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Crop-Rotation Experiments in the Ohio Valley [1925-1936]

by T. C. McIlvaine and G. G. Pohlman

FOR CENTURIES men have recommended the practice of alternating crops systematically. Early agriculturists noted that the practice led to increased yields. Such increases have been found to be due in part to better control of weeds, insects, and diseases and to better utilization of plant nutrients. It is known, too, that certain rotations will aid in maintaining the supply of organic matter and nitrogen in the soil and will lessen erosion. However, not all systems of crop rotation are equally desirable. Some rotations may actually bring about soil depletion almost as rapidly as continuous cropping with the same crop, whereas other systems may maintain satisfactory yields with minimum applications of fertilizer.

In an attempt to ascertain the value of various cropping systems in West Virginia, an area of about ten acres was selected at the Lakin Experiment Farm in 1923. The area was practically level, and the soil appeared to be fairly uniform. The soil was classified as Wheeling fine sandy loam *(4)*. In 1923 and 1924, crops of oat hay and wheat were grown on the entire area to study the uniformity of the plots. Although the yields of these crops showed considerable variation within the area, it was concluded that by proper use of replicates valuable information regarding rotations could be obtained *(3)*. Later studies *(2)* using analysis of variance indicated that the systematic arrangement used for some of the two-, three-, and four-year rotations gave a representative sample of the total variance within the area.

PLAN OF THE EXPERIMENT

The experiment was planned and carried out with the following objectives:

(1) To compare different crop rotations, with particular reference to their value for specific West Virginia conditions.

(2) To determine the effect of lime on different crops and in different rotations.

(3) To compare rotations receiving manure to those receiving only the crop residues.

(4) To compare the effect of different cover crops on certain rotations.

A total of 270 plots, each 21 feet by 68 feet, were laid off for the experiment as shown in Figure 1. The plots were laid out in three double series with a 14-foot roadway between each double series and around the entire field. The plot numbers and the letters used to designate the various rotations are given in the diagram. Within each double series differential treatments were made within each rotation. For example, plots 1 and 51 both were cropped according to the plan for Rotation A; they differed in that plot 51 received lime whereas plot 1 was unlimed. Similarly, differences in lime treatment, manure treatment, and cover crops or slight variations in cropping systems were made between the other contiguous plots in the double series.

The cropping systems included in the experiment are given in Table 1. These include most of the crops commonly grown in West

Roadway

Roadway	Plot	Plot	Roadway	Plot	Plot	Roadway	Plot	Plot	Roadway
	1 a	51		101 s	151		201 m′	251	
	2 b	52		102 t	152		202 n′	252	
	3 c	53		103 q	153		203 o′	253	
	4 d	54		104 v	154		204 m′	254	
	5 e	55		105 r	155		205 n′	255	
	6 f	56		106 q	156		206 o′	256	
	7 g	57		107 q	157		207 m′	257	
	8 h	58		108 u	158		208 n′	258	
	9 i	59		109 v	159		209 m′	259	
	10 j	60		110 x	160		210 w′	260	
	11 k	61		111 a′	161		211 p	261	
	12 l	62		112 b′	162		212 p	262	
	13 a	63		113 c′	163		213 p	263	
	14 b	64		114 d′	164		214 p	264	
	15 c	65		115 e′	165		215 q	265	
	16 d	66		116 f′	166		216 r	266	
	17 e	67		117 g′	167		217 s	267	
	18 f	68		118 h′	168		218 t	268	
	19 g	69		119 i′	169		219 u	269	
	20 h	70		120 j′	170		220 q	270	
	21 i	71		121 k′	171		221 r	271	
	22 j	72		122 l′	172		222 s	272	
	23 k	73		123 a′	173		223 t	273	
	24 l	74		124 b′	174		224 q	274	
	25 a	75		125 c′	175		225 s′	275	
	26 b	76		126 d′	176		226 r	276	
	27 c	77		127 e′	177		227 t′	277	
	28 d	78		128 f′	178		228 q′	278	
	29 e	79		129 g′	179		229 u′	279	
	30 f	80		130 h′	180		230 r′	280	
	31 g	81		131 i′	181		231 q′	281	
	32 h	82		132 j′	182		232 q′	282	
	33 a	83		133 k′	183		233 q′	283	
	34 b	84		134 l′	184		234 r′	284	
	35 c	85		135 a′	185		235 s′	285	
	36 w	86		136 b′	186		236 t′	286	
	37 m	87		137 c′	187		237 u′	287	
	38 n	88		138 d′	188		238 q′	288	
	39 o	89		139 e′	189		239 r′	289	
	40 m	90		140 f′	190		240 v′	290	
	41 n	91		141 g′	191		241 t′	291	
	42 o	92		142 h′	192		242 q′	292	
	43 m	93		143 a′	193		243 r′	293	
	44 n	94		144 b′	194		244 s′	294	
	45 m	95		145 c′	195		245 v′	295	

Roadway

FIG. 1—Field plan of the plots used in the rotation experiments at Lakin, W. Va.

TABLE 1—*Cropping Systems and Treatment*

Rotation	Duration	First year	Cover crop	Second year	Cover crop	Third year	Cover crop	Fourth year	Differential treatment
	(*years*)								
A	4	Potatoes	Rye-vetch	Corn		Wheat		Cl.-Tim.	Limed vs. unlimed
B	4	Corn	Rye-vetch	Potatoes		Wheat		Cl.-Tim.	Limed vs. unlimed
C	4	Corn		Wheat		Cl-Tim.		Timothy	Limed vs. unlimed
D	3	Corn		Timothy		Cl-Tim.			Limed vs. unlimed
E	3	Corn	Rye-vetch	Soybeans		Potatoes	Rye-vetch		Limed vs. unlimed
F[1]	3	Corn	Rye-vetch	Soybeans		Wheat	Rye-vetch		Limed vs. unlimed
G[1]	3	Corn	Rye	Cowpeas		Wheat	Timothy		Limed vs. unlimed
H[1]	3	Corn	Rye	Soybeans		Wheat	Timothy		Limed vs. unlimed
I	2	Corn	Sw. Cl.-Vetch	Soybeans	Sw. Cl.-Vetch				Limed vs. unlimed
J	2	Corn	Rye-vetch	Soybeans	Rye-vetch				Limed vs. unlimed
K	2	Corn	Cr. clover	Soybeans	Cr. clover				Limed vs. unlimed
L	2	Corn		Soybeans					
M	4	Corn	Rye-vetch	Soybeans		Wheat		Cl.-Tim.	Manure vs. crop residue
N	3	Corn		Oats		Clover			Manure vs. crop residue
O	2	Corn	Rye-vetch	Soybeans	Rye-vetch				Manure vs. crop residue
P	4	Tobacco		Weeds		Weeds		Weeds	None
Q	6	Corn	Sw. clover	Soybeans		Oats		Alfalfa (3)	Spring vs. fall seeding
R	4	Tobacco		Wheat		Hay		Hay	Clov. vs. tim.-red top
S	3	Corn		Oats		Hay			Red cl. vs. sw. cl.
T[1]	3	Corn		Wheat		Hay			Soys vs. soys-Sudan
U	2	Corn		Oats	Clover				Hubam vs. red clover
V	2	Corn	(See treat.)	Soybeans	(See treat.)				Wht. & vetch vs. sw. cl.
W	1	Corn	(See treat.)		(See treat.)				Rye-vetch vs. sw. cl.
X	1	Wheat	(See treat.)		(See treat.)				Hubam vs. red clover

[1] Manure returned.

Virginia. The various cropping systems included one six-year rotation, six four-year rotations, eight three-year rotations, seven two-year rotations, and two in which the same crop was grown continuously. In addition, as stated above, each cropping system was grown with two differential treatments.

In Rotations A to L, inclusive, one-half of the plots received lime; the other half was unlimed. In Rotations M, N, and O one-half received manure; the other half received only the crop residues. The hay crops were varied in Rotations R, S, and T. Rotations U, V, W, and X had different cover crops in the contiguous plots, and Rotation Q was designed to compare spring *vs.* fall seeding of alfalfa.

Each crop in the rotation was grown in duplicate each year with each treatment. For example, in Rotation A-unlimed, corn was grown on plots 1 and 111, wheat on plots 13 and 123, clover and timothy on plots 25 and 135, and potatoes on plots 33 and 143. The plots joining these (51, 161, 63, 173, etc.) had the same cropping system but received lime. Duplicate plots are indicated in Figure 1 as a′, b′, etc.

The rates of seeding for the various crops are given in Table 2. These are about average rates used in farm practice in the vicinity of Lakin.

TABLE 2—*Rate of Seeding Crops in Rotations*

Crop	Rate per acre	Crop	Rate per acre
Corn	10 lbs.	Timothy (alone)	12 lbs.
Wheat	6 pecks	Timothy (in mixture)	8 lbs.
Oats	8 pecks	Redtop (in mixture)	6 lbs.
Rye	8 pecks	Alfalfa	20 lbs.
Rye (with vetch)	5 pecks	Soybeans (hay)	6 pecks
Red Clover	10 lbs.	Soybeans (seed)	30 lbs.
Red clover (in mixture)	8 lbs.	Soybeans (with Sudan grass)	5 pecks
Alsike clover (in mixture)	4 lbs.	Cowpeas	8 pecks
Sweet Clover	25 lbs.	Vetch	25 lbs.
Crimson clover	20 lbs.	Sudan grass (with soybeans)	20 lbs.

The corn was planted 4 grains per hill and thinned to two stalks with hills and rows 42 inches apart. Tobacco was planted in rows 36 inches apart with 15 inches between plants. Potatoes were planted in rows 34 inches apart with plants 12 inches apart in the rows. The clover-timothy mixture used consisted of 8 pounds of red clover, 4 pounds of alsike clover, and 8 pounds of timothy.

The crops were seeded at the normal date for the section of the state. Corn was planted early in May; wheat October 5 to 10; soybeans, cowpeas, and Sudan grass June 1 to 10; potatoes March 20 to April 10; and oats the last of March or early in April. Timothy was seeded in the fall with wheat except in Rotation D, in which it was seeded after the removal of the corn. Sweet clover, vetch, and crimson clover were seeded in corn at the last cultivation. Rye was seeded after the corn had been cut by means of a double disk drill. This made it possible to seed rye in vetch without seriously injuring the vetch. Wherever cover crops containing legumes followed wheat, potatoes, or soybeans for hay, the legumes were seeded as soon as practical after harvest and the rye was drilled in the early part of September. Rye and vetch were seeded together after soybeans harvested for seed.

Legumes seeded in corn or after soybeans usually winterkilled badly and made little growth. A good stand of vetch was secured when seeded after wheat or potatoes. Rye usually proved very satisfactory both from the standpoint of stand and growth. Wheat as a cover crop in Rotation V made very little growth.

The only commercial fertilizer used during the experiment was 20 percent superphosphate, applied at the rate of 200 pounds per acre per year. This was applied at the time of seeding the crop wherever possible. In the case of hay crops it was applied as a top-dressing in the spring. Lime was applied to all plots, except those indicated as "unlimed", at the rate of 1½ tons of finely ground limestone per acre in 1924. The application was repeated in 1927. These applications were sufficient to maintain a soil reaction of about pH 6.5.

The manure used in certain of the rotations was produced from the crops grown in these rotations. The straw was used for bedding and the forage was fed to horses along with the necessary grain. The manure was applied in the spring before plowing the land for corn. In Rotations M, N, and O, in which a grain farming system was used, the straw and corn stover were applied and plowed under in preparing the land for corn. Only one crop of hay was cut on all the clover and timothy plots, the second growth being left on the plots and plowed under. Although this is not common farm practice, it was thought that it would partially replace manure, which was not available for the entire experiment but which is commonly used by farmers.

In obtaining yields of various crops a border of 3½ feet around the outer edge of the plot was discarded; the yield of the central portion only was determined.

EXPERIMENTAL RESULTS

The average yields of all crops for all rotations are given in Table A (Appendix). Because of the large number of rotations and the wide differences in cropping systems, it appeared desirable to group the rotations in order to simplify the discussion of results. They have therefore been grouped according to length, use of manure, and general similarities in cropping systems.

Four-Year Rotations Without Manure

The cropping systems used in the four-year rotation (without manure) were as follows:

Rotation	*1st Year*	*2nd Year*	*3rd Year*	*4th Year*
A	Potatoes (rye & vetch*)	Corn	Wheat	Clover-timothy
B	Corn (rye & vetch*)	Potatoes	Wheat	Clover-timothy
C	Corn	Wheat	Clover-timothy	Timothy

* Cover crop.

Rotations A and B differed only in that corn and potatoes were reversed to determine the effect of sod on the two crops. Rotation C was used to determine the effect of an additional year in sod on grain yields. Limed and unlimed plots were compared in all three rotations.

The average yields of various crops in these three rotations are given in Table 3.

Value of Liming

It will be noted that the yields on the limed plots were consistently higher for corn, wheat, and hay. In corn the yields were significantly* higher on the limed plots in Rotations A and C, but the differences in Rotation B could be attributed to experimental error. The reason for the small differences in B is not readily evident. Since corn followed clover in this rotation, more benefit from a good clover crop would be expected than in Rotation A, where corn followed potatoes, or in Rotation C, where corn followed second-year timothy. However, it should be noted that an excellent cover crop was obtained following potatoes. This may have furnished as much available nutrients on decomposition as did the clover and timothy sod. Wheat yields were from 2.2 to 4.3 bushels higher on the limed soils than on the unlimed. These differences are all significant. Potato yields were slightly lower on the limed plots in Rotation A, but the difference was too small to be significant and was probably due to plot variation rather than an actual difference due to treatment. In Rotation B the potato yields were practically the same on both limed and unlimed plots.

The most striking increase from lime was in the hay crop. This was due to the influence of the lime on the clover stand which was much better on the limed than on the unlimed plots. Since the second cutting, consisting primarily of clover, was much better on the limed areas but was not included in the yields, the differences in yield were less than might be expected under average farm conditions, where two cuttings of hay are made.

In considering the value of applications of liming materials, it is necessary to consider, in relation to returns, cost of liming as well as increase in yield per acre. Using the average farm prices,† the increase in annual acre value of crops as a result of liming amounted to $6.23 for Rotation A, $4.39 for Rotation B, and $5,66 for Rotation C. The returns per ton of lime were, therefore, $24.92, $17.56, and $22.64

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* The significance of differences in yield was determined by analysis of variance. Although this method is designed for randomized plots it was felt that it could be used in these experiments because of the earlier invvestigations (2) and because of the close grouping of the plots considered in each group. Paired plots were used in comparing yields within a rotation. These gave much smaller errors; as a result, differences in yields between treatments within a rotation had to be only about one-half as great as differences between rotations in order to be significant.

† The prices used in calculating the average yearly value of the crops in the rotations were average prices as reported in Bulletin (N. S.) 1, West Virginia Agricultural Statistics, for the years 1925 to 1935, and in the Yearbook of Agriculture for 1936. These were as follows: Corn $.87 per bushel, wheat $1.08 per bushel, oats $0.54 per bushel, soybeans $2.06 per bushel, potatoes $1.11 per bushel, and hay $15.05 per ton.

TABLE 3—*Crop Yields and Value in Four-Year Rotation*

Rotation		Corn	Wheat	Clover and timothy	Timothy	Potatoes[1]	Ave. value of crops per year	Change in organic matter
		(bu.)	*(bu.)*	*(tons)*	*(tons)*	*(bu.)*	*(dollars)*	*(percent)*
A	Limed	66.6	14.4	1.71		84.8	48.34	−1
	Unlimed	59.3	11.6	1.12		78.8	42.11	−4
B	Limed	63.2	24.4	1.71		64.1	44.56	+4
	Unlimed	60.4	20.1	0.97		64.7	40.17	−9
C	Limed	65.1	14.2	1.66	1.27		29.02	+8
	Unlimed	57.4	12.0	1.09	1.27		23.36	−4

[1] Yield of primes plus one-half the yield of seconds.

TABLE 4—*Yield of Crops in Three-Year Rotation Receiving Manure*

Rotation		Corn	Wheat	Soybeans	Cowpeas	Soybeans—Sudan grass	Ave. value per year	Change in organic matter
		(bu.)	*(bu.)*	*(tons)*	*(tons)*	*(tons)*	*(dollars)*	*(percent)*
F	Limed	75.1	25.2	2.46			43.19	+9
	Unlimed	73.9	23.2	2.22			40.63	+7
G	Limed	71.8	24.8		1.93		39.43	+9
	Unlimed	69.1	22.8		2.01		38.33	+2
H	Limed	72.8	22.1	2.35			40.86	+3
	Unlimed	66.9	17.3	2.10			36.16	+1
T	Soybeans	70.0	16.5	2.35			38.03	−2
	Soys / Sudan	70.8	16.3			2.51	38.99	0

respectively for Rotations A, B, and C. These returns were in all cases much greater than the cost of applying liming materials.

Value of Various Cropping Systems

There was little difference in corn or hay yields in the various rotations. However, wheat was decidedly better in Rotation B, wherein it followed potatoes, than in either of the other rotations, in which it followed corn. Undoubtedly the fallow period following the removal of potatoes permitted the production and accumulation of available plant food, particularly nitrogen, which was beneficial to the wheat. The application of nitrogenous fertilizers would probably prove especially valuable in rotations in which wheat follows corn. Although no noticeable differences in scab infection were observed, there is also the probability of less scab on wheat following potatoes than following corn.

Potato yields were low in both Rotations A and B, probably because of the limited fertilization given. It was quite evident, however, that potatoes were better following clover and timothy sod than following corn, even though a rye-and-vetch cover crop was seeded in the corn. Other experimental evidence has shown that potato yields are better in soils well supplied with organic matter. Since the vetch seeded in corn made little growth, the supply of nitrogen as well as readily decomposing organic matter was undoubtedly higher for potatoes in Rotation A than in Rotation B.

Direct comparisons of value of crops were possible in Rotation A and B inasmuch as the crops grown and the cultural practices are the same. As shown in Table 3, Rotation A-limed produced \$3.78 more produce per acre per year than did Rotation B-limed, and Rotation A-unlimed produced \$1.94 more per acre per year than Rotation B-unlimed. The differences are due to the higher yields of potatoes, which more than offset in value the lower yields of wheat in Rotation A. It appears doubtful that the difference in costs is as great as the difference in value of crops in these two rotations.

Because of the relatively high acre value of potatoes, the total value of crops was much less in Rotation C than in either of the other two rotations. However, comparisons of value of crops have little meaning unless these can be related to cost of production. The present studies do not permit such direct comparisons, but considering the low yields of potatoes in Rotations A and B, it is doubtful that these crops were any more profitable than the second year hay in Rotation C. However, the decline in yield of hay the second year was evident in Rotation C. This suggests the advisability of keeping clover and timothy meadows for only one year.

Changes in Organic Matter

The most evident changes in organic-matter content of the soil were associated with the use of lime. In all three rotations the unlimed portions declined in such content during the experiment.

This was probably the result of poor growth of clover, which has been noted previously. In general, the organic-matter content was at least maintained on the limed plots, and there was a very decided increase in Rotation C. This rotation would be expected to maintain a higher level of organic matter since it had a cultivated crop only once in four years, whereas Rotations A and B had two cultivated crops in four years. Besides, the organic matter is known to be reduced under cultivation and to be built up under sod crops.

Three-Year Rotations With Manure

The cropping systems in the three-year rotations receiving manure were as follows:

Rotation	*1st Year*	*2nd Year*	*3rd Year*
F	Corn (rye-vetch*)	Soybeans	Wheat (rye & vetch*)
G	Corn (rye*)	Cowpeas	Wheat (timothy*)
H	Corn (rye*)	Soybeans	Wheat (timothy*)
T	Corn	Wheat	Soybeans or soybeans and Sudan grass

Rotations F and H may be used to compare the effect of legume used in cover crop. In Rotations G and H, cowpeas are compared to soybeans. The value of adding Sudan grass to soybeans for hay is studied in Rotation T. The yields of crops in these rotations are given in Table 4.

Value of Liming

Despite the fact that the crops grown in these rotations are relatively tolerant to soil acidity, the yields on the limed plots were usually higher than on the unlimed areas. The effect of lime was particularly marked in Rotation H, in which corn yields were increased by 5.9 bushels, wheat yields by 4.8 bushels, and soybean hay by 0.25 tons. Although the trend was toward higher yields in other rotations, the only other differences greater than experimental error were in soybeans in Rotation F. The greater effect in Rotation H than in Rotation F was rather surprising since a rye-and-vetch cover crop was grown in Rotation F. One would expect vetch to be benefited more by the lime than would the cover crops in Rotation H, and consequently that lime would have more effect on the yields. However, it should be noted that the cover crop in F-unlimed has also been effective in maintaining yields (compare with H). Cowpeas are less sensitive to acid soils than soybeans, which probably explains the lack of response to lime on the cowpea hay in Rotation G.

In general the effect of lime was less pronounced than in the four-year rotations. The value of manure in increasing yields even on unlimed land was probably responsible for this difference, since it is known that crops are less sensitive to acidity on soils high in organic matter.

The effect of lime on the value of crops in the rotation showed positive gains in value of $2.56, $1.10, and $4.70 per acre per year for rotations F, G, and H, respectively. In terms of increased crop value per ton of lime this amounted to $10.24, $4.40, and $18.80, respectively. These values show that lime was definitely profitable on Rotations F and H. Whether the use of lime in Rotation G would be profitable would depend on the rate of liming, the cost of lime, and the original acidity of the soil.

Value of Various Cropping Systems

Considering yields of all crops and value, Rotation F-limed (corn, soybeans, and wheat) gave the highest yields of all crops as well as the highest acre value. As previously stated, Rotations F and H were alike in all respects but cover crop. The use of vetch as a cover crop along with rye increased the value of the crops $2.33 and $4.47 per acre per year for lime and unlimed portions, respectively. Although these increases are not very great, it must be remembered that all the manure produced from feeding the crops was returned before plowing the land for corn. Since there were no storage losses, the amounts applied were in excess of that used in ordinary farm practice. This undoubtedly helped in maintaining a high state of productivity on all plots. Without manure or with smaller applications, leguminous cover crops would probably give greater returns. Data showing results without manure are presented later.

In comparing Rotations F and G, it should be noted that cowpeas gave lower yields of hay than soybeans on both limed and unlimed soils, the differences being 0.53 and 0.21 tons, respectively. There seems to be no advantage in using cowpeas in these rotations.

Changing the order of cropping from corn, wheat, and soybeans (Rotation T) to corn, soybeans, and wheat, as in Rotation F, resulted in a significant increase in wheat yields. This shows the desirability of seeding wheat after soybeans for hay rather than corn wherever this is possible. Corn yields were also slightly higher in Rotation F, with the net result that the average return per year was $5.16 more per acre.

The growing of a mixture of soybeans and Sudan grass instead of soybeans alone gave a slight increase in yield of hay but did not affect the yields of other crops. The differences in all cases were so small that the question of whether to use a mixture of soybeans and Sudan grass or soybeans alone can largely be left to individual tastes. The mixture will probably give better erosion control on sloping lands, in which case its use would be desirable.

Changes in Organic Matter

There again appeared to be slight but consistent increase in organic matter in the plots of Rotation F, G, and H, particularly on the limed plots. The return of large quantities of manure was sufficient to more than counter-balance relatively large losses which would be expected on rotations having no sod crops.

Three-Year Rotations Without Manure

The three rotations considered here represented a rather miscellaneous group which had only corn in common. Rotation D consisted of corn followed by timothy seeded after cutting the corn, with alsike and red clover seeded in the timothy the following spring. The land was kept in hay for two years, the first year's crop being largely timothy and the second year timothy and clover. This rotation was tried with and without applications of lime. Rotation E was a corn-soybean-potato rotation with cover crops of rye and vetch following both corn and potatoes. The soybeans were harvested for seed, and the straw was returned after threshing. Both limed and unlimed plots were used for this rotation. Rotation S consisted of corn, oats, and red clover *vs.* corn, oats, and sweet clover, both on limed soil. No cover crops were grown and only one cutting of hay was removed. The yields of crops are given in Table 5.

Value of Liming

Increases in yields of both corn and hay as a result of liming were marked in Rotation D. The increased value as a result of liming amounted to $13.88 per ton of limestone applied. In Rotation E, liming also increased the yields of all crops with the result that there was a return of $31.36 per ton of lime applied. These increases are certainly sufficient to justify the use of lime in these rotations.

Value of Various Cropping Systems

A direct comparison of value of the three rotations is not possible because they differed so widely in the value of individual crops grown. Potatoes have a relatively high acre value which gives rotations in which they occur a decidedly high average value. This was probably more than counter-balanced in these rotations by the higher cost of production of potatoes.

The substitution of sweet clover for red clover in Rotation S did not affect the average value as calculated. Differences in corn and oat yields were not significant but indicated a trend toward higher yields following red clover. Although yields of both red and sweet clover were abnormally low, the sweet clover yielded slightly more per acre than red clover. Both crops were given the same monetary value. This undoubtedly gave high values for sweet clover since it is not usually considered as good a hay crop as red clover.

The yields of timothy following corn were low in both limed and unlimed portions of Rotation D. Timothy seeded alone at this time did not give satisfactory growth at any time during the experiment. Potatoes did not give satisfactory yields in the corn-soybean-potato rotation.

TABLE 5—*Crop Yields in Three-Year Rotations Without Manure*

	Rotation	Corn	Oats	Potatoes[1]	Soybeans	Timothy	Clover and timothy	Clover	Average acre value	Change in organic matter
		(bu.)	*(bu.)*	*(bu.)*	*(bu.)*	*(tons)*	*(tons)*	*(tons)*	*(dollars)*	*(percent)*
D	Limed	66.4				0.70	1.61		30.89	+2
	Unlimed	62.2				0.52	1.35		27.42	–8
E	Limed	66.1		56.9	25.2				57.53	–11
	Unlimed	62.1		49.8	19.3				49.69	–13
S	Red Clover	64.8	21.1					0.69	26.05	+1
	Sweet clover	61.3	19.5					0.98	26.20	0

[1] Yield of primes plus one-half the yield of seconds.

TABLE 7—*Comparison of Livestock and Grain Rotations*

	Rotation	Corn	Wheat	Soybeans Hay	Soybeans Seed	Clover / Timothy (Hay)	Oats	Ave. value of crops per year	Change in organic matter
		(bu.)	*(bu.)*	*(tons)*	*(bu.)*	*(tons)*	*(bu.)*	*(dollars)*	*(percent)*
M	Livestock	72.8	22.7	2.40		1.41		36.30	+19
	Grain	69.1	17.7		25.4	1.22		37.48	+23
N	Livestock	69.7				1.12	22.7	29.92	+10
	Grain	68.1				1.01	22.0	28.78	+7
O	Livestock	65.8		2.24				45.48	+11
	Grain	60.2			25.9			52.86	–4

Changes in Organic Matter

The most marked changes in organic matter in the soil were found in Rotation E, in which all three crops were cultivated. Even the use of cover crops in this rotation did not furnish enough organic matter to make up for the rapid losses under cultivated crops. Slightly higher losses occurred on the unlimed plots than on the limed plots. This was probably because less soybean straw was returned and smaller amounts of cover crops were plowed under. In Rotation D the organic matter was slightly increased on the limed plots, but there was a decided loss on the unlimed area. The differences were probably associated with the difference in the clover growth, this being noticeably lower on the unlimed plots. Very little change in organic matter occurred in Rotation S, indicating that the gains from the corn and oats stubble plus the second cutting of clover were just about equal to the losses by decomposition.

Two-Year Rotations with Different Cover Crops

Rotations I, J, K, L, and V consisted of corn and soybeans grown in two-year rotations with various cover crops following both crops. The cover crops used were as follows:

Rotation	*Cover Crop*
I	Sweet clover and vetch
J	Rye and vetch
K	Crimson clover
L	None
V	Wheat and vetch
V	Sweet clover

In all rotations except V the crops were compared with and without lime. Soybeans were harvested for seed for the first five years in Rotations I, J, K, and L. During this period the cover crops following soybeans were badly winterkilled because of the late seeding. For the last seven years the soybeans were harvested for hay. The earlier harvest allowed earlier seeding of cover crops and as a result better stands and growth were obtained.

The yields of crops are given in Table 6.

Value of Liming

Significant increases in yields of corn as a result of liming were evident only in Rotation J, which had a cover crop of rye and vetch. Rotations I and L also showed a slight apparent increase in yield as a result of liming, and although these were too small to be significant, they do indicate the general trend toward higher yields on limed soils.

There was a decrease in yield of corn on the limed plots in Rotation K amounting to 4.7 bushels. The cover crop used in this rotation was crimson clover, which made relatively poor growth both on the limed and unlimed plots. The decline in yields on the limed plots was particularly noticeable during the last three years of the experiment, during which time the limed plots averaged 16.7 bushels per acre less than the unlimed plots. The appearance of the corn plants in the field indicated potash deficiency on the limed plots. Applications of potash fertilizer to part of the plots since 1936 have given large increases in yield. The decrease in yields may therefore be explained on the basis of potash deficiency on the limed plots rather than a direct effect of lime in decreasing the yields.

The yields of soybean seed and hay were significantly higher on the limed plots, regardless of cover crops grown. In this experiment, as previously indicated, the soybean seed yields represent the first five years of the experiment and the soybean hay yields the last seven years.

Table 6—*Yields of Crops in Two-Year Rotations*

	Treatment	Corn	Soybeans Hay[1]	Soybeans Seed[2]	Average yearly value	Change in organic matter
			(bu.)	(tons)		
I	Limed	49.8	1.54	20.8	$37.35	–16
	Unlimed	46.8	1.35	15.6	32.98	–12
J	Limed	55.9	1.67	23.0	41.56	–12
	Unlimed	50.6	1.36	16.4	35.02	–7
K	Limed	45.2	1.57	21.1	35.57	–11
	Unlimed	49.9	1.43	18.0	35.71	0
L	Limed	43.0	1.45	20.8	34.00	–23
	Unlimed	41.9	1.32	16.2	30.98	–9
V	Wheat and vetch	46.6	1.77		35.59	–15
	Sweet clover	40.9	1.76		31.04	–13

[1] Average 1930-1936 for rotations I, J. K, and L.
[2] Average 1925-1929.

The returns from liming as measured by increase in value of crops per ton of lime applied showed increases in value of $17.48, $26.16, $0.56, and $12.12 for Rotations I, J, K, and L, respectively. With the exception of Rotation K, the increases were more than sufficient to justify the use of lime. The greatest returns were in Rotation J, which had the rye-and-vetch cover crop. This appeared to be more satisfactory from the standpoint of growth than the cover crops of crimson clover or vetch and sweet clover.

Effect of Cover Crops on Yields and Value

On the unlimed plots, corn yields were increased by 4.9 bushels, 8.7 bushels, and 8.0 bushels by the use of sweet clover and vetch, rye and vetch, and crimson clover cover crops, respectively. All of these increases were statistically greater than differences which might be expected due to chance variation. The vetch and sweet clover cover crop was not satisfactory on the unlimed soils since sweet clover failed in all years, and only a partial stand of vetch was secured. However, the growth made was apparently sufficient to increase yields of corn over the plots having no cover crop. Crimson clover also made relatively poor growth but was better than no cover crop. Rye and vetch made most satisfactory growth of the cover crops tested and is generally recommended even though average corn yields on the unlimed area were about the same as on the plots having crimson clover. The reason for this is apparent in Figure 2, which shows corn yields and yield trends in these rotations.

As shown in this figure, the corn yields in Rotations K and L were higher during the first two years than in Rotations I and J. This apparent difference in initial fertility was included in the average yields and made Rotations K and L appear relatively better than they showed during the latter years of the experiment. From this figure it is evident that during the latter part of the experiment Rotation J was better than the others. Rotation L, which had no cover crop, produced the lowest average yields during each of the last six years of the experiment. The trend toward declining yields was evident in all four rotations, indicating that even with cover crops grown each year, it has not been possible to maintain fertility in a corn-soybean rotation. Rotation J, having a rye-and-vetch cover crop, has almost maintained yields, but at a relatively low level as compared with some of the better rotations.

Yields of soybeans for both seed and hay showed no appreciable

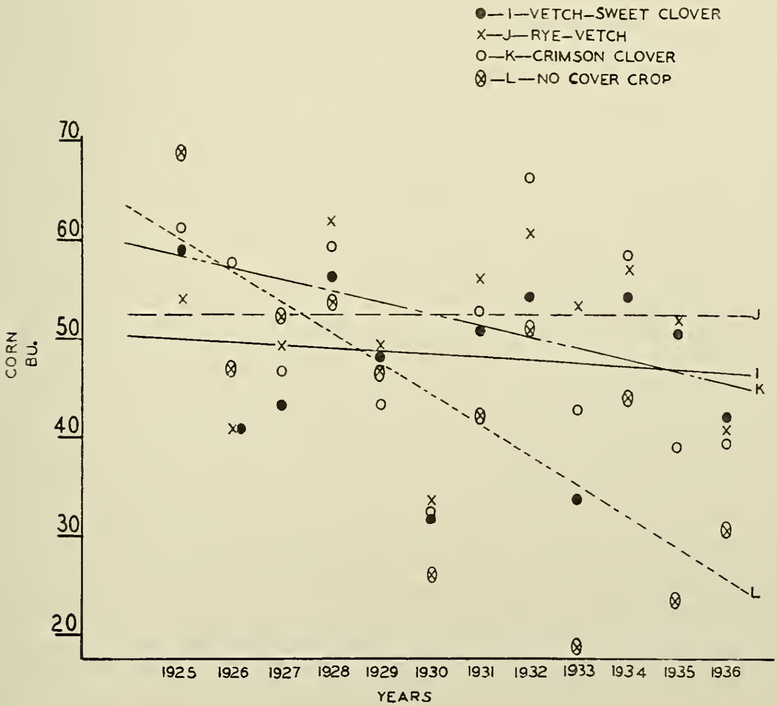

FIGURE 2—YIELD TRENDS IN UNLIMED CORN-SOYBEAN ROTATIONS

effect of the various cover crops on the unlimed areas, although Rotation K again was slightly higher in seed yield, probably as a result of the higher initial fertility.

The values of the unlimed rotations were in the same order as corn yields. At seed prices current the summer of 1942 the annual cost of seed of cover crops would be $4.98, $4.44, and $3.00, respectively, for Rotations I, J, and K. Except for Rotation K, these costs were greater than the value of the increase in yield so that on the average the practice has not been profitable. However, if the trends in yield of corn shown in Figure 2 are considered, it appears that the practice has been profitable for the last half of the period during which yields of corn have declined materially in Rotation L.

The average yields of corn on the limed plots show rye and vetch to be decidedly superior to any of the other cover crops tested, the increase in yield amounting to 12.9 bushels over the plot without cover crop. Yields of corn in Rotation I, having sweet clover and vetch cover crop, were also higher than yields in Rotations K and L, which had crimson clover and no cover crop, respectively. The low average yields on Rotation K were probably the result of potash deficiency, as previously mentioned.

Corn yields in Rotation V were relatively low, indicating that

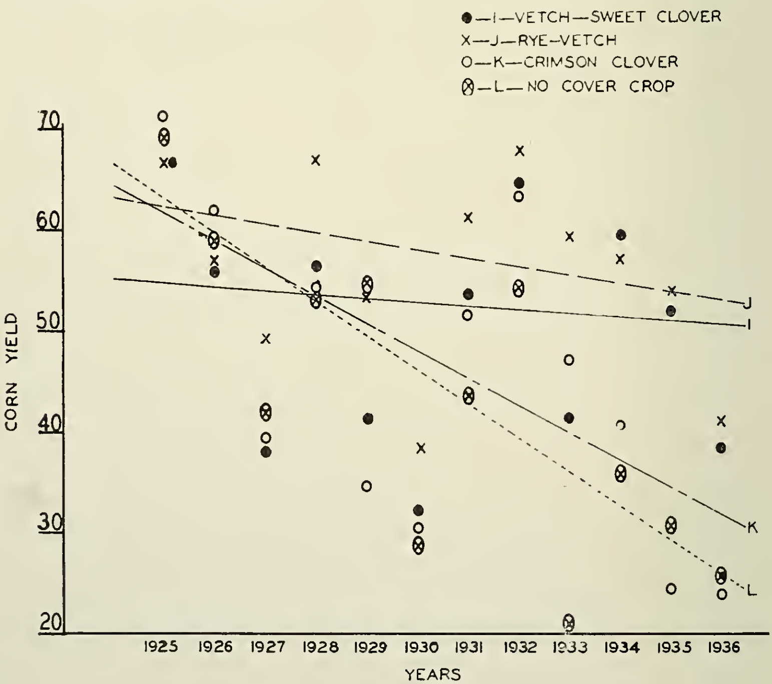

FIGURE 3—YIELD TRENDS IN LIMED CORN-SOYBEAN ROTATIONS

wheat was not as good as rye for a cover crop, and the use of sweet clover alone proved very unsatisfactory. This was undoubtedly due to the fact that it must be planted late when following corn or soybeans, and it winterkills badly.

Corn-yield trends for the limed rotations, as given in Figure 3, show that Rotations K and L have declined markedly, whereas the trends for Rotations I and J were only slightly downward. Sweet clover as a part of a cover-crop mixture has been more satisfactory on limed soil, which probably accounts for Rotation I-limed being relatively better than Rotation I-unlimed. However, it is again evident that none of the rotations was able to maintain the yields, as all showed a greater or lesser downward trend. Although this is not great in Rotations I and J, it should be remembered that the corn yields in both of these are low compared with yields in most of the longer rotations on limed soil. Yields of soybean hay or grain were not materially affected except in Rotation J-limed, in which the yields are significently higher than those in Rotation L having no cover crop. The apparently higher yield of soybeans in Rotation V was the result of seasonal variation as the yields for the last seven years of the experiment averaged 1.59 and 1.53 tons per acre for the plots having wheat and vetch and sweet clover, respectivelly.

A direct comparison of value of cover crops in limed rotation was possible in Rotations, I, J, K, and L. These showed that cover crops increased the value of crops on the limed plots by $3.35, $7.56, and $1.57, respectively, for vetch and sweet clover, rye and vetch, and crimson clover. These increases were not great enough to pay seed costs except in the case of rye and vetch, in which case it was sufficient to pay also the labor cost in seeding.

Changes in Organic Matter

A decrease in the organic-matter content of the soil was evident in all of the two-year rotations under consideration. Losses have been consistently higher on the limed plots, in which case they probably represent losses due to more rapid decomposition. Cover crops have reduced the losses in practically all plots, the effect being most evident on the limed areas, but the organic matter added by the corn-and-soybean stubble plus that grown in cover crops has not been sufficient to balance the losses which have occurred under corn and soybeans.

Comparison of Livestock and Grain Systems of Farming

A study of comparative value of manure and crop residues for the maintenance of crop yields and soil fertility was made in Rotations M, N, and O. These consisted of one four-year rotation (M), in which the cropping system was corn, soybeans, wheat, and a mixture of clover and timothy; and one three-year rotation (N), consisting of corn, oats, and clover; and one two-year rotation (O), consisting of corn and soybeans. On one-half of the plots the crops were harvested, fed, and the manure returned. On the other half the crops were harvested for grain, which was sold; the residues, consisting of stover and straw, were returned to the land. Both manure and residues were applied before plowing the land for corn. The yields of crops in the three rotations are given in Table 7 (page 14).

Livestock vs. Grain Farming

The yields of crops were generally somewhat higher in the rotations which had the manure returned than in those which had only crop residues. In the case of wheat, which shows a very significant difference, a part of this difference may be attributed to the late removal of soybeans for seed in the grain rotation. This practice has been found to lower wheat yields *(1)*. In all other crops the differences appear to be due to the effect of manure. The increase in yield of corn was significant only in Rotation O, but the fact that all rotations showed the same trend makes it appear unlikely that the other differences are entirely due to chance variation. Likewise, the differences in hay yield in both Rotation M and N indicate a definite trend toward higher yields in the manured rotation, although differences in N are not quite great enough to be significant statistically. Oat yields in Rotation N are not significantly different.

The figures for average value of crops are comparable only in Rotation N, in which the livestock rotation gave a return of $1.14 per acre more than the grain rotation. Rotations M and O gave higher values for the grain rotation because of the higher acre value of soybean seed as compared with soybean hay.

Length of Rotation and Crop Returns

Under both livestock and grain systems of farming the average yield of corn decreased as the rotation was shortened. The decreases are statistically significant between M and O in both grain and livestock sections and between N and O in the grain rotation. The fact that Rotation N is intermediate in yield in both sections is likewise indicative of the trend toward lower yields with short rotations. The data also show lower yields of clover and timothy hay in the three-year rotation in comparison with the four-year rotation, and lower yields of soybeans hay in the two-year than in the four-year rotation. Soybean-seed yields were practically the same in Rotations M and O.

Considering yearly value of crops, the two-year rotations had the highest value, followed by the four-year and the three-year rotations in that order. These differences are principally due to the fact that certain of the crops had a relatively low value per acre. The average values per acre for the crops grown place them in the following order: corn, soybeans for seed, soybeans for hay, wheat, clover and timothy hay, and oats. Rotation O (grain) had the two crops having the highest acre value and therefore gave the highest average value. On the other hand, Rotation N had the two crops having the lowest acre value which made it lowest in average value. The relative values of M and N are also low because only one crop of clover and timothy hay was harvested, whereas two are normally expected. In comparing values it should be remembered that additional seedbed preparations are needed in Rotations O and M. Rotation O requires plowing each year and has had cover crops of rye and vetch seeded each year. Rotation M is plowed before corn and before soybeans, which makes an average of one plowing each two years; it also had one cover crop each four years. Rotation N has had only one plowing every three years. Thus, if one considers the variation in costs in the systems, the average values lose a considerable part of their apparent difference in value. Furthermore, losses by erosion would affect the rotations having soybeans on rolling land. On level land Rotation O would produce the most feed and would probably be most desirable if a limited amount of land were available. On hilly land Rotation M or N would probably give better results because of lower erosion losses.

Changes in Organic Matter

Rotation M has been most effective in increasing the organic matter content of the soil, the grain system appearing to be slightly better than the livestock system. Rotation O (livestock) has been as effective as Rotation N (livestock), the higher manure production in O apparently offsetting the sod crop in Rotation N. The return of soybean straw and corn stover in Rotation O (grain) has not been sufficient to maintain the organic matter.

Spring vs. Fall Seeding of Alfalfa

Rotation Q was a six-year rotation designed to compare spring *vs*. fall seeding of alfalfa. One-half of the plots were used for corn, soybeans, and oats, with alfalfa seeded in the spring and allowed to remain for three years. The other half of the plots had potatoes in place of oats during the first five years, after which the potatoes were replaced by oats. In these plots the alfalfa was seeded in the fall after potatoes or oats. The stand of alfalfa was uniformly poor, probably because of lack of potash fertilizer. The yields of the rotations are given in Table 8.

TABLE 8—*Yields of Crops in Rotations Q*

	Corn	Soybeans	Oats	Potatoes	Alfalfa
Fall seeded alfalfa	66.8	2.10	18.2[1]	52.0	1.16
Spring seeded alfalfa	67.2	2.20	22.8		0.94

[1] Average for 1930-1936

As was to be expected, the time of seeding alfalfa had no effect on the yield of corn or soybeans. Oat yields are not comparable because oats was grown only the last seven years in the fall-seeded alfalfa plots. Alfalfa yields were low in both cases because of poor stands, probably as a result of potash deficiency. However, the slightly higher yield of alfalfa as a result of fall seeding is of interest since it has been found in other tests that fall-seeded alfalfa is usually less weedy than spring-seeded alfalfa. Under certain conditions this advantage of fall seeding may be offset by the additional seedbed preparation required and the greater dangers from erosion. The latter will probably be the determining factor on rolling land.

Red vs. Hubam Clover as Cover and Green-Manure Crops

Rotation U compared the effect of red clover *vs.* Hubam clover as green manure crop seeded in oats. The results of the test are shown in Table 9.

TABLE 9—*Red Clover vs. Hubam Clover as Cover Crop*

Treatment	Corn	Oats	Change in organic matter
	(bu.)	*(bu.)*	
Red clover	52.3	52.3	–9
Hubam clover	50.5	19.8	–11

Differences in yields of both corn and oats were too small to show any significant difference between the two crops as green-manure crops. Differences in organic matter content were not significant but do show that these cropping systems have been unable to maintain the original level of organic matter.

Continuous Cropping Systems

Rotations W and X were designed to show the effect of continuous cropping with corn and wheat respectively. In the corn plots rye and vetch were compared with sweet clover as cover crops. In the wheat plots red clover and Hubam clover cover crops were compared. The yields are given in Table 10.

TABLE 10—*Yields of Corn and Wheat under Continuous Cropping*

Rotation	Corn	Wheat	Change in organic matter
	(bu.)	*(bu.)*	
W—Rye and vetch	38.9		–9
W—Sweet clover	37.3		–18
X—Red clover		19.8	–15
X—Hubam clover		21.6	–7

Differences in corn yields were not large enough to be significant. This was not surprising, since both sweet clover and vetch usually failed, and the comparison was more properly rye *vs.* no cover crop. Yields in both series were low as compared with yields of corn secured on other rotation plots. Rye cover crop has lessened but not stopped depletion of organic matter.

Wheat yields were almost two bushels higher on the plot having Hubam clover. This crop makes rapid summer growth, and, although it is an annual, the total amount of growth turned under was greater than for red clover. Additional evidence to this effect is shown in the change in organic matter in which the loss was less than half as much as under red clover cover crop.

Yields of Tobacco in Four-Year Rotations

Rotations P and R were four-year rotations having tobacco as the cash crop. In Rotation P the plots were allowed to grow up to weeds following the tobacco. In Rotation R the cropping system was tobacco, wheat, and a mixture of red and alsike clover in one series, and tobacco, wheat, timothy, and redtop in the other series. The yields of crops are given in Table 11.

TABLE 11—*Yields of Crops in Tobacco Rotations*

Rotation	Tobacco	Wheat	Clover	Timothy and redtop
	(lbs.)	*(bu.)*	*(tons—hay)*	*(tons—hay)*
P	1359			
R	1249	22.7	1.38	
R	1178	19.4	·	0.76

Although the tobacco yields were somewhat higher in Rotation P than in R, the difference was not sufficient to make up in value for loss of crops during the three years it was allowed to grow up to weeds. Clover in Rotation R made a good crop the first year but was practically a failure the second year. The mixture of redtop and timothy was seeded with wheat in the fall. The timothy disappeared and the hay crop harvested consisted primarily of redtop, which made a good sod.

The tobacco in Rotation R frenched badly during the early years of the experiment. Consequently one ton of a 4-10-6 fertilizer was applied each year from 1932 on. This practice increased yields by 64 percent and greatly improved the quality of the tobacco.

Length of Rotation

Direct comparisons of length of rotation were not possible in many cases because of differences in treatment or cropping system. Reference has already been made to the effect of length of rotation in the comparison of the livestock *vs.* grain farming system, in which case relatively large amounts of manure and residues were returned. The results showed that yields were slightly higher in the longer rotations. Similar groupings showing effect of length of rotation on crop yields in rotations without manure are shown in Table 12.

The most marked differences are noted in corn yields, which increased 24.8 bushels as the cropping system was changed from continuous corn to a three-year rotation. The differences in corn yield

TABLE 12—*Effect of Length of Rotation on Yields*

Rotation	Corn	Oat	Clovver Hay
	(bu.)	*(bu.)*	*(tons)*
Continuous corn (W)	38.3		
Corn—soybeans (J)	55.9		
Corn—oats (U)	51.2	18.5	
Corn—oats—clover (S)	63.1	20.3	.69
Corn—wheat—clover and timothy (2 yrs.) (C)	65.1		1.47
Corn—soybeans—oats—alffalfa (3 yrs.) (Q)	67.0	22.8	

between the three- and four-year rotations were too small to be of much significance, but there did appear to be a continued upward trend in corn yields as the length of time in sod was increased. The effect of length of rotation was much more marked in those rotations in which no manure was used than in rotations receiving heavy applications of manure. Oat and hay yields likewise showed a slight increase with increasing length of rotation.

Effect of Manure in Rotations

In addition to the comparison of manure *vs.* crop residues in Rotations M, N, and O, a direct comparison of manure with no manure or crop residues may be made between Rotations N and S and Rotations O and J. The yields in these rotations are given in Table 13.

TABLE 13—*Effect of Manure on Two- and Three-Year Rotations*

Rotation	Corn	Oats	Clover	Soybeans
	(bu.)	*(bu.)*	*(tons)*	*(tons)*
N (manure	69.7	22.7	1.03	
S (no manure)	64.8	21.1	0.69	
O (manure)	65.8			2.24
J (no manure)	55.9			1.67[1]

[1] Average for 7 years.

These results further emphasize the importance of proper conservation and use of manure. It will be noted that the effect on corn yields was greater in the two-year than in the three-year rotations. In short rotations with frequent cultivated crops the careful conservation and return of manure is particularly necessary for the maintenance of satisfactory yields.

DISCUSSION

The soil at Lakin is naturally more fertile than the average soil in the state. However, before establishment of the experiment the land was considered practically worn out. In spite of this condition, crop yields were for the most part well above the average for the state. Because of the low native fertility, the soil responded well to treatment. Even the plots having continuous cropping systems (W and X) have yielded more than average for the state, although these have received only 3 tons of limestone in the twelve-year period and 100 pounds of 20 percent superphosphate applied annually. The use of cover crops has undoubtedly helped to keep up yields of wheat and probably of corn, although the growth in the latter crop was not as good as one would wish.

It will be noted that major attention has been given to corn in the discussion of effects of various cropping systems on yield. Corn is the most important grain crop in West Virginia and probably will continue as such, since corn will produce a greater amount of total digestible nutrients per acre than any other crop. Because of this fact, corn was included in most of the rotations, and therefore direct comparisons of corn yields were usually possible.

The range in average corn yields from 37.7 to 75.1 bushels per acre emphasize the importance of the cropping system in relation to yield. When one also considers that these yields are averages over a twelve-year period and that there has been a definite downward trend in yields of the poorer rotations as indicated in Figures 2 and 3, the importance of good rotations is even more evident. For example, in 1936 the corn yields varied from 8.3 bushels per acre in rotation W to 67.7 bushels per acre in Rotation F.

The factors affecting corn yields in these experiments were: (1) use of lime, (2) use of manure, (3) length of rotation, and (4) crop system in the rotation. Of these it appears that lime was about equally effective under practically all conditions. Manure brought about greater increases in yields in the short rotations but also increased yields in the four-year rotation in which it was used. The length of rotation appears to have had greatest effect where no manure or crop residues were returned. Where sufficient manure is available, where the land is not subject to severe erosion, and where cover crops are turned under as green-manure crops, corn may give satisfactory results in short rotations. Such conditions are limited to small areas inasmuch as sufficient manure is usually not available and much of the farmland is too steep for the continuous production of crops which do not reduce soil and water losses.

Potato yields were low in all cases, probably largely because of inadequate fertilization. However, the yields were considerably better when potatoes followed clover and timothy sod than when the preceding crop was either corn or soybeans.

The marked effect of the preceding crop on wheat has already been noted. When possible in the rotation, wheat should follow a crop which has been removed several weeks before wheat planting time, such as early potatoes or soybeans for hay. Late removal of the preceding crop does not allow sufficient time for making plant nutrients available. Evidence already cited *(1)* in the case of wheat following soybean seed indicates that the use of nitrogen fertilizer at planting time will furnish the nitrogen necessary for satisfactory fall growth. Where corn precedes wheat there is also probably increased scab infection, since the organism causing scab lives over in the corn stubble or stalks. Seed treatment will help to reduce the chance of infection but will not control the scab organisms living in the soil. Where scab is a serious problem it may be necessary to rearrange the rotation so that wheat does not follow corn or to replace wheat with some other crop.

The value of manure in increasing wheat yields has been noted in Rotation M. It may also be pointed out that wheat yields were generally higher in Rotations F, G, and H than in those rotations which did not receive manure. Liming increased wheat yields 2.0 to 4.8 bushels, with an average of 3.0 bushels per acre in the six rotations in which direct comparisons are possible.

Liming has also been the principal factor affecting timothy and clover hay yields, the increases ranging from 0.18 tons in the case of timothy hay in Rotation D to 0.74 tons in Rotation B. The planting of timothy after corn did not give a satisfactory crop the following year. The mixture of timothy, red clover, and alsike clover appeared to be better than mixtures without the timothy (see Rotations A, B, C, and M), and the second year timothy was inferior to the first-year mixed hay in Rotation C.

Soybeans gave very satisfactory yields of both hay and grain. Despite the relative tolerance of soybeans to acidity, yields were increased markedly by applications of limestone. Cowpea yields were slightly lower than soybean yields, especially on limed land.

Spring oats were not very satisfactory as grain crops at Lakin. The yields were generally low, and the total feed produced was less than that produced by wheat. Unless winter oats can be grown successfully, it would appear that wheat or barley are more satisfactory grain crops in the southwestern section of the state.

Alfalfa yields were low in Rotation Q because of lack of fertilizer. On these soils alfalfa responds particularly well to potash, and satisfactory stands cannot be maintained unless potash fertilizers are used.

Stover and straw yields are given in Table A (Appendix). They have not been included in tables discussed since these are in most cases closely related to yields of grain. This being the case, the value of the various increases in yields is enhanced by increased value of straw and stover. In certain areas in the state and on certain farms this increase in value may have considerable importance.

The importance of maintaining a plentiful supply of organic matter has been emphasized in the discussion of the various rotations. It is of interest to make further comparisons showing the effect of organic matter content of soils on the average corn yields obtained in the experiments. In Figure 4 the average corn yield for each of the limed rotations is plotted against the organic-matter content determined in 1936. These show a high correlation ($r=0.8286$) and indicate that over 68 percent of the variation in corn yield was associated with variation in organic-matter content.

The regression equation $y = -39.1 + 74x$ is highly significant. For each increase of 0.1 percent in organic-matter content, the corn

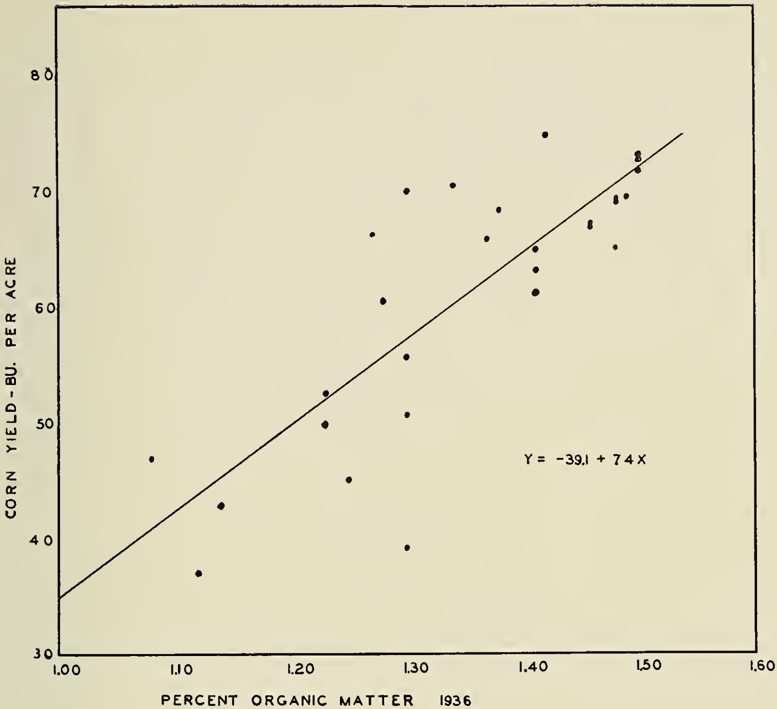

FIGURE 4—YIELD OF CORN IN RELATION TO ORGANIC MATTER

yield increased on the average 7.4 bushels. When one considers that other factors such as season affect yields of the various rotations differently, the importance of organic matter becomes even more evident. The seasonal effect was especially noted in 1930, when the manured plots gave lower yields than the unmanured ones.

There was little correlation between yield of corn and organic-matter content on the unlimed plots (r=0.3731)). In these plots the lack of lime was undoubtedly more important in influencing yield than was the organic-matter content.

The use of all manure produced by feeding the crops grown on the land has been effective in all cases in maintaining or increasing the organic matter supply. In Rotation T, which had corn, wheat, and soybeans without cover crops between the wheat and soybeans, there was no increase in organic matter. The use of cover crops in Rotations F, G, H, and O, in addition to manure, has resulted in a noticeable gain in the organic matter content. In Rotations M and N the use of manure plus the second cutting of clover has likewise been effective in increasing the organic-matter supply. The crop residues returned in Rotations M and N increased the organic matter, but in Rotation O there was a measurable decrease.

In those rotations which did not receive manure only Rotations A, B, C, D, and S have been able to maintain or increase the organic-matter supply. All these rotations included clover or a clover-timothy mixture, in which one cutting was left on the land. It would appear, therefore, that for maintenance of organic-matter supply at the level present in these plots, there must be a return in addition to the crop residues normally left in harvesting crops.

The evidence here presented indicates that the maintenance of organic matter is dependent on: (1) the use of all the manure on the crop land or (2) supplementing smaller quantities of manure with either green-manure crops or legumes such as clovers or alfalfa regularly in the rotation. Unless the manure is carefully conserved, it must be supplemented even though it is all applied to the crop land. Under average conditions in West Virginia it seems most likely that the maintenance of a satisfactory level of organic-matter content of soils can be attained best by the regular use of sod crops in the rotation as indicated above, plus the application of the manure produced by feeding the crops grown.

SUMMARY

Yield data and change in organic matter content of the soil are reported for 24 cropping systems differing in kind of crop, in crop sequence, or in cover crops used. Although no specific rotation can be pointed out as being superior to all others, there are several significant features of the various rotations which have given consistently good results.

(1) Liming has proved profitable on most crops used. The exceptions are for potatoes and cowpeas. Even when these crops are included in the rotation, the beneficial effect on other crops has been sufficient to make liming a profitable practice in most rotations.

(2) The growing of cover crops in rotations which do not provide winter cover has helped to maintain crop yields. In these trials the combination of rye and vetch was the most satisfactory cover crop following corn and soybeans. This combination gave the greatest total amount of growth under the conditions of the experiment. Sweet clover made very poor growth when seeded in corn, probably because of the excessive shading. Crimson clover was not satisfactory in these tests but is being used successfully in certain sections of West Virginia.

(3) The use of manure has given consistently good results. Since West Virginia is particularly well adapted to livestock production, special attention should be given to the adequate care and return of manure to the crop land.

(4) Although satisfactory yields have been obtained in two-year rotations when manure and cover crops have been used, the yields are not as high as when longer rotations are followed. Even greater differences in favor of longer rotations, including sod crops, would be expected on hilly land where erosion is a major problem.

(5) For best results potatoes should follow a sod crop rather than corn in the rotation.

(6) Wheat yields have been much better when the wheat follows early potatoes or soybeans cut for hay than when wheat follows corn.

(7) Spring oats have given very poor yields. The use of winter wheat or winter barley in the rotation in place of oats will give much more feed and at the same time provide winter cover.

(8) The maintenance and increase of organic matter appears to be related to high yields. The return of manure, the use of sod crops, and the growing of cover crops for green manure, all have been valuable in maintaining a plentiful supply of organic matter.

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Table A—*Summary of Crop Yields in Rotation Experiments, 1925-1936*

Rotation and crop	Treatment	Corn Grain	Corn Stover	Potatoes (total)	Wheat Grain	Wheat Straw	Timothy, alsike, & red clover	Timothy	Mammoth timothy & alsike clover	Soybeans Seed	Soybeans Straw	Soybeans Forage	Cowpeas
		(bu.)	*(tons)*	*(bu.)*	*(bu.)*	*(tons)*	*(tons)*	*(tons)*	*(tons)*	*(bu.)*	*(tons)*	*(tons)*	*(tons)*
A	Lime	66.6	2.06	106.3	14.4	0.71	1.71						
p, c, w, art	No lime	59.3	1.88	112.2	11.6	0.57	1.12						
B	Lime	63.2	1.99	90.2	24.4	1.29	1.71						
c, p, w, art	No lime	60.4	1.86	89.3	20.1	1.05	0.97						
C	Lime	65.1	2.03		14.2	0.68	1.66	1.27					
c, w, art, t	No lime	57.4	1.86		12.0	0.55	1.09	0.94					
D	Lime	66.4	1.98					0.70	1.62				
c, t, am	No lime	62.2	1.91					0.52	1.35				
E	Lime	66.1	2.06	72.5						25.2	1.33		
c, s, p	No lime	62.1	1.85	81.9						19.3	1.20		
F	Lime	75.1	2.44		25.2	1.29						2.46	
c, s, w	No lime	72.9	2.26		23.2	1.15						2.22	
G	Lime	71.8	2.19		24.8	1.33							1.93
c, co, w	No lime	69.1	2.15		22.8	1.21							2.01
H	Lime	72.8	2.23		22.1	1.13						2.35	
c, s, w	No lime	66.9	2.12		17.3	0.82						2.10	
I	Lime	49.8	1.63							20.8[1]	1.03[1]	1.54[2]	
c, s	No lime	46.8	1.31							15.6[1]	0.89[1]	1.35[2]	
J	Lime	55.9	1.63							23.0[1]	1.09[1]	1.67[2]	
c, s	No lime	50.6	1.46							16.4[1]	0.91[1]	1.36[2]	

Summary of Crop Yields in Rotation Experiments (Cont'd.)

Rotation and crop	Treatment	Corn		Soybeans		Forage	Wheat		Red & alsike clover	Oats		Tobacco	Timothy and redtop
		Grain	Stover	Seed	Straw		Grain	Straw		Grain	Straw		
		(bu.)	*(tons)*	*(bu.)*	*(tons)*	*(tons)*	*(bu.)*	*(tons)*	*(tons)*	*(bu.)*	*(tons)*	*(lbs.)*	*(tons)*
K	Lime	45.2	1.38	21.1[1]	1.05[1]	1.57[2]							
c, s	No Lime	49.9	1.44	18.0[1]	1.80[1]	1.43[2]							
L	Lime	43.0	1.44	20.8[1]	1.05[1]	1.45[2]							
c, s	No lime	41.9	1.30	16.2[1]	0.90[1]	1.32[2]							
M	Livestock	72.8	2.56			2.40	22.7	1.14	1.41				
c, s, w, ar	Grain	69.1	2.22	25.4	1.45		17.7	0.82	1.22				
N	Livestock	69.7	2.25						1.12	22.7	0.54		
c, o, ar	Grain	68.1	2.08						1.01	22.0	0.50		
O	Livestock	65.8	2.16			2.24							
c, s	Grain	60.2	1.88	25.9	1.62								
P, Tobacco,	Weeds											1359	
R													
T, w, ar, ar							22.7	1.15	1.38			1249	
T, w, trt, trt							19.4	0.98				1178	0.76
U	Hubam	52.3	1.65							17.1	0.45		
c, o	Red cl.	50.5	1.53							19.8	0.42		
V	W. V.	46.6	1.49			1.77							
c, s	Sw.	40.9	1.37			1.76							
W	Rye, V.	38.9	1.28										
Corn	Sw.	37.3	1.35										

Summary of Crop Yields in Rotation Experiments (Concluded)

Rotation and crop	Treatment	Corn Grain	Corn Stover	Oats Grain	Oats Straw	Potatoes	Alfalfa	Red clover	Sweet clover	Soybeans and Sudan	Soybeans	Wheat Grain	Wheat Straw
		(bu.)	*(tons)*	*(bu.)*	*(tons)*	*(bu.)*	*(tons)*	*(tons)*	*(tons)*	*(tons)*	*(tons)*	*(bu.)*	*(tons)*
Q													
c, s, o, alf.	Fall seeded	66.8	2.10	18.2[2]	0.53[2]	52.0[1]	1.16				2.10		
	Spring seeded	67.2	2.08	22.8	0.52		0.94				2.20		
S													
c, o, r	Red clover	64.8	1.94	21.1	0.47			0.69					
c, o, sw.	Sw. clover	61.3	1.94	19.5	0.45				0.98				
T													
c, w, s		70.0	2.02								2.35	16.5	0.77
c, w, s, su		70.8	1.98							2.51		16.3	0.77
X													
Wheat	Red cl.[3]											19.8	1.09
	Hubam[3]											21.6	1.10

[1] Average for 5 years, 1925-1929.
[2] Average for 7 years, 1930-1936.
[3] One plot only.