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Relation of Temperature and Rainfall to Crop Systems and Production

University of Tennessee Agricultural Experiment Station

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BY

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KNOXVILLE, TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University, on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

RELATION OF TEMPERATURE AND RAINFALL TO CROP SYSTEMS AND PRODUCTION

This study began with an effort to discover whether there was any climatic reason why Tennessee should not produce as many bushels of corn per acre as any other state. In the charting of the rainfall for the different seasons the necessity for a winter cover crop to prevent erosion and leaching was very clearly brought out. This led to the consideration of the double-cropping system as a source of humus and as a means for conserving our soil, our rainfall, and our heat, and thus largely increasing our crops.

We are entering an era of scientific farming. Experiment stations are at work all over the country testing this, that, or the other crop and working out rotations and systems of cropping that will be more profitable than the old methods. The reports of this work go broadcast over the whole country. An enterprising farmer may get reports from a dozen different stations each working under climatic conditions different from those of the others and all different from the conditions to which he himself is subject. Not a single one says a word about length of growing season, temperature, or distribution or amount of rainfall, and the farmer will not think of these things. He chooses from the dozen the plan that looks the most practical for him and tries it. He makes a failure and loses confidence in that particular station. He tries another with the same result and probably loses faith in all experiment stations. Had he realized the great part that climate plays in any cropping system and the great differences to be found between the climates of different sections of this broad country he would have tried the plan of the station working under conditions most nearly approaching his own and would in all probability have succeeded.

For the most effective and economical application of the results obtained by the experiment stations to the needs of the farmer a knowledge of climate is necessary. For forty years the Weather Bureau of the U. S. Department of Agriculture has been gathering data and publishing them in various forms until now there is no necessity for anyone to spend time experimenting with different systems of cropping in order to learn which is best suited to his climate.

The climatic data used in this bulletin were obtained wholly from published records of the U. S. Weather Bureau and it is hoped that this study may be of use not only as one means of extending this most valuable system of cropping but also as an illustration of the value of weather records as an aid in the practical application of the results of experiment station work to the needs of the farmer.

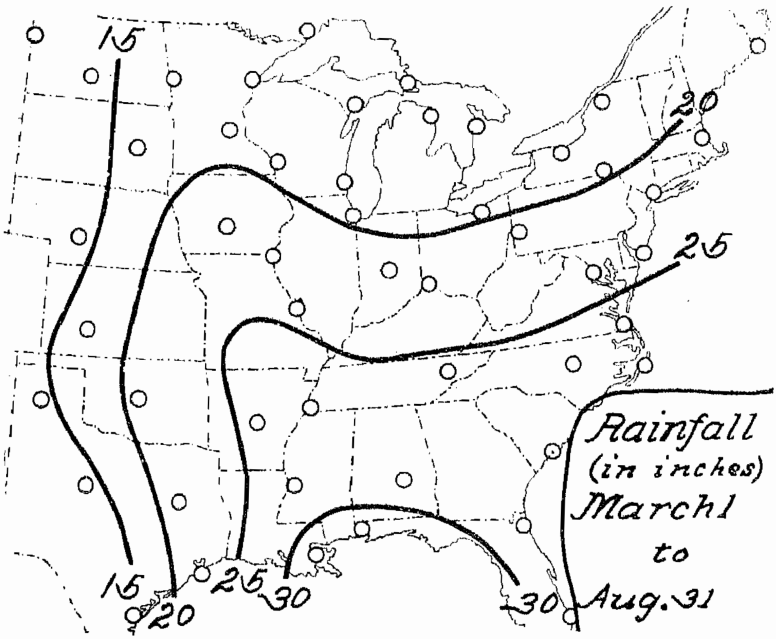


CHART 1—AVERAGE RAINFALL IN INCHES FOR THE SIX MONTHS MARCH 1 TO AUGUST 31

Chart 1 shows the average number of inches of rainfall during the six months from March 1 to August 31 for that portion of the United States east of the Rocky Mountains. Note the steady decrease from the east Gulf Coast to the North and West. The section east of the Mississippi River and south of Kentucky and Virginia is much better supplied with rain during the corn-growing season than the section commonly known as the corn belt.

Chart 2 shows the average number of days in the growing season, or the period between the last killing frost in the spring and the first killing frost in the fall. The states south of Kentucky and Virginia have an advantage of from 25 to 75 days over the states north of the Ohio River. This not only gives more time for the crop to grow but gives more leeway at planting time and a better opportunity to get the seedbed in the best condition. Tennessee has a growing season about 25 days longer than the average for Illinois.

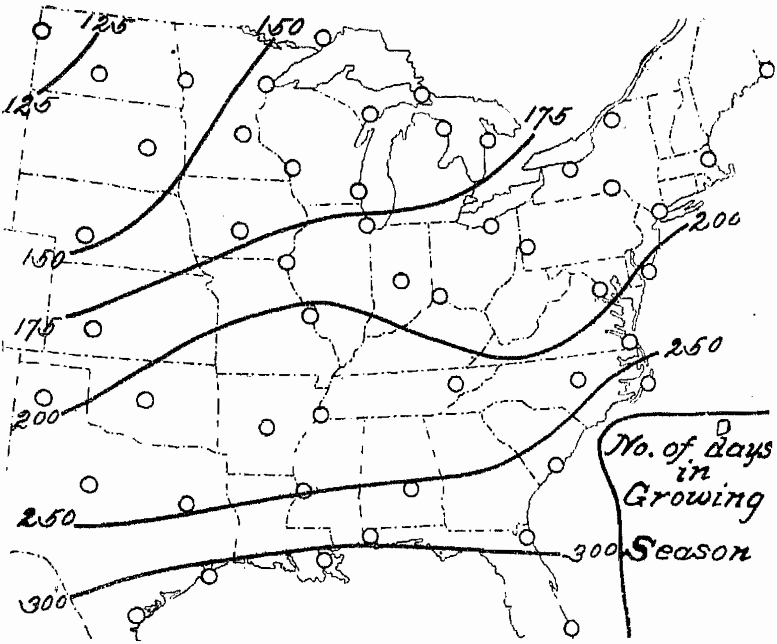


CHART 2—AVERAGE LENGTH OF GROWING SEASON, OR NUMBER OF DAYS BETWEEN THE LAST KILLING FROST IN THE SPRING AND THE FIRST KILLING FROST IN THE FALL

Chart 3 is a comparison between the corn crop and the July rainfall in Tennessee. The solid line represents the average corn crop for the State for 15 years, in bushels per acre, as shown by the figures in the lefthand margin. The years, 1894 to 1908, are shown by figures at the top of the chart. The broken line represents the average rainfall for the State for July of each year, in inches, as shown by the figures in the righthand margin. It will at once be noticed that there is a great similarity between the two lines. When July is wet the corn crop is large and when July is dry the corn crop is small. In like manner the rainfall for each month of the year was charted and compared with the yield of corn, but no other month was found in which the fluctuations of rainfall corresponded with the fluctuations of the corn crop.

Since July is the month when most of the corn in Tennessee tassels we may fairly conclude that the amount of moisture available at tasseling time is one of the principal factors controlling the size

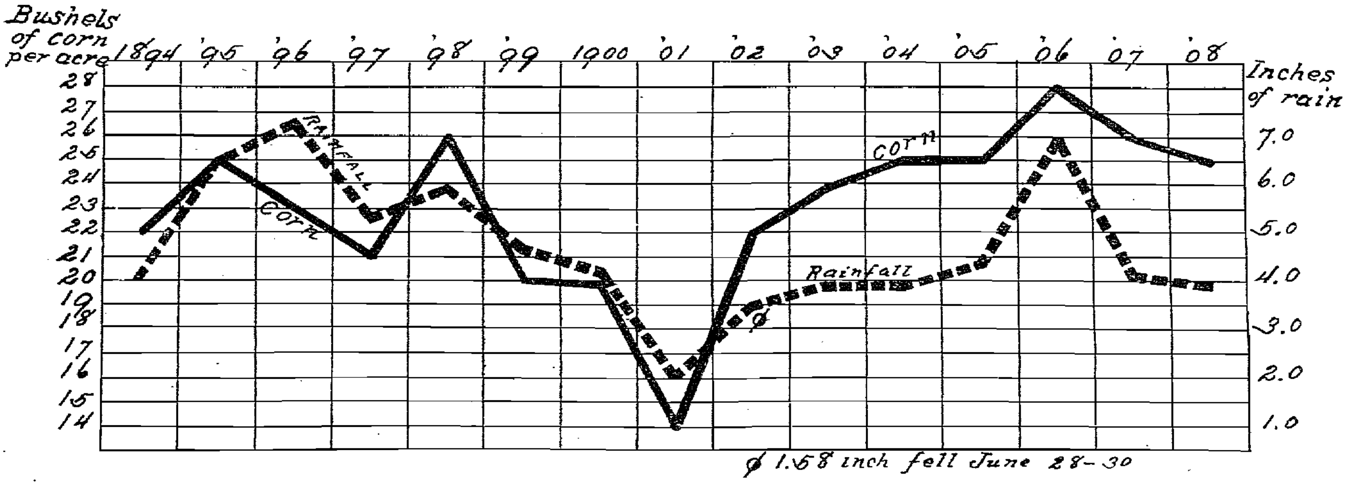


CHART 3—COMPARISON BETWEEN THE CORN CROP OF TENNESSEE, IN BUSHELS PER ACRE, AND THE JULY RAINFALL, FOR 15 YEARS

Solid line represents corn crop

Broken line represents rainfall

of the corn crop. From Tennessee northward and westward the corn all tassels during the months of July and August. Since the crop is largely dependent upon the moisture available during tasseling time, July and August are the critical months, and we must consider the

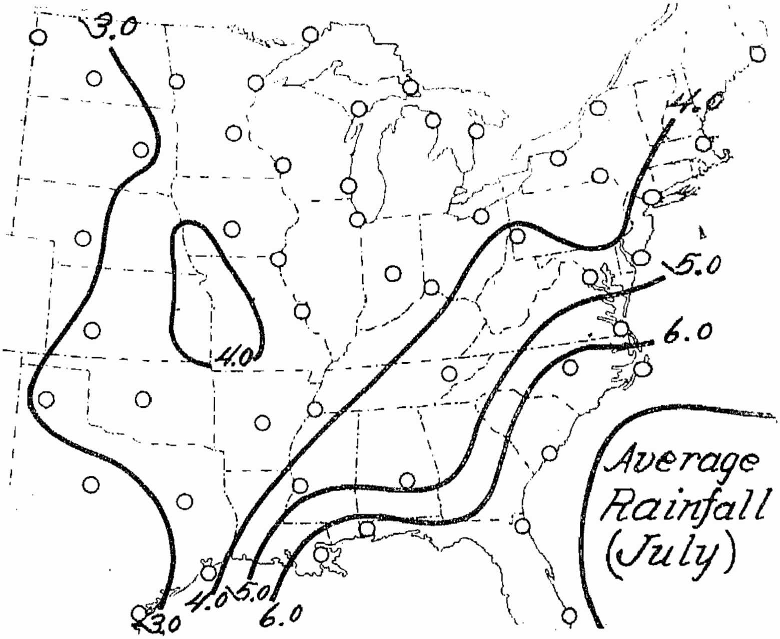


CHART 4—AVERAGE RAINFALL FOR JULY IN INCHES

rainfall for that period in any comparison we make. Charts 4 and 5 represent the average rainfall for July and August, respectively, for the region under discussion. They show that Tennessee has a greater rainfall in July (her critical period) than the states north and west of her have in either July or August. In this respect, then, her opportunity for producing a large crop of corn is greater than that of these other states.

Another important factor upon which the amount of moisture available for the crop at tasseling time depends is the water from the earlier rains that may be retained in the soil by proper methods of cultivation. Chart 7 shows the average rainfall for the three months December, January, and February. Central Mississippi and Alabama have the greatest amount, over 15 inches, while the entire Southeastern section has 12 inches or more. Over the Ohio and upper Mississippi Valleys the rainfall for these three months is from 3 to 9 inches only. Here again Tennessee has a great opportunity for increasing the amount of available moisture at tasseling time by conserving the heavy winter rainfall. The opportunity south and east of Tennessee is even greater.

King in his "Irrigation and Drainage" describes some careful experiments made to determine the amount of rainfall necessary to

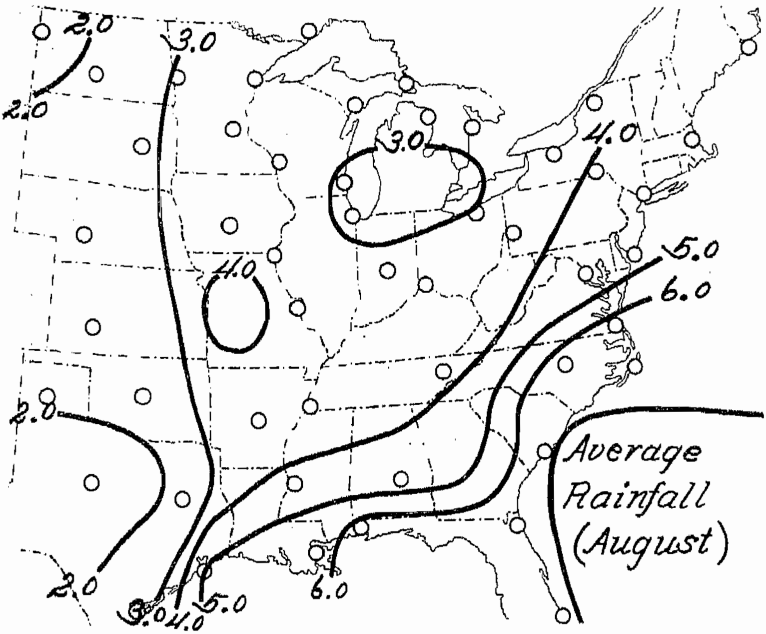


CHART 5—AVERAGE RAINFALL FOR AUGUST IN INCHES

produce a certain yield of corn. In 13 Northeastern and North Central states having an average rainfall of about 15 inches during the corn-growing season he estimates that after deducting a certain amount for loss by percolation and from light showers the average effective rainfall is about 12 inches. His experiments show that this rainfall, if it came in the right amounts and at the right time for greatest efficiency, would be enough to supply the necessary moisture for a crop of over 70 bushels of corn per acre. In actual practice the average yield for these 13 states is about 30 bushels per acre, or less than one-half of the calculated amount. King rightly ascribes this great difference to the fact that the rainfall is seldom or never properly distributed for greatest efficiency. He also shows by actual experiments that by conservation in the soil of moisture from earlier rains the bad effect of improper distribution may be overcome to a considerable extent and the crop largely increased.

Looking at the subject from the standpoint of climatic conditions, there is no good reason why Tennessee or the states southeast of

Tennessee should not be among our best corn-growing states. The summers are as warm as in the valleys of the Ohio, Missouri and upper Mississippi Rivers; the growing season is longer, the summer rainfall is more abundant, and the winter rainfall with its opportunity for moisture conservation is far greater. The fact then is that the yield of corn per acre in Tennessee is small, not because of climatic conditions but in spite of them. Neither is the soil responsible for the deficiency, for many farmers scattered over all parts of the State have produced crops of corn that can not be ex-

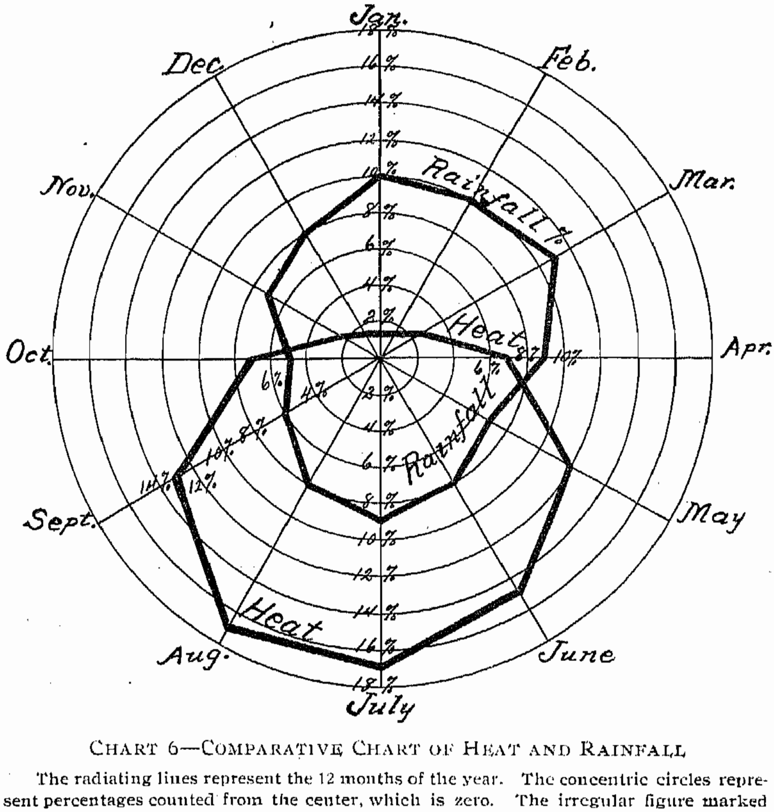


CHART 6—COMPARATIVE CHART OF HEAT AND RAINFALL

The radiating lines represent the 12 months of the year. The concentric circles represent percentages counted from the center, which is zero. The irregular figure marked "rainfall" represents the per cent of the annual rainfall that falls each month. The figure marked "heat" represents the per cent of the year's effective heat that is received each month.

ceeded anywhere. The trouble is that most of us have not adapted our farming methods to our climatic and soil conditions. What is needed is a system of farm management and a rotation of crops that will utilize the abundant heat and moisture that our land receives.

We must have a system that will increase the humus content of the soil and a rotation that will keep the ground covered in winter as well as in summer. We should also time our operations so that they will come at the most favorable seasons.

The double-cropping system as practiced at the Tennessee Experiment Station and to a greater or less extent by the most successful farmers of the State is well adapted for this purpose and should be used on all lands not in meadow or pasture. By this system the supply of humus in the soil is increased, making it more receptive and more retentive of moisture, thus preventing erosion by the surplus rains of the wetter seasons and storing up water for use when rain is deficient. Increasing the supply of humus is the most important function of the double-cropping system because it is only through an abundant supply of humus that the best results in the conservation of soil and rainfall may be attained. The necessary humus may be supplied in two ways. Either the crop may be fed and the manure returned to the land or the crop may be turned under for green manure. The latter method is the quicker, while the former is possibly the more economical. Either method is good and one or the other is absolutely necessary. Which is better in any particular case must be determined by circumstances. With this system Tennessee may not only increase her corn yield until it is second to none but she may increase all her other crops in proportion. And not only Tennessee but the whole region south and east of Tennessee may be benefited by the use of the double-cropping system.

We will now show more in detail the relation between the climate of the South and the double-cropping system and also the relation between the single-cropping system and the climate of the North Central States. We also wish to point out the folly of using either system in a climate not adapted to it.

The first essential in a climate for the double-cropping system is a long enough growing season for the maturing of two crops. Chart 2 shows approximately the length of the growing season in days for the United States east of the 100th meridian. By "growing season" is meant the time between the average date of the last killing frost in the spring and the average date of the first killing frost in the fall. Experience has shown that two crops may be grown where the average growing season is as long as 200 days. The line on Chart 2 marked "200" is the probable northern boundary of the region to which this system is adapted. Another important point in connection with temperature is that in the region under discussion there are many days during the winter season that are warm enough to make crops grow. Most botanists that have investigated the matter agree that most plants grow whenever the daily mean temperature exceeds 43 degrees Fahrenheit. Temperatures above that point are called effective temperatures. Temperature records for this region show that the effective temperature between the average date of the first killing frost in the fall and the average date of the last killing frost in the spring is about 10 per cent of the total effective temperature of the year and is greater than the average effective temperature for the month of April. Crops sown in the fall use this extra heat and the total plant growth for the year is increased that much and a saving accomplished that far exceeds that of any of the great irrigation projects of the West.

This, however, is only a small part of the heat conserved by the double-cropping system. In this section fall-sown or spring-sown crops mature anywhere from June first to October and during the remainder of the season the land is left idle. Anywhere from 25 to 50 per cent of the heat that is available for plant growth during the year is lost because there is no crop on the ground to utilize it. The double-cropping system will prevent the greater part of this loss by keeping some useful crop on the ground all the year round. Not

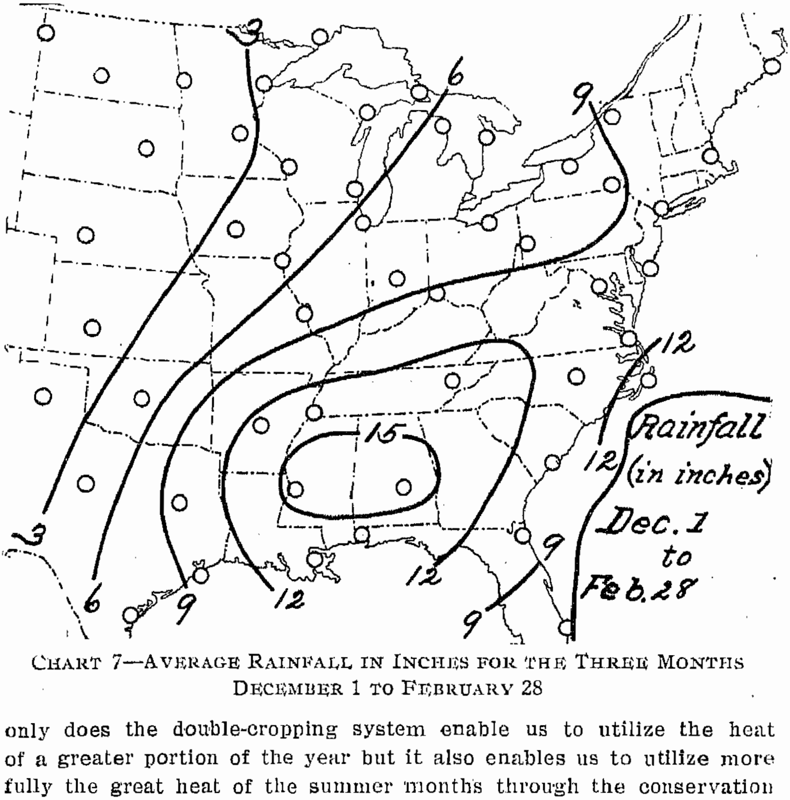
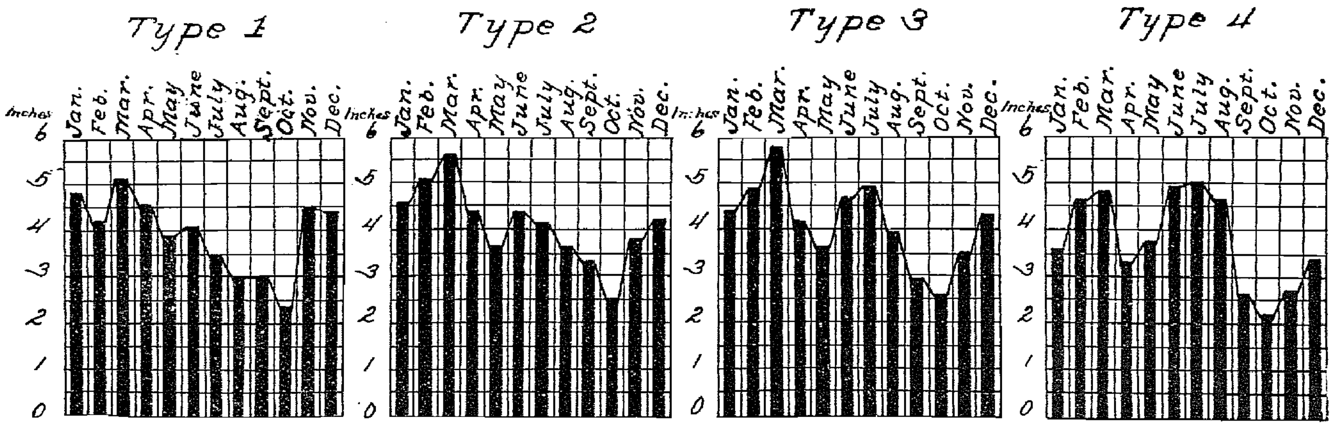


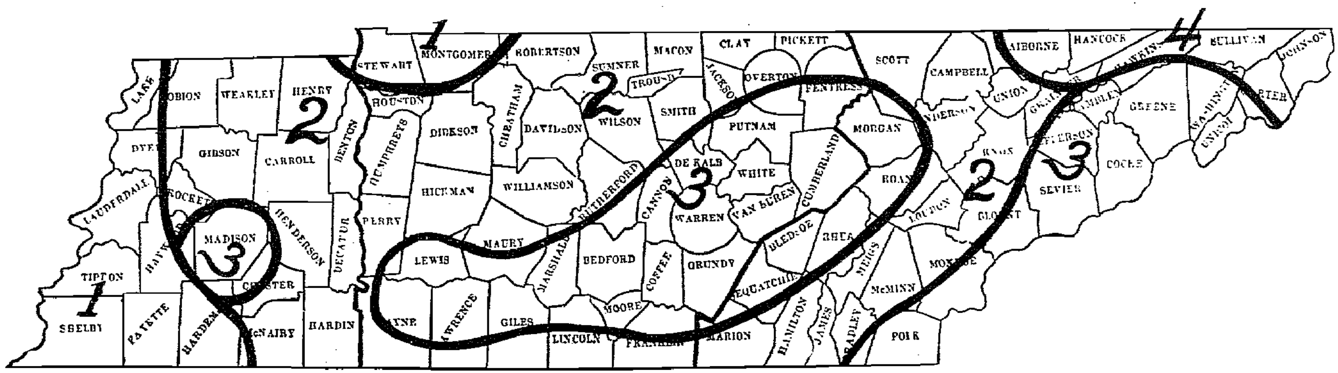
CHART 7—AVERAGE RAINFALL IN INCHES FOR THE THREE MONTHS DECEMBER 1 TO FEBRUARY 28

only does the double-cropping system enable us to utilize the heat of a greater portion of the year but it also enables us to utilize more fully the great heat of the summer months through the conservation of the winter rainfall. The two most important factors in plant



Four Types of Rainfall Distribution in Tennessee

CHART 8



Areas covered by four types of rainfall

CHART 9

growth are heat and moisture. To produce a given amount of vegetable matter we must have a definite amount of heat and a definite amount of water. If the supply of either heat or water is reduced the resulting crop is also reduced. The simplest experiment in irrigation will prove that the average summer rainfall in the United States is considerably short of the amount necessary to give us the benefit of all of the summer's heat in plant growth. The winter rainfall, on the other hand, is far in excess of the need for that season. If we can, then, by means of deep tillage and a winter cover crop, keep part of this excess moisture in the soil until summer we will be able to utilize just that much more of the summer's heat in crop production.

Chart 6 shows graphically the relative distribution of heat and rainfall through the year in percentages of the total amount of each for each month.

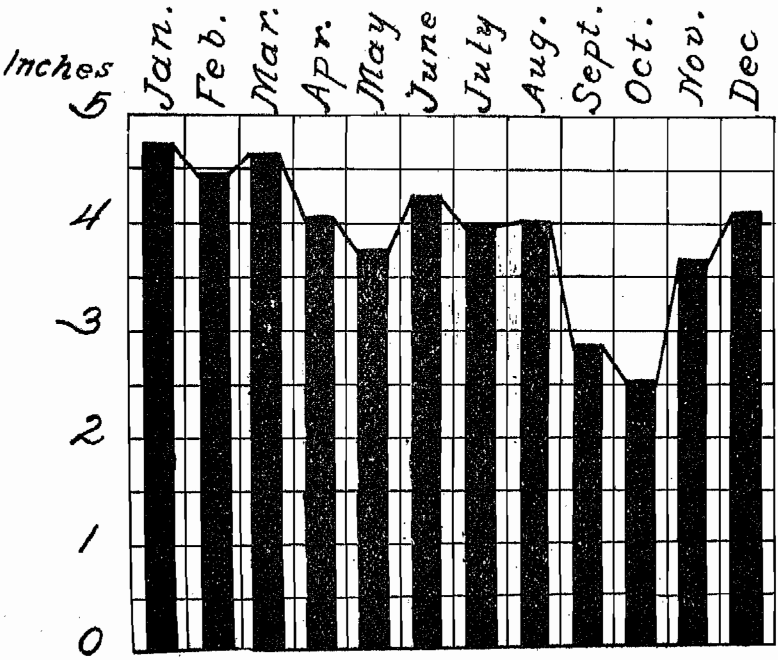


CHART 10—DISTRIBUTION OF RAINFALL FOR TENNESSEE, SHOWING WET PERIODS IN WINTER AND SUMMER WITH DRIER PERIODS IN SPRING AND FALL

The second climatic essential for the success of the double-cropping system is sufficient rainfall properly distributed through the year. Let us first consider the winter rainfall as shown in Chart 7.

Over the greater portion of the six states under discussion the winter rainfall is 12 inches or more, while over the greater part of Mississippi and Alabama it is more than 15 inches. This amount of water falling on a bare soil in so short a time can not fail to do considerable

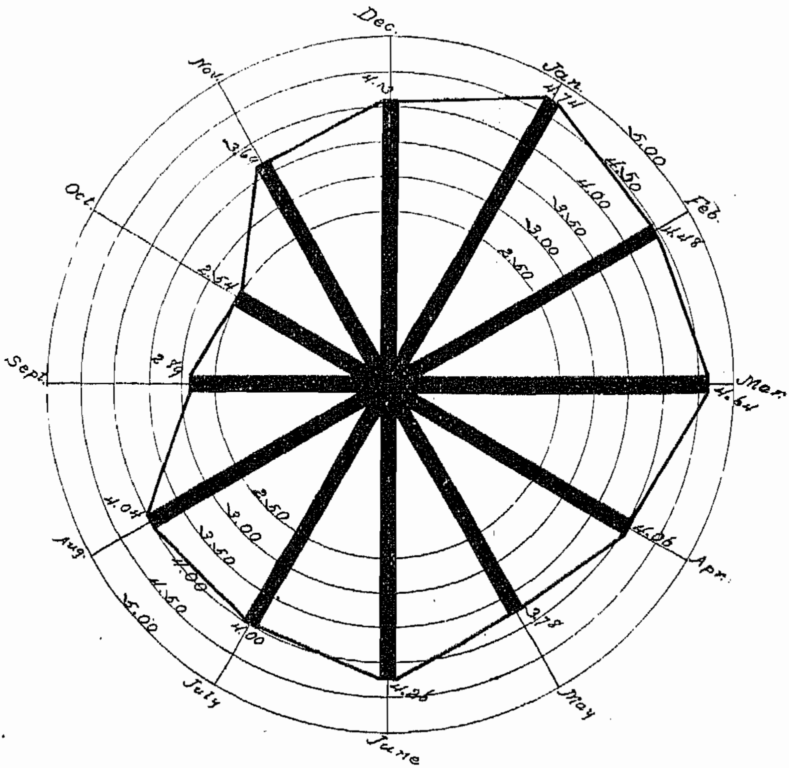


CHART 11—DISTRIBUTION OF RAINFALL FOR TENNESSEE ARRANGED IN CIRCULAR FORM TO SHOW MORE CLEARLY THE ANNUAL CYCLE OF RAINFALL WITH WET PERIODS IN WINTER AND SUMMER AND DRIER PERIODS IN SPRING AND FALL

damage both by washing and leaching. This is especially true if the soil is deficient in humus. Under these conditions a winter cover crop is a necessity for the sake of soil conservation and would be profitable if no other benefit were received from it. Under the double-cropping system there is always a crop on the ground during the winter to conserve the soil and use the abundant rainfall.

We will next consider the annual distribution of rainfall, first for Tennessee and then for the whole district under dicsussion. The rainfall for Tennessee may be divided into four types according to its distribution through the year as shown in Chart 8. They differ chiefly in the relative heights of the winter and summer maxima. For present purposes let us note the resemblance between these four types and the area covered by each as shown in Chart 9. These types resemble each other in that each has a winter and a summer

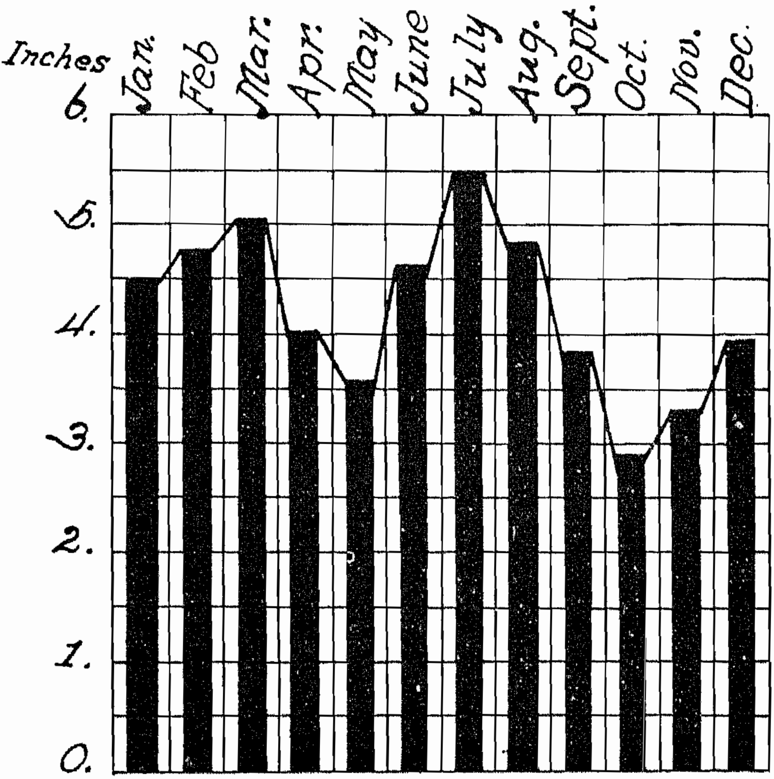


Chart 12—Average Distribution of Rainfall for the Six States of Tennessee, the Carolinas, Mississippi, Alabama, and Georgia, Showing Wet Winter and Summer and Drier Spring and Fall

maximum and a May and an October minimum. Type 1 occupies a narrow strip at the west end of the State and type 4 covers a still smaller area in the northeast corner. The remainder of the State, which is over 90 per cent, is covered by types 2 and 3.

Chart 10 represents the average distribution of rainfall through the year for the whole State. Type 1 is the only one of the four types that differs materially from Chart 10, and as this type occupies less than one-tenth of the State any conclusions based on Chart 10 may be applied with reasonable fairness to the State as a whole.

(In Chart 10 and all following charts the months have each been

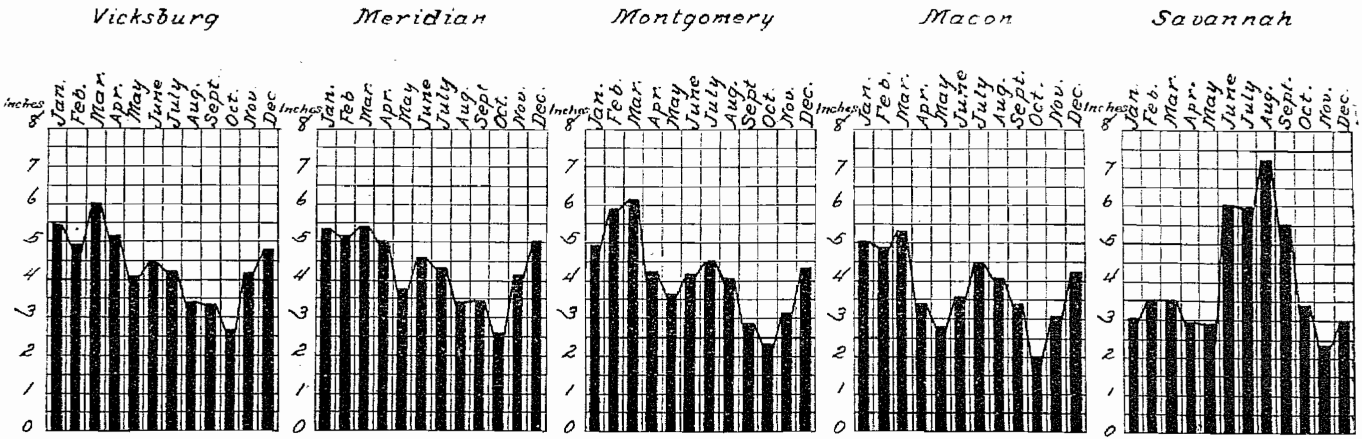


CHART 13—AVERAGE DISTRIBUTION OF RAINFALL AT FIVE SELECTED STATIONS, SHOWING SIMILARITY TO THE AVERAGE FOR THE WHOLE REGION AS SEEN IN CHART 12

reduced to a uniform period of thirty days in order that the actual relation between them might be more exactly represented).

Chart 11 is identical with Chart 10, except that the heavy lines representing rainfall instead of rising from a common base line are

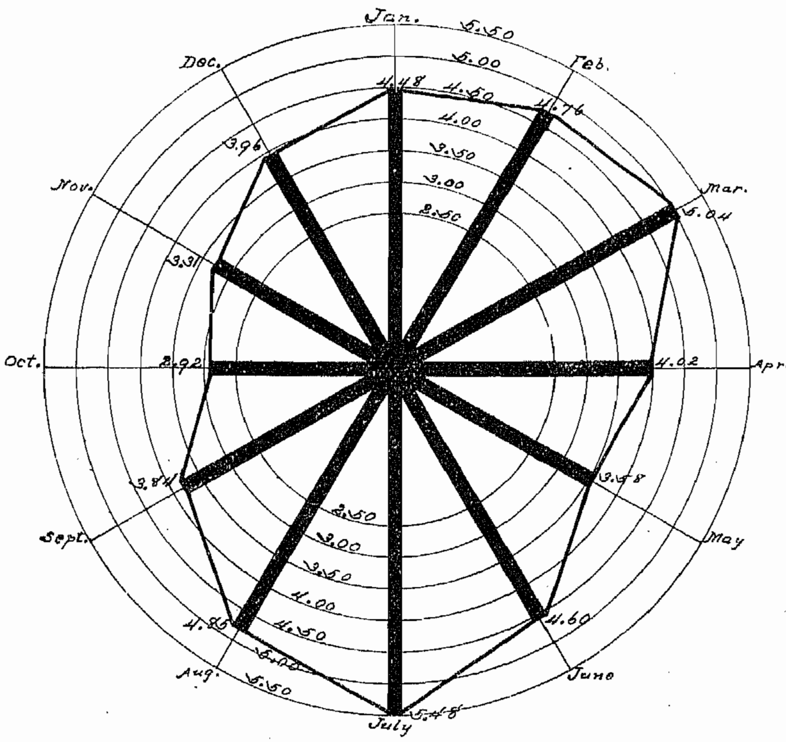


CHART 14—AVERAGE DISTRIBUTION OF RAINFALL FOR SIX STATES AS SHOWN IN CHART 12, ARRANGED IN CIRCULAR FORM TO SHOW ANNUAL CYCLE OF RAINFALL WITH WET WINTER AND SUMMER AND DRIER SPRING AND FALL

arranged to radiate from a common center. This shows clearly the rain cycle for the year and enables us to locate the various operations of the double-cropping system in their relation to rainfall. As practiced at the Tennessee Experiment Station the winter cover crop is sown during the comparatively dry months of September and October and occupies the ground through the wet months of winter and early spring. It is ready to be turned under for green manure in March or April or to be cut for forage during May, which is drier than the months either before or after it and offers the most favorable opportunity for harvesting one crop and putting in another. This second crop put in in May covers the ground during the wet summer months, protects it from washing rains when they are most frequent, and is ready to harvest during the drier months of fall.

In extending this study to cover the states east and south of Tennessee it was found that the conditions are more favorable for the double-cropping system over this region as a whole than they are in Tennessee, where the system originated. Chart 12 represents

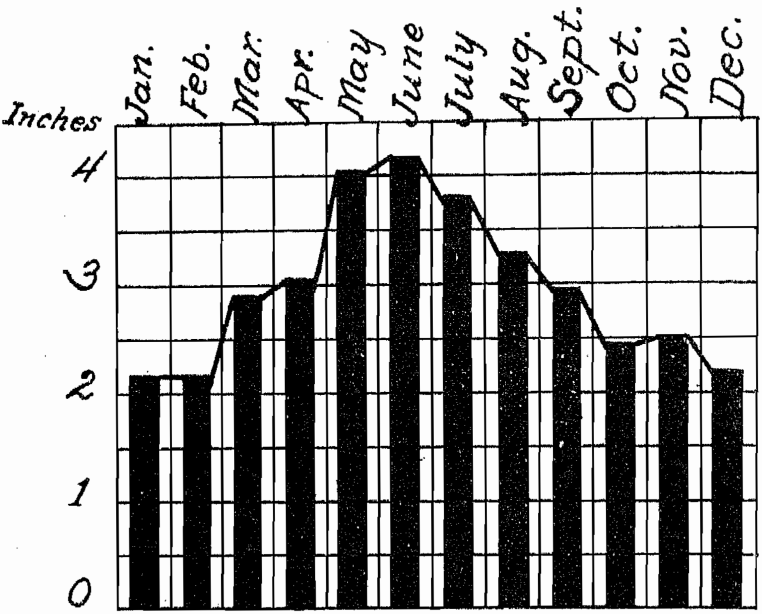


CHART 15—AVERAGE DISTRIBUTION OF RAINFALL FOR THE FIVE STATES OF OHIO, INDIANA, ILLINOIS, MISSOURI, AND IOWA

the average monthly rainfall for the whole section, which includes Tennessee, the Carolinas, Mississippi, Alabama, and Georgia. Chart 13 represents the average monthly rainfall for five selected stations, which are situated on a line extending across the section from west to east and passing very near its center. This chart is introduced to show that the rainfall distribution at different points over the section corresponds very closely to the general average as shown in Chart 12. Vicksburg on the west and Savannah on the east are the only points that differ materially from the type and they represent two narrow strips which are a very small part of the whole section.

Chart 14 is a circular arrangement of the lines on Chart 12 and shows the average yearly cycle of rainfall for the whole region. Here we find tne same general distribution that we saw in Tennessee, but with this difference, that the rainfall during the summer months is much heavier and the dry period in May, which is so favorable for harvesting and planting, is more marked. There will of course be variations in the distribution of rainfall from year to year, but the average condition as shown by these charts is ideal for the double-cropping system.

The old plan of growing only one crop a year which is practiced throughout the country is a great success in the North but is a glaring

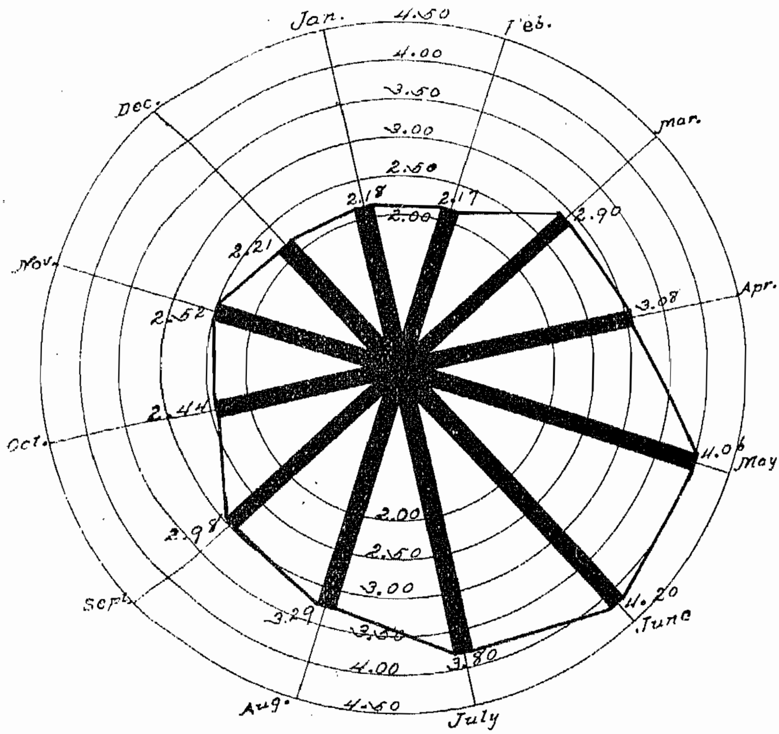


CHART 16—CIRCULAR ARRANGEMENT OF DATA IN CHART 15, SHOWING ANNUAL CYCLE OF RAINFALL WITH WET SUMMER AND DRY FALL, WINTER, AND SPRING

misfit in the South. This is due to the great difference in climatic conditions. First, the growing season north of Tennessee is generally too short for two crops in one year. Second, the ground is usually frozen in the winter and the winter precipitation is small and is usually in the form of snow, so that there is no imperative demand for a winter cover crop to prevent washing. Third, the annual distribution of rainfall is entirely different from that of the Southern States, as is shown by Charts 15 and 16, which represent the five states of Ohio, Indiana, Illinois, Missouri, and Iowa. Instead of two wet seasons we find only one, and that is in the late spring and summer. There is also only one dry season, which includes fall, winter, and early spring. Crops put in the ground in the fall or spring occupy it during the wet summer season and are harvested in the late summer or fall. Here the conditions are just suited to the single-cropping system and the single-cropping system is suited to the conditions because it was developed under and for those conditions. It would be absurd for an Iowa farmer with his short growing season and his light winter rainfall to attempt to use the double-cropping system. But it would be no more absurd than for the Southern farmer to stick to a system developed to fit conditions entirely different from those under which he is working. He must have a system that fits his conditions if he is to get the most out of farming, and when he realizes that his conditions are almost perfectly adapted to the growing of two crops each year instead of one he will be in a position to live up to his opportunity.

APPENDIX

CROP ROTATIONS WHICH PROVIDE WINTER SOIL COVER

INTRODUCTORY NOTE

Investigation has shown two great neglected factors in Tennessee agriculture: 1. We have not used the growing days of our winter season for crop production. 2. We have neglected to save the rainfall for use during the drought periods of the summer. The winter is about one-fourth our year, and during the greater number of winter days such crops as wheat, barley, oats, and rye among the cereals, and winter legumes, will grow, and by their growth protect the soil from washing. By deep-tilling these crops into the land, at least one year in three, we improve the moisture-holding capacity of our soil so greatly that much of our rainfall, amounting to 48 inches a year, is saved to the crops for use during drought periods.

The following rotations are based on these important facts, and any of them will result in soil improvement and increased crop production when mineral fertilizers are properly used in them.

A—FOUR-YEAR ROTATIONS

1. 1st year—Corn or cotton, with wheat or rye sown in at last cultivation.
   2d year—Soy beans, for hay.
   3d year—Winter wheat.
   4th year—Clover and grass.
2. 1st year—Wheat or barley, or winter oats, top-dressed in winter, followed by soy beans, sown last of June, for hay.
   2d year—Wheat.
   3d year—Clover and grass, for hay.
   4th year—Pasture.
3. 1st year—Winter barley or winter oats, top-dressed in winter, for grain, followed by soy beans for hay.
   2d year—Wheat and vetch (sown previous fall) plowed under. Ground fallowed until August, then sown to red clover without a nurse crop.

3d year—Clover, for hay. Plowed after first cutting and sown to soy beans, for hay.

4th year—Wheat and vetch, sown after bean crop. Turned under, followed by corn or cotton.

4. (For rich land only). 1st year—Barley, wheat or winter oats, plowed immediately after harvest, fallowed until August, then sown to crimson clover and turnips. Turnips off in the fall.

2d year—Crimson clover turned under in May. Land fallowed until July, then planted to Irish potatoes.

3d year—Wheat and vetch (following potatoes) for hay, followed by red clover, sown without nurse crop, in August.

4th year—Red clover, for hay, followed by soy beans, for hay.

(For Tobacco)

5. 1st year—Tobacco; wheat or rye sown at last cultivation.

2d year—Soy beans, for hay.

3d year—Winter wheat.

4th year—Red clover.

6. 1st year—Tobacco.

2d year—Wheat.

3d year—Clover.

4th year—Pasture, to be fall-plowed.

B—THREE-YEAR ROTATIONS

1. 1st year—Corn and peas.

2d year—Winter oats, sown previous fall, followed by soy beans, for hay.

3d year—Wheat or rye, sown previous fall, turned under for cotton, sown at last cultivation to rye.

2. 1st year—Winter oats or wheat, seeded in spring to Japan clover—Japan clover pasture.

2d year—Japan clover hay or pasture.

3d year—Wheat or rye, sown previous fall, turned under for cotton or corn.

3. (For rich land). 1st year—Winter wheat, barley or oats. Land plowed immediately after harvest, fallowed to August, then sown to crimson clover and turnips. Turnips off in the fall.

2d year—Crimson clover turned under. Ground fallowed until August, then sown to red clover without nurse crop.

3d year—Clover for hay. Land plowed after first crop, and sown to soy beans, for hay.

NOTE—In rich-land rotations, alfalfa may be sown in place of red clover, provided the land is heavily limed and prepared for this crop.

(For Sweet Potatoes)

4. 1st year—Corn, with cowpeas. Hogged off and sown to wheat and vetch.
   2d year—Wheat and vetch turned under in April; sweet potatoes.
   3d year—Winter oats and vetch (sown previous fall), for hay; soy beans, for hay; wheat and vetch, sown in fall, to be turned under next spring before planting corn.

C—TWO-YEAR DAIRY ROTATION

(Two Crops a Year)

1st year—Barley, wheat or winter oats, top-dressed with manure, followed by soy beans, for hay.

2d year—Wheat and vetch, or winter oats and vetch, followed by corn and peas, or sorghum and peas, for silage.

D—FIVE-YEAR ROTATION

1st year—Corn and peas, hogged off.

2d year—Wheat and vetch (sown previous fall) turned under, followed by soy beans, off for hay or hogged off with corn.

3d year—Oats or wheat (sown previous fall) seeded to Japan clover in spring. Japan clover, pasture or hay if heavily seeded.

4th year—Oats for hay, sown previous fall on Japan clover, disc-drilled without plowing, followed by Japan clover hay.

5th year—Wheat or rye sown on Japan clover previous fall, turned under, followed by cotton, cotton seeded to wheat or rye at last cultivation, to be turned under for corn and peas the next spring.