.75
2-8-2, 190	24.27	8.12	7.31	2.09	5.22	16.24	4.80	11.44
2-8-2, 380	24.22	8.07	7.26	4.18	3.08	16.14	9.59	6.55
No treatment	16.15	......	......	......	......	......	......	......
3-8-5, 150	22.77	6.62	5.96	2.10	3.86	13.24	5.85	7.39
3-8-5, 300	25.31	9.16	8.24	4.20	4.04	18.32	11.70	6.62

It may be seen from an examination of this table that very striking increases in yield have been obtained from all treatments. As an average of the four years' results, the yield of the fertilized wheat, including all fertilizers used, has been 24.36 bushels per acre as compared with 17.19 bushels where no fertilizer was applied. This is an increase of over 7 bushels per acre—a very substantial average increase in yield. There has also been a satisfactory net return in each case. Moreover, at 1918 prices of grain and fertilizer the net returns are from two to four times as great as at 1913 prices. Even the fertilizers which contain two and five per cent respectively of high priced potash have given substantial profits. These results indicate the great importance of fertilizing wheat on this kind of land under war conditions, as well as under normal conditions.

A comparison of the return from different rates of application shows that in no case did the heavier applications average a sub-

EFFECT OF FERTILIZER UPON WHEAT (1917)

SPRING CONDITION

The plot on the left received no soil treatment. The plot on the right received ~~100~~ 150 pounds of bone meal per acre.

HARVEST CONDITION

The plot on the left yielded 15.37 bushels per acre. The plot on the right produced 27.41 bushels per acre.

stantial increase in yield over the lighter applications. It was only in the case of the 3-8-5 fertilizer that any appreciable increase was recorded, and this was not sufficient to pay for the extra cost of the fertilizer. An average of all net returns at 1913 prices shows an annual profit of $4.16 per acre for the smaller applications and $2.17 for the larger ones. At 1918 prices the average profit from the smaller applications is $9.46 and for the larger ones it is $6.45. The indications are, therefore, that the lighter applications, as they were used, are more satisfactory than the larger ones. It will be observed, however, that with the exception of the bone meal the smaller applications are still somewhat above the average amounts used by Northeast Missouri farmers. These larger applications were given in order to keep the money values of the applications equivalent to 1913 prices of the bonemeal.

These results do not show any great superiority of one fertilizer over another. While the smaller application of the 2-8-2 has shown a somewhat higher profit than any of the other fertilizers at both 1913 and 1918 prices, this superiority is not very significant, particularly when the different rates of application are considered. The 3-8-5 has fallen somewhat below the others according to the 1918 prices, evidently because of the large amount of potash it contains.

THE USE OF FERTILIZERS ON WHEAT GROWN CONTINUOUSLY ON THE SAME LAND

There is a tendency in parts of Missouri for farmers to grow wheat several successive years on the same land, using fertilizers to maintain the yield. It was thought wise in this experiment to compare such a plan with wheat in rotation, and accordingly one series of plots has been handled under such a system. The results are shown in Table 7.

TABLE 7.—NET RETURN FROM FERTILIZER APPLIED TO WHEAT CONTINUOUSLY GROWN ON SAME LAND
(Average of five crops)

	At 1913 prices					At 1918 prices		
Treatment Pounds per acre	Average yield bushels per acre	Increase over no treat-ment bu. per acre	Value of in-crease per acre	Cost of treat-ment per acre	Net return per acre	Value of in-crease per acre	Cost of treat-ment per acre	Net return per acre
Bone meal 100	15.25	2.40	$2.16	$1.40	$0.76	$4.80	$2.25	$2.55
Bone meal 150	14.66	1.81	1.63	2.10	—0.47	3.62	3.37	0.25
No treatment	12.85	......	......	......	......	......	......	......
Bone meal 200	15.48	2.63	2.37	2.80	—0.43	5.26	4.50	0.76
Bone meal 250	17.26	4.41	3.97	3.50	0.47	8.82	5.62	3.20
3-8-5, 100	15.14	4.40	3.96	1.40	2.56	8.80	3.90	4.90
3-8-5, 150	16.14	5.40	4.86	2.10	2.76	10.80	5.85	4.95
No treatment	10.74	......	......	......	......	......	......	......
3-8-5, 200	14.26	3.52	3.17	2.80	0.37	7.04	7.80	—0.76
3-8-5, 250	14.67	3.93	3.54	3.50	0.04	7.86	9.75	—1.89

An examination of this table shows less return from fertilizer on continuous wheat than on wheat grown in rotation. As a matter of fact when the five crops are averaged and the net return figured at 1913 prices, little profit is shown except in the case of the 3-8-5 fertilizer, where the smaller applications brought a fair net return. At 1918 prices the net returns averaged somewhat better, the highest being obtained on the smaller applications, as was the case under 1913 prices.

One reason for the low average yields under continuous wheat growing is that the 1916 crop was practically a failure on these continuous wheat plots, altho there was much wheat in the neighborhood that was no better. The wheat was materially damaged by winter killing and by the Hessian fly.

Table 8 shows a comparison between the plots where wheat was grown continuously and in rotation, with and without fertilizer. It shows an average annual increase of 5.4 bushels per acre due to rotation where no fertilizer was applied, and of 9.01 bushels with the use of fertilizers. The importance of using fertilizers on wheat grown in rotation instead of on wheat grown continuously on the land is thus further emphasized.

TABLE 8.—COMPARISON OF WHEAT GROWN CONTINUOUSLY WITH THAT GROWN IN ROTATION

	Average yield in bushels per acre		Average net return from all fertilizer treatments	
	Unfertilized	Fertilized	1913 prices	1918 prices
Wheat in rotation	17.19	24.36	$3.44	$7.96
Continuous wheat	11.79	15.35	.76	1.75
Average annual increase due to rotation	5.40	9.01	2.68	6.21

While the foregoing tables do not give the results for the individual years, it can be said that the fifth year, under continuous wheat, showed very poor yields, in spite of the fact that it was not particularly affected by Hessian fly or to any extent winter killed as was the case the year before. There is, therefore, very little argument for continuous wheat growing on this land, even where fertilizers are used, particularly at rates of from 100 to 125 pounds per acre. There is little doubt that wheat grown continuously with these small amounts of fertilizer tends to impoverish the soil. There is not enough fertilizer used to keep up the soil but enough to stimulate the wheat and help it to come thru the winter. While the use of fertilizer alone will bring good returns for a few years, the time will come when a paying crop cannot be harvested. Where fertilizers are used at heavier rates on wheat grown continuously, the wheat yields will be maintained thru a longer period; but the fertilizing of wheat in rotation will invariably bring better returns in the long run. It is only under the stress of the present war emergency and the great demand for wheat that the continued production of wheat either with or without fertilizer on this land should be considered. On the better portions of this soil or where it has been well cared for, wheat may be grown for two or three years as a war measure. The application of fertilizer with it will materially increase the yields, but it must be distinctly understood that such a practice is comparatively short-lived.

FERTILIZERS RECOMMENDED FOR WHEAT

After a consideration of these various trials it can be said, with every assurance, that the fertilizing of wheat on this land under proper conditions will bring excellent average net returns. The best returns will be obtained when wheat is grown in rotation with other crops. The applications that can be recommended are acid phosphate, bone meal, preferably the steamed bone meal, and one of the highly phosphatic mixed fertilizers at the rate of 125 to 200 pounds per acre. At present prices it would seem wise to limit the amount of potash in a mixed fertilizer to about two per cent, altho at normal potash prices as high as five per cent may be used. The indications are that even at 1918 prices of potash five per cent could be used with some profit. Of course, at this time fertilizers which contain five per cent of potash are unavailable because of the shortage of this material.

RETURNS FROM COWPEAS AND CLOVER

The plan of cropping on the rotated plots of this experiment field provided for a rotation of corn, oats, wheat and clover. Neither lime nor manure was applied to any of the crops, since the experiments were designed simply to determine the effect of different kinds and amounts of fertilizers on the untreated soil of this region. Owing to the sour condition of the soil, to rather poor drainage and to several unfavorable seasons, the clover crop invariably failed. Cowpeas were substituted, but since fertilizer was not applied to this crop and as the cost of the fertilizer has in every case been charged to the crop with which it was used, no results are given as to the residual effect of the fertilizer on the peas. It should be said that on this field, as on other fields of the Northeast Missouri prairie, fertilizer applied to preceding crops has shown little effect on the pea crop. The peas have, of course, helped to maintain the productiveness of the rotated land and a part of the superiority of yields where wheat has been grown in rotation may be attributed to their use.

SUGGESTIONS TO FARMERS USING FERTILIZERS ON THE NORTHEAST MISSOURI PRAIRIE

There is an increasing use of commercial fertilizers on the Northeast Missouri prairie land. This use is becoming so common that a word of caution seems advisable. It has been shown by these experiments that the use of fertilizers on wheat pays well, and under proper conditions the same will be found true in the case of corn. Many farmers are applying fertilizers to both wheat and corn and a few are using them on oats. There is some danger that when farmers find fertilizers do pay they will be depended upon too largely and insufficient attention will be given to those practices which tend to maintain soil fertility. Fertilizers alone do not maintain fertility. When used in small quantities without attention to rational systems of soil management, the tendency is toward soil depletion.

THE NEED OF CROP ROTATION

These experiments, as well as many others, show clearly that crop rotation will maintain higher yields than are possible under continuous cropping. Too often fertilizers are used to a certain extent to take the place of rotation. Such a plan is rarely advisable. It is only under pressure of wartime needs or under the stimulation of temporary high prices of grain that such a use of fertilizers is warranted, and then for short periods only. In the long run, larger yields will be obtained and greater profits realized where crop rotation is followed.

Crop rotation helps to maintain the soil's supply of organic matter and all rotations should contain a legume, such as clover, soybeans or cowpeas. Fertilizers give better results where the supply of organic matter is maintained. On this prairie land clover is not usually successful because of soil acidity and poor drainage. Liming, and usually thoro drainage, are necessary to grow red clover with the minimum number of failures. On the wetter portions of the land alsike clover should be substituted, and because of its small size usually should be mixed with timothy. The soybean crop is excellent for this land, while cowpeas also give very satisfactory returns. Neither of these is injured as seriously by soil acidity as is red clover.

THE USE OF FARM MANURES

Farmers handling livestock should make every reasonable effort to care for manure and return it to the land. As an average of all trials on the outlying experiment fields the crop increase from a ton of manure has been worth $2.46 at 1913 prices and $4.40 at 1918 prices. Manure is worth too much money to allow it to waste. Manure also helps materially in keeping up the supply of organic matter in the soil, which is necessary to the continued profitable use of fertilizers. A combination of crop rotation with the saving of barnyard manure and the use of commercial phosphates will doubtless give the highest continued profits.

FERTILIZERS CANNOT BE SUBSTITUTED FOR OTHER METHODS OF INCREASING PRODUCTION

Fertilizers cannot take the place of lime, of drainage or of proper soil preparation. Such an irrational system of using fertilizers is to be guarded against. Mention has been made already of the need of maintaining organic matter where fertilizers are used. Similarly, the greatest return from fertilizer can only be expected where sour soil is limed or where wet soil is drained. Finally, the seedbed should be well prepared. Fertilizers pay best on well prepared land. In other words, the rational use of fertilizers presupposes that the farmer has done all other things necessary to insure a large yield.

SUMMARY

1. In these experiments only the lighter applications of acid phosphate and bone meal paid a net return when applied to corn, and these returns were small. This was due in part to two very dry seasons and one exceptionally wet season during the four-year

experimental period. The results confirm those of other experiments in that the returns from fertilizers on corn were greatly affected by the season. Exceptionally dry weather during July and August preceded by wet weather during May and June is very unfavorable to the action of the fertilizers. The application of 150 to 200 pounds per acre of acid phosphate, bone meal or of one of the highly phosphatic mixed fertilizers applied in advance of the corn planter with a fertilizer grain drill will usually bring paying returns on this soil. The same may be said of a smaller application (60 to 90 pounds) of similar fertilizer applied in the row with a fertilizer attachment on the corn planter.

2. As an average of three years' trials the use of fertilizer on oats was not accompanied by paying returns. This was due partly to unfavorable seasons for oats, since very good returns were obtained in the one season when weather conditions were favorable. Seasons as they usually run, however, are not particularly favorable for oats production in this part of Missouri, so the average return from fertilizers on this crop cannot be expected to be very marked. Where clover and grass follow oats the return on these crops may be as great or greater than on the oats crop. Under such conditions, therefore, fertilizers may bring a good net return when the two seasons are considered.

3. The use of fertilizers with wheat brought excellent net returns in practically all cases where this crop was grown in rotation with others. When wheat was grown continuously for five years on the same land and fertilizer used each year, the yield, as well as the average net return, was much less than under rotation. In some cases no net return was obtained. The average yield of wheat grown in rotation was five bushels per acre more than where wheat was grown continuously. This does not mean that wheat may not be grown for two or three years without change and good results be obtained from the use of fertilizers, but that for longer periods the plan is not advisable.

4. The returns from all the trials with wheat indicate that there is little choice between acid phosphate, bone meal and the medium grade mixed fertilizer. Each one brought substantial net returns at pre-war prices and much better profits at 1918 prices. It was shown further that the larger applications were not as profitable, on the whole, as the smaller ones. For instance, the average net return at pre-war prices from all fertilizer trials on wheat grown in rotation was $4.16 for the smaller applications and $2.17 for the larger ones. At 1918 prices the net returns were $9.46 and $6.45 respectively.

These wheat experiments seem to warrant the use of from 125 to 200 pounds per acre of acid phosphate, steamed bone meal or one of the highly phosphatic mixed fertilizers, limiting the use of potash in the mixed fertilizers during the potash shortage to two per cent or less. On lands where the supply of nitrogen and organic matter is kept up, acid phosphate or highly steamed bone meal, is doubtless to be preferred.