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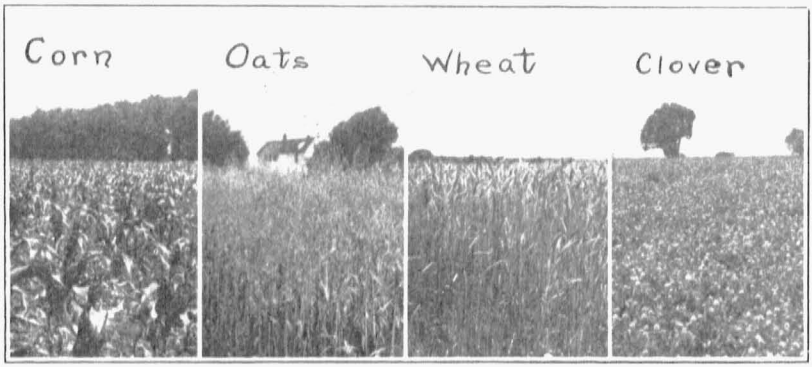
CROP ROTATIONS FOR MISSOURI SOILS



A good rotation for the better soils of Missouri.

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COLLEGE OF AGRICULTURE

Agricultural Experiment Station

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

[2]On leave of absence

Crop Rotations for Missouri Soils

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The term crop rotation means that different kinds of crops follow one another in a regular order for a definite period of years.

Field experiments extending over 30 years and comparing the values of different rotations have been conducted by the Missouri Experiment Station. Continuous growing of corn and other common crops on the same land has been tested also. All crops have been grown both with and without manure. From the records of these experiments some interesting results are here presented as to the effects of different cropping systems on the yields after a period of 30 years. The year 1919 was the thirty-first year and the following table shows the yields of plots which were in corn that season. The season of 1919 is selected because it is the most recent year when the four-year rotation plots were cropped with corn.

Yields of Corn on Rotation Field at Columbia.

Cropping system and soil treatment	Yields in bu. per acre 31st year, 1919.
Continuous corn, no treatment	19.6
Continuous corn, manured	39.1
Corn, oats, wheat, clover rotation, no treatment	52.5
Corn, oats, wheat, clover rotation, manured	60.1

These results show the high value of rotation in maintaining the yield of corn. Corn in rotation is shown to yield twice as much as where grown continuously. With twice the yield and little increase in cost of production the profits are several times as great. Based on 1919 yields, one crop of corn in the rotation series is more valuable than three crops of corn produced on continuous cropped plots. It is the margin above cost which counts.

The other crops of the rotation are affected almost if not quite as much as corn. The following table shows the yields of wheat from the same plots in 1917, which was the most recent year when these plots were cropped with wheat.

Yields of Wheat on Rotation Field at Columbia.

Cropping system and soil treatment	Yields in bu. per acre 29th year, 1917.
Continuous wheat, no treatment	0.2
Continuous wheat, manured	10.9
Corn, oats, wheat, clover rotation, no treatment	30.0
Corn, oats, wheat, clover rotation, manured	39.4

From these records it is evident that rotations may make all the difference between a total failure of the wheat crop and a very satisfactory yield when the cropping system is continued through long periods of time. The plot growing continuous wheat with no manure or fertilizer does not give so complete a failure every year but the wheat is so weakened by lack of fertility and other unfavorable conditions that it is often badly winter-killed. Here again it should be noted that increased yields due to rotation are secured practically without increase in cost. While harvest and marketing costs will increase slightly with higher yields from crop rotation, this is offset through a better seasonal distribution of the labor secured from growing a variety of crops.

Corn is probably the best crop with which to measure fertility, since it seldom fails completely through attacks of insects or from bad weather conditions. The effects of 40 years' work with crop rotations are well represented in Figure 1, giving the 30-year average yields of corn under different cropping systems. From this plate it is evident that, on the average, the yield is increased by lengthening the period between corn crops. The one plot which is shown to have received manure was manured at the rate of six tons an acre every year for 30 years. While the use of 6 tons of manure per acre each year is too heavy for ordinary practice it shows that corn yields cannot be maintained at a high level by manure applications alone. As shown by Figure 1 a three-year rotation without manure or fertilizer was almost as effective, and the four- and six-year rotations were more effective in keeping up the yield of corn than was heavy manuring where corn was grown every year. On the average, therefore, rotation is more effective than heavy manuring in maintaining corn yields. Considering all of the crops grown on Rotation Field at the Missouri Station, the four-year rotation of corn, oats, wheat and clover was more effective in keeping up yields than any of the other rotations used.

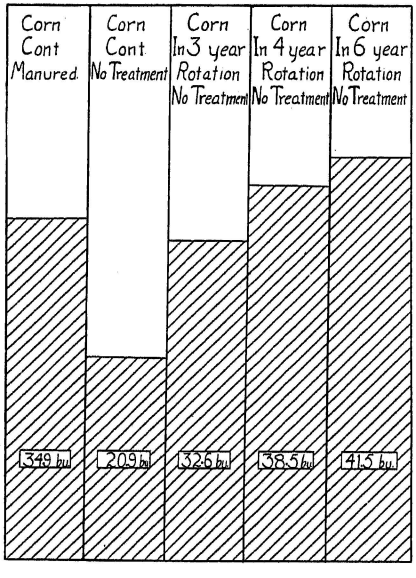


FIG. 1—Thirty-year average yields of corn under different rotations.

This evidence seems conclusive on the value of rotation for keeping up crop yields. If not, there is much other evidence in the experience of successful farmers of this and other countries, particularly in the older countries of Europe and Asia.

It should not be concluded, however, that crop rotation will absolutely maintain yields. It is found in our oldest experiments with crop rotation that after a period of years, even under good rotations, crop yields gradu-

ally but surely run down if all crops are removed and no manure or fertilizers are used. Proper rotation, including legumes and careful handling of manure, will keep up the organic matter and nitrogen in soils, but other factors such as the supply of lime and phosphorus must be taken care of. It is not the purpose of this publication to treat these latter factors.*

EFFECT OF CROP ROTATION ON THE SOIL

At the end of 25 years of cropping on the Rotation Field at Columbia all plots were carefully sampled and the soil analyzed. Little difference was found in the amounts of phosphorus and potassium in the soil of different plots. Very significant differences were found, however, in the nitrogen supply of soils that had been handled with different cropping systems

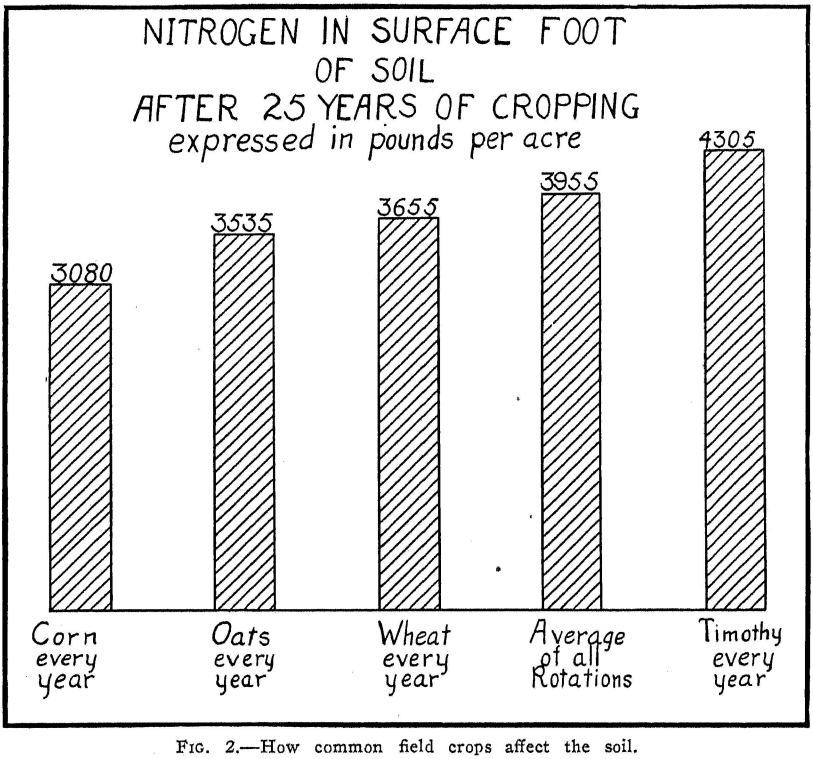


FIG. 2.—How common field crops affect the soil.

for a quarter of a century. The results of these analyses are shown in the diagram (Figure 2). A study of this chart shows how the common field crops vary in their effects upon soil nitrogen. The soil nitrogen is practically all in the organic matter and the chart therefore indicates the relative amounts of organic matter remaining in the soil.

Corn, the only cultivated crop included, is much the most exhaustive of soil nitrogen. This is due mainly to two causes. Corn is a gross feeder

*Write for circular No. 102 on "Keeping Soils Productive."

and uses much nitrogen; but even more important is the fact that corn ground lies bare throughout the season giving every opportunity for leaching and washing. The process of cultivation also hastens decomposition of the organic matter. It does this by repeatedly turning the soil over, stirring air into it and thus hastening oxidation or decomposition.

Wheat and oats are much alike in their drain on the soil nitrogen, being cultivated only when seeded. Wheat plots are shown to contain a little more nitrogen than oats plots, which is probably due to the fact that winter wheat partly covers the ground during the winter and gives less chance for the leaching away of plant food. Plant food as it becomes available is taken up by the growing wheat, part of it remaining in the root system and eventually being returned to the soil. Another factor to consider is the low yield of oats removed from these plots.

It was found impossible to grow clover continuously for 25 years, but timothy was quite successful. When the soil was analyzed timothy plots showed the highest amount of nitrogen of any of the continuous crop plots. It is constantly in sod, thus reducing the loss of nitrogen, by leaching erosion and cultivation. Practically all of the plant food in timothy sod is that taken off in the crop. Surface washing is prevented by the sod absorbing nearly all of the rainfall or at least checking the surface runoff until it runs so slowly as not to carry away the surface soil. It is also true that the sod is always on the ground and living plants take up plant food elements as quickly as they become available.

When the nitrogen content of the two, three, four, and six-year rotation plots is averaged the nitrogen supply is found to be higher than that in any but the continuous sod plots. This is to be expected since the sod crop tends to keep up the nitrogen, but cultivated and small grain crops tend to run it down. The rotation plots therefore occupy an intermediate position. Some sod crop should occur in practically every corn belt rotation.

CROP ROTATION DISTRIBUTES LABOR AND INCOME

The effects of crop rotation in keeping up soil fertility and crop yields are not its only benefits. It is well known that one source of the farmer's trouble in keeping competent help is his inability to make profitable use of the same amount of help throughout the year. Transient help is always unsatisfactory.

The use of a variety of crops in a rotation helps materially in distributing labor evenly over the year. Plowing and preparing wheat ground comes at a period when other crops need little attention. Wheat seeding also comes at a comparatively slack period.

Oats ground is prepared and oats are seeded before the corn planting season is on. Wheat, oats and rye harvests usually come at slightly different periods, though in close succession. Their harvest comes late enough that in average years corn cultivation is well in hand.

A certain labor advantage is to be secured from following clover or grass sod with corn. Corn following sod allows for a greater period over which ground can be plowed and prepared. Sod land can also be worked when

wet with less injury than land which has been under cultivation. As a rule sod land requires less cultivation and labor to keep the corn free of weeds. Continuously cultivated land is usually more foul with bad corn weeds.

OTHER BENEFITS OF ROTATION

Many other advantages of crop rotation may be listed. Weed control is most practical under rotative cropping systems. Buckhorn, major plantain, whitetop, yarrow and wild carrot are quite common in continuous grass land. Crab grass, yellow and green foxtail, cocklebur, bull nettle and morning glory are very troublesome weeds in cultivated and small grain crops. These weeds can most easily be held in check by the systematic alternating of cultivated, small grain and sod crops. Continuous sod also often reaches a sod-bound condition, thus lowering its production due to factors other than soil fertility.

One of the most effective means of control of plant diseases and insect attack is through crop rotation. Corn smut is carried over to the next season through crop residue left on the land. Wireworms and cutworms are more plentiful on land which has been left in sod over long periods.

Another benefit of systematic rotation is that the farm will thus produce a variety of products available at different periods during the growing season. A one-crop system may throw its entire product on a high or low market and thus return either a profit or a loss. Again under a one-crop system, a crop failure results in extremely hard times for the year. A variety of crops, on the other hand, helps to equalize losses on the year's production. A season is seldom equally bad on all crops. On the other hand, history shows that only in rare seasons are corn, oats and wheat equally favored. A large corn crop often follows a fair to poor wheat crop.

ROTATION IS BECOMING MORE COMMON

The farmers of the central states have been slow to adopt crop rotation for several reasons. In the beginning soils were fertile and good crops have been possible without much attention to methods of soil maintenance or improvement. Agricultural practice is still new in this country and it has not been necessary to give much thought to the use of improved methods. Older countries such as those of Europe have found it not only advantageous but practically necessary to adopt such measures as crop rotation. Farming in the central west has been of the extensive type in which large acreages of the most profitable crops are grown.

This condition is rapidly changing. Even our best soils are found to lose some of their native productiveness under careless or unsystematic methods. Gradually it is being learned that some attention to soil maintenance is necessary. Some evidence of this change in attitude is seen in the decreasing numbers of farmers who burn their corn stalks and their straw. One of the cheapest means of improving soil management is the adoption of a suitable crop rotation.

CROPS TO BE INCLUDED IN A ROTATION

If it is decided to adopt a rotation certain principles should be followed. In the discussion of 30 years of field experiments at Columbia it was shown that crops fall into different classes with respect to their effects upon the soil. These groups are known as cultivated crops, small grains and sod crops.

The cultivated crops are, for average conditions, nearly as fundamental as sod crops. They hold in check certain weeds which give much trouble in land left to sod for any great length of time. While cultivated crops are exhaustive upon soil fertility, at the same time they are among the principal money crops. Corn, sorghum, and soybeans comprise the bulk of cultivated crops, grown in this State.

Among the second group oats, wheat, and rye are the principal crops. When land begins to fail, after a year or two of corn growing, one or more

FIG. 2.—(Left) Corn in four-year rotation, 55½ bushels. (Right) Corn every year, 38 bushels. Both plots manured at same rate.

of these crops would logically follow. Wheat and rye are the best nurse crops for clover or grass. They also, being fall sown, will serve as a cover crop to prevent winter leaching and erosion. When these crops are followed with sod crops the land is kept covered at all times until again broken out for corn or other cultivated crop.

The reasons for using wheat or rye as a nurse crop for sod crops are two-fold. A nurse crop keeps weed growth under control, thus preventing the smothering out of the plants during their early period of growth. The second and most important value is in seeding land to grass or clover with no loss of time. On the better soils and in occasional years some returns are secured the same season following the grain harvest.

Sod crops, as a group, are the most important of all from a soil saving and soil building point of view. They include: clovers, alfalfa, timothy and pasture grasses. These crops cover the ground through the winter, reduce

soil washing and fill the soil with masses of roots which later decompose and increase the supply of organic matter. This greatly improves the soil tilth. If the sod crop is also a legume it has the double advantage of adding to the supply of nitrogen in the soil, provided of course, that this nitrogen is not all removed by selling the legume crop as hay. There are various legumes which do not belong to the class of sod crops but which have a value as nitrogen building crops. In this group are soybeans, cowpeas and Canada field peas. They are not so beneficial as clover and alfalfa which belong to both the legume and the sod forming classes.

The well known ability of legumes as nitrogen builders is of course due to the bacteria which they harbor in nodules on their roots. Sometimes these are lacking and must be supplied by means of inoculation. This is only in case of legumes which are new to a particular field or which show by the absence of root nodules that the bacteria are lacking. It is

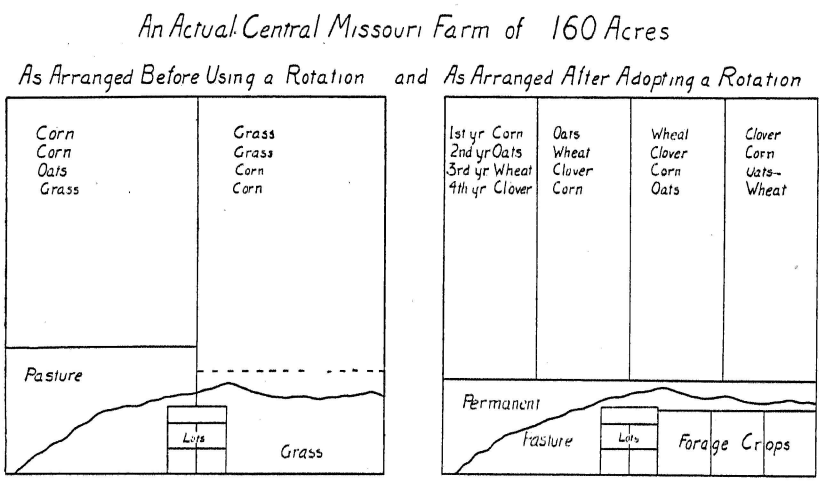


FIG. 4.—Laying out a farm to facilitate crop rotation.

highly important that the farmer provide inoculation if the soil is not inoculated. It can be done at little cost and is too important a matter to neglect.

Any rotation to be satisfactory must include at least one legume. Generally it should contain one or more sod crops as well as a cultivated crop which serves to keep the soil clean. On soils that are rolling or occupy steep slopes, sod crops are more imperative because they are effective in the prevention of soil washing or erosion.

From a business point of view crops are sometimes classified as cash crops, feed crops, and green manure crops. Cash crops are grown for sale as one of the chief sources of income. Wheat or potatoes are usually classified in this group, while corn, soybean seed and clover seed may be so used. Hay is usually classified as a feed crop to be fed on the farm, and corn and oats are frequently fed.

A green manure crop is one grown solely for soil enrichment. It is

therefore not harvested but is plowed under. Such a use of crops is not at all common because producing a crop for manure only is expensive since the cost of seed, work and rental must be charged against it. It is only justified in special cases such as growing a catch crop of cowpeas after wheat, a practice common in southeast Missouri, or rye grown during fall and winter to plow down before a summer crop, or cover crops grown in orchards or the second crop of clover. The use of green manure in such cases is a quick means of increasing the organic matter in soils as it returns much more organic matter than if the crop is fed and the manure returned. Where the green manure crop is a legume, much nitrogen may thus be added. It is usually better however, to grow a greater abundance of feed crops to balance the loss in feeding and gain the profit of feeding as well as the manure for soil enrichment.

METHOD OF HANDLING A CROP ROTATION

There are numerous difficulties involved in establishing and maintaining a crop rotation. The fields on a particular farm are often not laid out so as to fit a rotation. Land varies in its adaptation to clover; wheat may winter kill. Also the market may become very unfavorable to growing a particular crop.

In nearly every community of progressive farmers some will be found who have surmounted these difficulties. Their methods should be studied with a view to making crop rotation more successful.

It is practically necessary that the number and size of fields be adjusted or the crops selected so that there will be as many fields as there are years in the rotation. Where there are a large number of small fields they may be combined into groups, cropping each group as one field. These fields, or groups of fields, should be approximately equal in area, in order to give a steady supply of each crop, omitting seasonal variations which cannot be prevented. This is easy on level farms where all the land is tillable, but on farms which are cut up by ravines, steep slopes, bottoms or woodlands, it usually requires some ingenuity and a close study of the farm's possibilities. Fortunately in the better farming areas such cases are few. There are exceptional cases also where a bottom field has its soil annually renewed by overflow and which is suited best to almost constant cropping with corn. A very high percentage of farms can and should be arranged for systematic crop rotation.

The accompanying diagrams show how farms on which there is considerable rough land may be arranged to accommodate different rotations.

Each farm is an individual problem so far as its arrangement of fields is concerned. It is usually not practicable to move all fences at once and completely reorganize a badly arranged farm. A suitable plan of arrangement should be studied out, however, and adopted as rapidly as possible

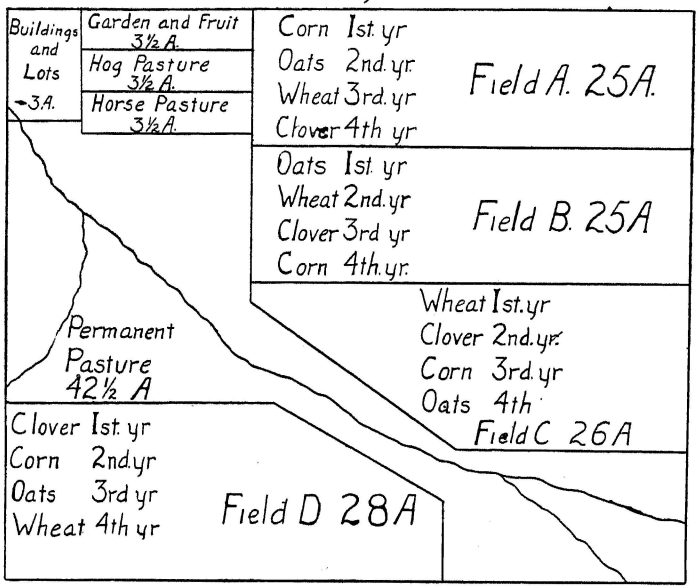
Plan for 160 acre farm that is all tillable and nearly level.

Buildings, Lots, Orchards, etc. 5 Acres.			
Field A	Field B	Field C	Field D
1st. yr Corn	Oats or Soybeans	Wheat	Clover and Timothy
2nd. yr Oats or Soybeans	Wheat	Clover and Timothy	Corn
3rd yr Wheat	Clover and Timothy	Corn	Oats or Soybeans
4th yr Clover and Timothy	Corn	Oats or Soybeans	Wheat

Rotation plan for a 160 acre dairy farm with a major and a minor rotation. Fields A, B, and C for major rotation of corn, oats, and clover Fields D, E, F, and G for minor rotation of forage crops as indicated.

Building and Lots	Field D 8 Acres. Oats and peas in early Spring. Followed by cowpeas, and seeded to rye in fall	Field A 40 acres 1st. yr Corn. 2nd. yr Oats 3rd. yr Clover Repeat after 1923
	Field E 10 Acres. Rye for winter and early spring feed. Followed by soybeans.	
	Field F 10 Acres. Corn with soybeans to be pastured by hogs or used for silage.	
	Field G 10 Acres. Alfalfa to be left for 6 years, and then shifted to Field D.	
Field C 40 acres 1st. yr Clover 2nd. yr. Corn 3rd yr Oats Repeat after 1923		Field B 40 acres 1st yr Oats 2nd. yr Clover 3rd. yr Corn Repeat after 1923

FIG. 5.—Rotation plan for level land.



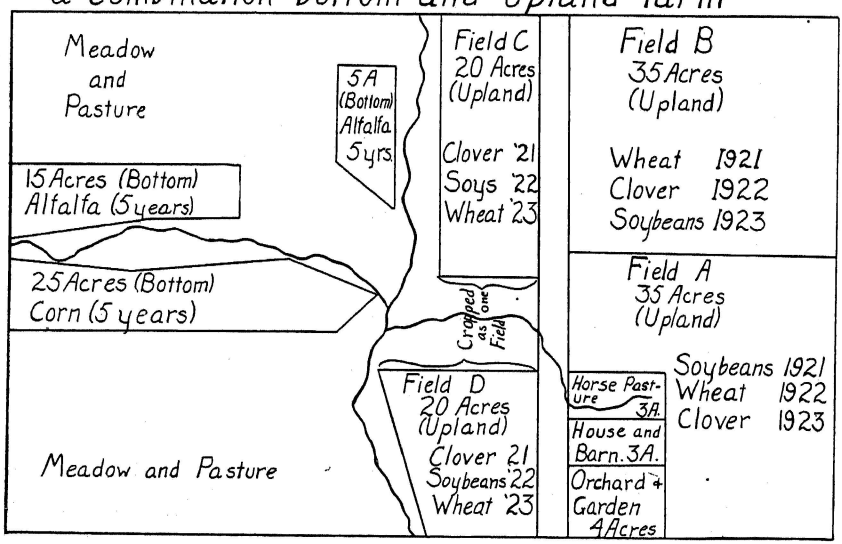


FIG. 6.—Rotation plan for rough land.

SEQUENCE OF CROPS

Following the principles which have been laid down, each farmer should select the crops best suited to the type of farming which he desires to follow. These should then be arranged to follow each other in proper order to get the best results with the least expenditure of labor.

Oats are grown in Missouri mainly because of their low labor costs and in that they pave the way for wheat or grass. It is not the common practice to plow ground for oats. The preparation of the seed-bed and time of seeding come at a period before corn planting.

In cropping systems following corn with oats and wheat in the order named, ground is usually plowed before corn and after oats. Except in the northern one-fourth of the State oats are not, as a rule, a paying crop.

Soybeans work well in a cropping system, replacing oats. They may replace the oats crop entirely or only in part as best suited to the individual farm. Where soybeans are thus used no more plowings are required than for oats. Ground is plowed before corn and again before soybeans. Wheat is seeded on the soybean stubble without plowing. On average land where both clean and level cultivation of soybeans is practiced, an ideal seed bed is automatically prepared for wheat. Double disking and harrowing soybean stubble is the only preparation required.

The most common cultivated crop is corn and it will have a place in nearly all of the rotations selected by Missouri farmers, but in special locations soybeans may be the cultivated crop.

The cultivated crop leaves a good seed bed for a small grain crop. Often two crops of small grain are grown in succession.

The small grain offers suitable conditions for seeding grasses. Timothy is often seeded in wheat or rye in the fall, while seeding the wheat, or seeded with clover in the spring on the same field. This gives two chances for a successful stand of hay. If both succeed, the clover makes up the bulk of the first year's hay crop, but timothy largely replaces it in the second and succeeding crops. After one to three seasons the sod is plowed and again prepared for the corn or other cultivated crop.

One of the chief difficulties in maintaining a regular order of cropping is the failure of certain crops of the rotation. It is a rather common practice to replace any unsuccessful crop with corn and start a new round of the rotation, but this gives a larger acreage of corn than is beneficial to the soil and starts two fields at the same point in the rotation thus breaking up the system. These crop failures should be provided for in the plan by substituting a similar crop for one that fails. If wheat winter kills oats may be substituted. If clover fails when seeded with timothy the latter crop may be left as the sod crop. If clover fails when seeded alone or if clover and timothy both fail, the next best possibility is the substitution of a legume crop usually soybeans or cowpeas. Such a plan does not disarrange the rotation. Good farming will prevent many crop failures, but when unavoidable failures come the field should be brought around to bearing its proper crop in the prearranged plan as soon as possible. The use of lime and phosphates will reduce the number of clover failures.

Many farmers do not attempt to follow any regular systematic rota-

tion but change from one crop to another as their immediate judgment dictates. This method loses some of the advantages of a more farsighted plan, however, because the proportion of legume and sod crops is often not kept clearly in mind and there is always a temptation to choose more corn or other soil wasting crops because the immediate profit is frequently greater. The excessive use of grain crops although likely to swell the immediate gains is at the expense of soil fertility and eventually tells in reduced yields. Without a prearranged plan most farm operators will not always follow their own best farsighted judgment.

CROP ROTATION ON RENTED FARMS

Lack of any cropping system is most common on rented farms because the man who rents on the usual short time lease cannot be expected to have any interest in the farm beyond the term of his own contract. He ordinarily puts in a larger proportion of grain crops than is justified on the best of soils because this serves his immediate purpose best and he has no other interest in the particular farm. The landowner and not the tenant is to blame. Many landowners attempt to protect their soil by stating the amount of grass to be sown each year, but this is often done in a half-hearted manner and is not sufficient protection. Often the landowner, in his desire for immediate profits is as shortsighted as the short-time tenant. If he really desires to protect his property, however, the lease should be so exact as to specify the cropping system to be followed on each field each season. It is possible to include a diagram of the farm on which each field is represented and the crop to be grown each year is specified. In the long run this would benefit both tenant and owner.

ROTATIONS FOR THE BEST MISSOURI UPLANDS

The chief area included in this group is the large district of rolling black prairie soils in northwest Missouri. The more level and better areas in the north central part of the state are also included as well as the black prairie soils lying east and south of Kansas City.

These are districts of fertile soils and extensive farming. The very fertility of their soils has often operated against the soil saving practice of systematic crop rotation. To preserve their present standing in crop production, however, much more attention must be given to soil maintenance. No soil is so good that it will maintain itself against the ravages of careless cropping.

Partial List of Crops Suited to the Best Uplands.

Cultivated Crops	Sod Crops
Corn	Red clover
Soybeans	Alsike clover
Potatoes	Alfalfa
Tobacco	Timothy
Sorghum	Bluegrass

Small Grains	Annual Legumes not Included in Sod Crops
Wheat	Soybeans
Oats	Cowpeas
Barley	Canada Field Peas
Rye	

These crops may be combined in rotations to suit various types of farming such as dairy, livestock, grain, or mixed farming. They should be combined according to the principles previously set forth. Where oats are included before wheat in these rotations soybeans may be substituted. The soybean is a more valuable crop and is conveniently followed by wheat. If grown for seed, however, the crop requires labor at the same time that corn is needing cultivation which does not make a good distribution of labor.

Alfalfa is not commonly included because it is unsuited to short time rotations. The expense of seeding and the value of the crop make it advisable to leave a stand of alfalfa at least five years or as long as it is

FIG. 7.—An old, standard three-year rotation.

good. Where alfalfa is grown an extra field should be provided for it. When ready to plow up alfalfa a new stand may be seeded on one of the other fields and the alfalfa field taken into the rotation.

Where potatoes, tobacco or other cultivated crops are grown they may be substituted for part of the corn, following the sod crop.

Suggested Rotations for Best Missouri Uplands.—Rotation No. 1 for general farming: 1. corn, 2. oats, 3. clover.

This three-year rotation is an old standard one proved by long experience. It is well balanced and simple to maintain being suited to farms having either three or six fields. It keeps one-third of the land in corn, which is enough for even the best of soils unless more than ordinary care is given to manuring and fertilizing. One-third of the land is kept in a legume-sod crop. Labor is well distributed, only one-third of the land being plowed each year. Even this rotation will not maintain the soil

unless the manure, stalks, straw, etc., are returned to the soil. This rotation has the one objection of using oats as a nurse crop for clover. Oats shade the ground heavily and are harvested rather late. Early oats make a better nurse crop than late oats.

Rotation No. 2 for general or grain farming: 1. corn, 2. wheat, 3. clover.

This rotation has the same advantages as No. 1 except that it is more difficult to sow wheat after corn than to sow oats. It is especially well adapted to farms where corn is cut and shocked or used for ensilage.

Rotation No. 3 for general farming: 1. corn, 2. corn, 3. oats, 4. wheat, 5. clover.

This rotation increases the amount of corn to two fifths of the farm and to maintain the soil, much care must be given to putting back, manure, stalks, straw, etc.

Rotation No. 4 for the larger stock farms: 1. corn, 2. corn, 3. oats, 4. clover and timothy, 5. clover and timothy.

This gives an abundance of corn and hay as well as oats and oat straw. Where timothy is seeded with clover the chances of getting a stand of hay are increased. In this system timothy and clover are seeded in the oats in the spring. Wheat may be used instead of oats.

Rotation No. 5 for grain farming: 1. corn, 2. soybeans for seed, 3. wheat, 4. clover for seed.

This is a good rotation in that it keeps a legume on the land most of the time and includes a sod crop. For a strictly grain system where little manure is provided, wheat and soybean straw as well as clover chaff and corn stalks must be returned to the soil if the soil is safely kept up. The soybeans and corn compete for labor but this includes only half of the farm in cultivated crops. Wheat follows soybeans most advantageously. Sufficient clover should be cut to supply hay for the stock necessary even on a grain farm.

This rotation may be used for mixed farming where all roughage and part of the grain is fed, if the manure is then taken care of. In this case part or all of the clover may be cut for hay.

ROTATIONS FOR THE LEVEL PRAIRIES

The level prairies of Missouri are chiefly in the northeast and southwest sections of the state. They vary from undulating to level plains where drainage is sometimes a problem. Most of these soils are sour and will not grow red clover satisfactorily until the soil has been limed.* The clay subsoils under these prairies are often rather compact and impervious.

Timothy and wheat are among the best adapted crops and are widely grown. There is at present a very serious lack of legume crops on these prairies and the soils are usually not being well maintained. Lime should be used and clover seeded. In the southwest Missouri prairies, periods of dry weather offer an additional problem in the way of growing clover. Alsike clover withstands wet conditions better than red or sweet clover.

*Write to the Missouri Experiment Station for Bulletin 171 on Liming.

Where clover is used in the following rotations it is understood therefore that alsike clover may well be used where drainage is poor.

None of the clovers can be considered a dependable crop on sour soils and it will often be necessary to use lime before any of them can be grown. Where liming can not be done immediately a temporary rotation of crops suited to sour soils may be used, but in most cases it is advisable to use lime as soon as possible, and then adopt a rotation containing one of the clovers. Where clover is uncertain it is advisable to mix timothy and clover, thus increasing the chances for a stand of hay and for a sod crop. Timothy is usually seeded in the fall, either in wheat or rye or alone. The clovers are all seeded in the spring.

In Southwest Missouri the grain sorghums, such as kafir, milo, and feterita may well be used instead of corn in some cases. They are cultivated crops and occupy the same place in the rotation. Where grain sorghum is grown in place of corn* the kafirs are to be preferred over all other varieties. They may therefore be substituted freely in the following rotations where corn is included.

Partial List of Crops for the Level Prairies:

Cultivated crops

- Corn
- Soybeans
- Kafir
- Sweet sorghum

Sod crops

- Timothy
- Red clover
- Alsike clover
- Sweet clover
- Redtop
- Bluegrass

Small grains

- Wheat
- Oats
- Rye

Annual legumes not included in sod crops.

- Soybeans
- Cowpeas

Suggested Rotations for Level Prairies—Rotation No. 1 for large stock farms: 1. corn, 2. corn, 3. oats, 4. wheat, 5. clover and timothy, 6. clover and timothy.

This is a well balanced rotation for soil upkeep and distribution of labor. The crops follow each other conveniently. Soils of the level prairies should never have corn on them more than a third of the time unless in cases of emergency. This rotation requires six fields and is therefore not so well suited to small farms.

Rotation No. 2 for large stock or general farms: 1. corn, 2. corn, 3. soybeans, 4. wheat, 5. clover and timothy, 6. clover and timothy.

This is the same rotation as No. 1 except that soybeans replace oats. It has the same advantages except that it is even better for the soil by having an additional legume crop. The soybean is a better crop than oats, but requires a little more labor.

*Write for the Missouri Experiment Station Bulletin No. 185, "Corn in Missouri."

Rotation No. 3 for stock farms: 1. corn, 2. oats, 3. clover and timothy, 4. clover and timothy.

This is a good soil-maintaining rotation since it keeps the soil covered with a crop for over half of the time. It gives only one-fourth of the farm to corn, which reduces labor but does not give as much corn as some feeders may require. By plowing up the sod after the first hay crop this rotation may be reduced to three years and adapted to a three field farm. Rye may be drilled in the corn for fall and winter pasture but the land will then need plowing for oats.

Rotation No. 4 for general farms: 1. corn, 2. oats, 3. wheat, 4. clover and timothy.

This is an old standard rotation proved by the experience of many farmers. On a livestock farm all but the wheat and part of the oats should be used for feed and bedding. Oats straw makes good winter roughage, while clover hay, corn and oats provide a fairly well balanced feed supply. The manure thus made will keep the soil in excellent condition if properly used. Soybeans may also be substituted for oats in this rotation.

Rotation No. 5 for sour soils: 1. corn, 2. soybeans or cowpeas, 3. wheat, 4. timothy.

The crops in this rotation will endure a certain amount of sourness in the soil. It is not so good as a rotation with clover in it, however, and it is usually advisable to lime the soil as soon as possible and then mix clover with the timothy. Even without liming it is usually advisable to sow some alsike clover with the timothy since this clover is a little more hardy than red clover. It stands wet land better and the seeding is less expensive.

ROTATIONS FOR THE BETTER ROLLING UPLANDS

This includes the rolling to rather hilly lands where the soils have good depth and fertility, but are subject to erosion if not carefully handled Experiments now being carried on by the Experiment Station show that even on gently rolling lands erosion may cause a large loss of nitrogen from the soil. More than ordinary care is necessary to prevent it. In selecting a rotation for rolling lands, therefore, attention must be given to choosing crops which will cover the land through the winter when erosion is often severe.

Some rolling lands occur throughout the state, but the districts in which they predominate and yet which have good deep soils are North Central Missouri, the river hill belt, chiefly along the Missouri and Mississippi rivers, and the Ozark Border Region. The Ozark Border Region is most extensive in Southwest Missouri, particularly in the Springfield district, but occupies a belt along the west, north, and east sides of the Ozarks. Naturally a great variety of conditions must be met in the various sections of rolling country. Not all of the good crops and good rotations can be given here.

Rolling lands are best suited to livestock or general farming, including dairying as a phase of livestock farming. Fruit growing is also adapted but cannot be included in this discussion. Grain farming is unsuited to the conditions. Limited districts in the river hill or brown loess area, par-

ticularly between St. Joseph and Kansas City grow considerable tobacco. Tobacco may be used as a part of the cultivated crop and substituted for corn in any of the following rotations.

Partial List of Crops for Use on the Better Rolling Upland Soils:

Cultivated crops

- Corn
- Soybeans for seed
- Kafir corn
- Sweet sorghums

Small grains

- Wheat
- Oats
- Rye
- Barley

Sod crops

- Red clover
- Sweet clover
- Alfalfa
- Timothy
- Bluegrass

Annual legumes not included in sod crops.

- Soybeans
- Cowpeas

Alfalfa is suited to the better soils of the rolling districts especially to the river hill lands, the darker colored glacial soils of north central Missouri, and the better soils of the Springfield district. Other areas may grow it by careful methods and the liberal use of limestone and phosphates.

FIG. 8.—A good rotation for sour soil.

Suggested Rotations for Rolling Upland Soils.—Rotation No. 1 for general or stock farms: 1. corn, with rye in fall for winter cover, 2. soybeans, 3. wheat, 4. clover and timothy.

This is a good rotation in which the land is never left bare through the winter. Rye seeded in the corn makes good winter and early spring pasture, but it must be plowed down early, or damage will be done to the following crop of soybeans. It is a more effective cover crop if not pas-

tured too close; neither can it be pastured while the ground is soft, without serious injury to the soil.

Oats may be used in place of soybeans but if rye is used as a cover crop this would require plowing the land for oats, which is usually impractical.

If the soil is sour and can not be limed at once, clover may be omitted from the fourth year until lime can be provided.

Rotation No. 2 for general farms: 1. corn, 2. wheat, 3. clover and timothy.

This is also a well balanced rotation with a crop on the land each winter. It requires but three fields and is therefore suited to small farms. It is, however, difficult to sow wheat in standing corn. The rotation is well suited to stock and dairy farms where the corn is used for silage, or where corn is cut and shocked. The timothy is included as insurance against a failure in securing a sod crop.

Rotation No. 3 for stock farms: 1. corn, with rye cover crop, 2. corn, 3. wheat, 4. clover and timothy, 5. clover and timothy.

This is a well balanced five-year rotation for soil maintenance. Difficulties in seeding rye and wheat in corn are encountered but this is unavoidable if corn ground is not to be left bare through the winter. It necessitates cutting the corn or seeding between the rows.

Rotation No. 4. for livestock farms: 1. corn, 2. rye for pasture, 3. clover or clover and timothy.

This rotation furnishes corn as the only grain, but gives an abundance of roughage especially if the corn is cut for silage, or shock corn. Rye may also be used for grain. It is hardy, matures early and does not shade the ground as much, which gives the clover a good chance.

Rotation No. 4 for general farm with part fertile bottom land and part upland soil: For bottom land, alfalfa 5 years, corn 5 years; for upland, 1. soybeans, 2. rye, 3. timothy and clover.

With this plan all corn is grown in the bottom, where half the area is kept in corn and the other half in alfalfa. This keeps corn on the same field longer than is usually advisable, but if it is kept in corn only half the time, and manured, bottom soil will be kept in a very satisfactory state of fertility. It is not feasible to reseed alfalfa more often than once in 4 or 5 years.

With no corn on the upland this arrangement provides soybeans for a cash crop, and rye may be either sold or fed. The upland soil is thus covered each winter, and an abundance of feed is provided.

ROTATIONS FOR THE POOR ROLLING UPLANDS

Limited areas of rather poor hilly upland soils occur at various places over the state. They are usually intermingled with areas of better soils. As a class they are inclined to be shallow, unproductive, and subject to severe erosion, if left unprotected. There is a higher percentage of such lands in the Ozark Region than in other districts.

The chief problem on lands of this character is the prevention of erosion. Much of it is best left in pasture, which is the greatest means of

avoiding erosion. Where not too steep farming is profitably done if care is used in selection of crops and methods of soil management. The soil should not be left bare over winter, and the acreage of cultivated crops must be kept down to the minimum. Farming should be done across the slope rather than up and down it. In some cases terracing is advisable.[1]

These areas of rolling lands have excessive drainage, and frequently suffer from drought. It is therefore best to select crops which withstand spells of dry weather well. In the Ozark uplands it has been found that the grain sorghums will yield more bushels of grain than will corn under the same circumstances. Their use in place of corn for either grain or silage is strongly recommended.[2] Rye which is hardy, early maturing and drought-resistant may be used instead of wheat in many instances.

Much of the poor rolling land is sour even though it may have been derived from limestone. Slopes lying below limestone outcrops are usually not sour because lime constantly washes down into them. Where the soil is sour, lime should be provided before much success is likely to be attained with the clovers.

Only livestock or fruit farming should be attempted on these lands. Just enough grain should be grown for use as feed, except that wheat or rye may often be sold.

Over this section soybeans and cowpeas should be grown. They are drought-resistant, are well adapted to slightly sour soils, and have the ability to make fair returns on thin soils. They are well adapted to growing for either seed or hay. As a cash crop for seed they are more profitable than corn over much of the section, and are not so hard on the soil.

Crops That May Be Grown on the Poor Rolling Uplands:

Cultivated crops

- Corn
- Kafir or other grain sorghums
- Sweet sorghums
- Soybeans for seed
- Cowpeas for seed

Small grains

- Wheat
- Rye
- Oats
- Millet

Sod crops

- Timothy
- Orchard grass
- Bluegrass
- Lespedeza or Japan clover
- Red clover

Annual legumes not included in sod crops

- Soybeans
- Cowpeas

Suggested rotations for poor upland soils.—Rotation No. 1 for general farming: 1. corn or grain sorghum, 2. rye or wheat, 3. timothy and clover, 4. timothy and clover.

This plan keeps the soil covered every winter and in sod more than half of the time. It will supply much forage and a fair supply of grain. If rye is used it may be ground with corn or grain sorghum for feed, thus

[1]Write for Experiment Station Circular No. 98 on The Mangum Terrace.
[2]Write for Experiment Station Bulletin No. 185 on Corn in Missouri.

providing for a strictly livestock system of farming. If the manure is properly handled this makes an excellent system for soil maintenance.

Rotation No. 2 for general farming: 1. corn or grain sorghum, with rye in fall, 2. soybeans or cowpeas, 3. wheat or rye, 4. clover and timothy, 5. clover and timothy.

This also provides winter cover, an abundance of legumes, to build up nitrogen, and a good acreage of sod crops. It provides for seeding wheat or rye after soybeans or cowpeas, which is often preferred to seeding after corn.

Rotation No. 3 for grain farming: 1. wheat, 2. wheat or rye, 3. clover and timothy.

On thin, eroded areas where a cultivated crop is not desired this plan may be used. If rye is used as one of the grain crops it will give a smaller chance of loss from a bad wheat season. Timothy is added as an insurance against a sod crop failure.

ROTATIONS FOR THE BEST BOTTOM SOILS

Lands of this character are found all along the bottoms of the Missouri and Mississippi rivers. There are also small areas along many smaller streams. The most extensive area is the large lowland region of southeastern Missouri. The most productive bottom soils are included, from those containing some sand but not enough to be harmful, to those that are too heavy to be farmed easily.

These soils are capable of producing corn more of the time than the upland soils, but this fact is realized too well, and in many cases corn is grown almost continuously. No soil will stand continuous corn production, however, with the possible exception of soils which are overflowed frequently. It is at least probable that no farm should have more than three-fifths of its area in corn if the soil is to be permanently maintained. It is much easier and cheaper, in the end, to keep a soil in a high state of productiveness than to build it up if it is once permitted to run down. Soils of this group need little besides a good rotation and proper use of manure and crop residues to keep them productive.

Alfalfa is better suited to the best bottom lands, where drainage is good, than to any other group of soils in the State. It does not lend itself to use in short time rotations, but after providing fields for a rotation an extra field should be set aside for alfalfa. When the stand finally fails or it is desired for any reason to plow it up, this extra field may be taken into the rotation and one of the rotation fields used for alfalfa.

Where potatoes are grown extensively they may be substituted for corn in these rotations. Wheat is a good crop to follow potatoes.

Crops Suited to the Best Bottom Soils:

Cultivated crops	Sod crops
Corn	Alfalfa
Potatoes	Red clover
Soybeans for seed	Alsike clover
	Timothy
	Bluegrass

Small grains	Annual legumes not included in sod crops
Wheat	Soybeans
Oats	Cowpeas
Barley	

Suggested rotations for the best bottom soils.—Rotation No. 1 for general farming: 1. corn, 2. corn, 3. oats or wheat, 4. clover.

This rotation gives half of the farm to corn and the clover crop combines the sod and legume crops necessary to a satisfactory rotation. Corn may be followed by oats better than by wheat. Early oats should be used since they make a better nurse crop.

Rotation No. 2 for general farming: 1. corn, 2. corn, 3. corn, 4. oats or wheat, 5. clover and timothy, 6. clover and timothy.

On large farms where six fields can be provided this is a good rotation. Under exceptional conditions, including a very fertile soil and exceptional care in returning manure, straw and other crop residues, the clover and timothy may be plowed up after one year, but it is doubtful whether such a practice can maintain productiveness unless considerable feed is bought, to make more manure, and nearly all of the corn is fed.

Rotation No. 3 for general farming: 1. corn, 2. corn, 3. corn, 4. soybeans, 5. wheat, 6. clover.

This is an exceptionally good rotation on strong soils where sufficient labor can be provided to take care of cultivating so much corn and soybeans. Less labor is required if oats be substituted for the soybeans, but the crop is not so valuable either for profit or soil maintenance.

ROTATIONS FOR SANDY BOTTOM SOILS

There are considerable areas of sandy soils in the bottomlands of nearly all streams. A small part of this acreage is too sandy for profitable cropping. Most of the area is fertile but needs more care than the silty soils, if its fertility is to be preserved.

Sandy soils are exceedingly well suited to legume crops, once they are established. The open character of these soils is favorable to the deep root systems of legumes, and nitrogen fixing bacteria on legume roots grow abundantly in an open soil. This is fortunate because open sandy soils lose their organic matter and nitrogen rapidly on account of the free air circulation and rapid decay in such soils.

The chief difficulty involved is in the seeding of clover and alfalfa. Sandy soils dry out quickly on the surface and small seeded crops of this type may be killed out before their roots become established deeply enough to draw moisture from lower levels. If the surface soil is kept well filled with organic matter as manure, straw, stalks, etc., this drying out process is largely avoided.

Some sandy soils are also found to contain too little lime for clover and alfalfa, but their most serious deficiency is in the supply of organic matter.

Cowpeas and soybeans are easy to establish and exceedingly well adapted to sandy soils. The best soybean and cowpea lands of the state are the sandy soils of southeastern Missouri. Special crops such as melons

and early potatoes are grown to considerable extent on certain sandy soils of the state. Several counties of southeastern Missouri also grow considerable areas of cotton. These cultivated crops may be interchanged with corn in the following rotations.

Crops Suited to Sandy Bottom Soils:

Cultivated crops

- Corn
- Soybeans
- Cotton
- Melons
- Potatoes

Sod crops

- Red clover
- Mammoth clover
- Alfalfa
- Alsike clover

Small grains

- Wheat
- Oats
- Rye

Annual legumes not included in sod crops

- Soybeans
- Cowpeas
- Vetches
- Velvet beans

Suggested rotations for sandy bottom soils.—Rotation No. 1 for general farming: 1. corn, 2. soybeans, 3. wheat, with cowpeas seeded in stubble.

With the soybeans grown for seed this rotation yields a seed or grain crop every year; but to maintain the soil soybean and cowpea straw must

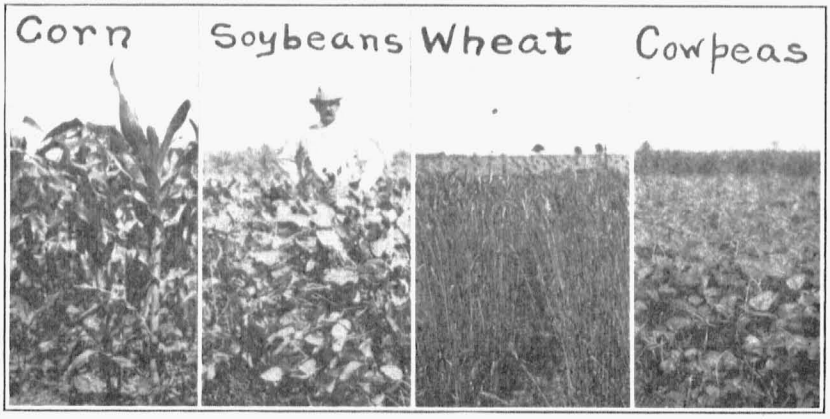


FIG. 9.—Sandy soil rotation for Southeast Missouri.

be returned to the soil either by spreading back on the fields or by feeding and saving all manure. The cowpeas may be pastured. Soybeans or cowpeas may also be seeded in the corn and both pastured down. All wheat straw should be returned either as straw or bedding.

Rotation No. 2 for general farming: 1. corn, 2. soybeans, 3. wheat, 4. clover or cowpeas.

This rotation is good for those areas which are not too sandy to get clover started.

Rotation No. 3 for general farming: 1. cotton, and rye, 2. cowpeas, 3. corn and rye, 4. cowpeas.

This plan includes rye seeded in both corn and cotton crops to be used as winter pasture and plowed under for organic matter in the spring. As much cowpea straw or manure should be returned as possible.

ROTATIONS FOR GRAY BOTTOM SOILS

Gray bottom soils occur in limited areas throughout the state, but are most extensive in the western part of the lowland area of southeastern Missouri. They were formed under conditions of poor drainage or are very old soils that have been subjected to much leaching. They usually have rather heavy, compact subsoils, and consequently under drainage and aeration may be insufficient. Most of these soils were originally timbered

Corn, wheat, cowpeas and timothy are adapted to these soils. In general they need lime before clover does well on them. Where well cultivated, corn is a fair to good crop. The use of lime, followed by alsike clover, will do much for these soils. Rice is grown successfully on certain soils of this group in southeastern Missouri.

Crops Suited to the Gray Bottom Soils:

Cultivated crops

- Corn
- Soybeans

Sod crops

- Timothy
- Redtop
- Bluegrass
- Alsike clover
- Red clover
- Lespedeza or Japanese clover

Small grains

- Wheat
- Oats
- Rye
- Rice (in some cases)

Annual legumes not included in sod crops

- Soybeans
- Cowpeas

Suggested rotations for gray bottom soils.—Rotation No. 1 for general farming: 1. corn, 2. wheat, 3. timothy and alsike clover.

This rotation is well balanced and suited to the soil. It is very good if arrangement is made for seeding wheat on corn ground. Oats or rye may be used instead of wheat. If desired the timothy and clover may be left for two years, making a four year rotation, which is highly beneficial to the soil.

Rotation No. 2 for general farming: 1. corn, 2. cowpeas, 3. wheat, 4. timothy and alsike clover.

This is an easier rotation to maintain since cowpeas follow corn more easily than does wheat. It may also be extended by leaving the timothy and clover for another year.

Rotation No. 3 for rice farming: 1. rice, 2. rice, 3. soybeans cultivated for seed.

This use of cultivated legume crop in rice growing aids in cleaning out red rice and weeds as well as in adding some nitrogen to the soil.

ROTATIONS FOR GUMBO BOTTOMS

Soils of this class are inherently fertile, but difficult to handle. Drainage is usually poor and plowing difficult. The amount of work necessary in the spring when gumbo soils are wet must be reduced to the minimum. Fall plowing is advisable and erosion is not a problem.

Under conditions of poor drainage the best crops are wheat, timothy, alsike clover and corn. With improved drainage alfalfa and red clover are good crops and corn is greatly improved.

Gumbo is difficult to plow if not in just the right moisture condition. It is therefore highly desirable to have large plowing equipment to plow rapidly when conditions are favorable.

Crops Suited to Gumbo Soils:

Cultivated crops

- Corn
- Soybeans

Sod crops

- Timothy
- Alsike clover
- Red clover
- Alfalfa
- Bluegrass

Small grains

- Wheat
- Oats
- Barley

Annual legumes not included in sod crops

- Soybeans
- Cowpeas

Rotation No. 1 for general farming: 1. corn, 2. corn, 3. wheat, 4. timothy and alsike clover, 5. timothy and alsike clover.

This gives a good balance of crops for soil maintenance and is good where half of the corn can be cut. Where no corn is cut oats may be used instead of wheat, but oats are difficult to seed on gumbo because it is too wet during the oats sowing season. They usually lodge badly also.

Rotation No. 2 for general farming: 1. corn, 2. wheat, 3. wheat, 4. timothy and alsike clover, 5. timothy and alsike clover.

This gives a greater acreage of wheat and reduces the amount of ground necessary to be worked in the spring.

Rotation No. 3 for general farming: 1. corn, 2. soybeans, 3. wheat, 4. timothy and alsike clover, 5. timothy and alsike clover.

This plan combines crops that follow each other easily. By using an early variety of soybeans they may be seeded later than corn after the soil has dried out to some extent.

ROTATION THE FIRST STEP IN ESTABLISHING SYSTEMS OF PERMANENT FERTILITY

Not all the crops that may be grown in each locality have been treated here, nor have all the possible good combinations been arranged, but sufficient principles and examples have been given to enable anyone interested in special combinations of crops to devise a plan suited to his special conditions and needs.

There is great need for improved systems of cropping over most of the state; especially is there a need for a more general use of legume crops particularly red clover.

FIG. 10.—A good rotation for any part of the State.

Rotation alone will not maintain soils but is probably the greatest factor in most practical systems of soil management, and when supplemented with proper use of manures, lime, and phosphates, complete, profitable, and permanent systems of soil maintenance may be evolved, to the great benefit of the individual and following generations.