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RELATION OF SOIL CONDITIONS AND ORCHARD MANAGEMENT TO THE ROSETTE OF PECAN TREES

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The rosette of pecan trees is generally attributed by investigators and growers to unfavorable soil conditions. Whether rosette is a result of an unbalanced condition of nutrients in the soil, a lack of available soil moisture, a deficiency of organic matter, or is due to several of these factors has never been definitely determined. However, it is generally accepted that a lack of moisture and a deficiency of soil nutrients play an important part [1] in the development of this disease.

The relation of soil conditions to pecan rosette has received much attention from growers and investigators. McMurran [2] showed that the evidence of rosette in badly affected pecan trees was greatly reduced by heavy applications of stable manure. Whether the improved condition in the appearance of the trees is due to the additional plant food in the soil or to the greater ability of the soil to retain moisture during droughty periods as a result of the added organic matter is not definitely known. Further investigations by the United States Department of Agriculture, which should throw some light on these points, are in progress.

[1] Orton, W. A., and Rand, F. V. Pecan rosette. In Jour. Agr. Research, v. 3, p. 149–174, illus. 1914. Rand, F. V. Pecan rosette: Its histology, cytology, and relation to other chlorotic diseases. U. S. Dept. Agr. Bul. 1038, 42 p., illus. 1922.

[2] McMurran, S. M. Pecan rosette in relation to soil deficiencies. U. S. Dept. Agr. Bul. 756, 11 p., illus. 1919.

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EFFECT OF SOIL TREATMENT ON THE ROSETTE OF PECAN TREES

The first part of this bulletin reports the results of field experiments which were begun in 1918 and continued until 1923 on two prominent soil types in southern Georgia to study the effects of fertilizers of various composition and the effect of soil conditions on pecan rosette. No definite information as to the influence of commercial fertilizers or of any particular fertilizer ingredient was obtained, but some very interesting observations were made. Special study was made of the relation of the amount of organic matter in the soil to the prevalence of rosette in pecan orchards, as early observations indicated that the organic matter of the soil had considerable effect, either direct or indirect, on the condition of the orchard grown thereon. In these experiments fertilizers of various compositions and ratios were used. Phosphate, nitrogen, and potash were used singly and in combinations, the ratios varying in each mixture. One of the orchards on which the work was conducted is located near Cairo, Ga., on Norfolk fine sandy loam; the other is in Dougherty County, Ga., on Greenville sandy loam.

NORFOLK FINE SANDY LOAM

The Norfolk fine sandy loam on which the experiment was conducted consists of a gray to dark-gray fine sandy loam overlying a friable yellow sandy clay. Two phases of this soil type occur in the orchard, the medium phase and the deep phase. The medium phase is underlain at about 12 inches by a yellow heavy fine sandy loam which abruptly passes into bright-yellow friable fine sandy clay. The deep phase differs essentially in its greater depth to the subsoil clay. The gray loamy fine sand is underlain at 20 to 22 inches by a yellow heavy fine sandy loam which passes into a bright-yellow clay loam or fine sandy clay. The organic matter in this phase is more rapidly exhausted under cultivation than with the shallower phases. The natural drainage of the soil is good. The mechanical analysis of the Norfolk fine sandy loam is given in Table 1.

TABLE 1.—*Mechanical analysis of Norfolk fine sandy loam from Cairo, Ga.*

Soil material	Constituents (per cent)						
	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Soil	0.6	7.3	8.9	39.5	26.1	11.1	6.5
Subsoil	.9	6.8	5.3	37.5	17.9	9.7	21.9

The orchard has an area of about 14 acres. It was planted in December, 1904, to Frotscher pecan trees, and from that time to 1918 such crops as cotton, corn, peanuts, and velvet beans were grown between the rows. About 200 pounds of commercial fertilizer was applied each year to the annual crops. No effort was made prior to 1918 to increase the organic matter in the soil, and nothing was plowed under except cotton stalks and cornstalks. Forage crops were cut for hay. The soil at that time was not productive. The unproductiveness was apparently the result of many years of con-

stant cropping to cotton and corn, with no attempt to restore the steadily decreasing organic matter, although the soil is of a character making it readily susceptible to improvement.

The chemical analysis of a composite sample of soil taken from the orchard in 1918 is given in Table 2.

TABLE 2.—*Chemical analysis of Norfolk fine sandy loam* [1]

Soil material	Constituents (per cent)					
	Organic matter (C)	Nitrogen (N)	Phosphorus (P_2O_5)	Calcium (CaO)	Potassium (K_2O)	Magnesium (MgO)
Soil	0.64	0.031	0.0851	0.196	0.228	0.053
Subsurface soil	.30	.020	.0276	.120	.216	.060
Subsoil	.22	.021	.0276	.109	.216	.068

[1] Analysis by W. R. Leighty, Office of Soil-Fertility Investigations, Bureau of Plant Industry.

The soil is very low in nitrogen and organic matter, as well as in other plant-food constituents.

Rosette first appeared in the orchard in 1912, about the time the trees had reached the bearing age. From 1912 to 1918 it increased at an alarming rate, and at the end of that period the orchard was in such a condition that its abandonment was considered.

In 1918 an experiment was begun to determine whether or not the application of commercial fertilizers to the soil, in conjunction with the use of green-manure crops, might bring about an improved condition in the rosetted trees and increase the production of nuts. One hundred and eight badly rosetted trees were fertilized. A number were left unfertilized to serve as controls. Alternate trees in the orchard were top-worked in 1919 to the Moneymaker variety, and the others were left the original variety, Frotscher.

CULTURAL SYSTEM PRACTICED

The cultural management of the orchard was planned so that two cover crops a year would be grown over the entire orchard, a summer cover crop of some leguminous plant and a winter cover crop of clover or small grain. The entire vegetative matter produced was plowed under to enrich the soil in organic matter. The cover crops grown from 1918 to 1923 are recorded in Table 3.

TABLE 3.—*Cover crops grown in a rosetted pecan orchard on Norfolk fine sandy loam at Cairo, Ga.*

Year	Spring and summer	Fall and winter
1918	Fallow	Bur-clover.
1919	Cowpeas	Oats.
1920	Beggarweed	Rye.
1921	Cowpeas	Do.
1922	Velvetbeans	Rye and oats.
1923	do	Do.

The summer crop, which was usually planted in May, was plowed under in August or early September and the soil prepared for the winter crop, which was planted in early October. The winter cover crop was plowed under in April and the ground prepared for the summer crop. The cost of plowing and harrowing the land in preparation

for planting the crop, of the seed and seeding, and the plowing under of the vegetative matter produced by each crop on an acre basis is given in Table 4.

TABLE 4.—*Cost of growing cover crops in a pecan orchard on Norfolk fine sandy loam from 1918 to 1923 on an acre basis* [1]

Year	Fall crop		Summer crop		Total
	Plowing under summer crop and preparing seed bed	Seed and planting	Plowing under winter crop and preparing seed bed	Seed and planting	
1918	$2.00	$1.00	[2] $2.00	----------	$5.00
1919	2.50	1.25	2.50	$2.00	8.25
1920	2.00	1.00	2.00	1.75	6.75
1921	1.50	.75	1.50	1.50	5.25
1922	1.75	1.00	1.75	1.25	5.75
1923	1.75	1.00	1.75	1.50	6.00

[1] The items cover the expense of labor and team, no allowance for overhead or machinery depreciation being included.
[2] Cost of summer cultivation.

The cover crops improved the soil from year to year and were a success each year. Large quantities of vegetable matter were plowed into the soil each spring and fall. The cover crop of velvet beans grown in the summer of 1923 is shown in Plate I. Here the luxuriant growth was turned under in the fall for green manuring.

IMPROVEMENT OF THE SOIL

The soil's organic matter and nitrogen content, which seem to be the most important soil-fertility factors concerned, were noted from time to time. Composite samples of soil were taken from the orchard in 1918, 1921, 1922, and at the end of 1923 and the acidity, nitrogen, and organic matter determined. The results are given in Table 5.

TABLE 5.—*Analyses of soil from a pecan orchard on Norfolk fine sandy loam at Cairo, Ga.,*[1] *in stated years*

Year	Constituents (per cent)		Acidity (pH)
	Organic matter (C) [2]	Nitrogen (N)	
1918	0.64	0.031	5.4
1921	.90	.040	6.0
1922	1.23	.050	6.0
1923	1.39	.061	5.8

[1] Analyses by P. D. Boone and acidity determinations by E. F. Snyder, Office of Soil-Fertility Investigations, Bureau of Plant Industry.
[2] To convert this carbon figure to organic matter, multiply by 1.73.

The acidity of the soil is expressed in terms of the intensity of the acid character of the soil, technically called its P_H value.

A neutral soil has a P_H value of 7 and an acid soil a P_H value below 7, being increasingly more acid as the value becomes smaller.

The soil for the analytical work was taken from the middle of tree rows in order to avoid as much as possible locations where fertilizers had been applied. The large number of samples taken were combined to make a composite sample representative of the entire orchard.

The organic matter (carbon) was shown to have increased from 0.64 per cent in 1918 to 1.39 per cent in 1923, or more than double. The nitrogen increased from 0.031 to 0.061 per cent, just about double. The soil had an acidity (P_H) value of 5.4 in 1918, 6 in 1921 and 1922, and 5.8 in 1923, which shows it had been slightly acid, as determined by its hydrogen-ion concentration, since the beginning of the experiment. Its acidity was less in 1923 than in 1918.

The physical condition of the soil has improved considerably. In the beginning it was rather compact and became hard and baked in the summer. As a result of growing and turning under cover crops for six years, it is more open and porous and does not become so hard and dry in the summer.

IMPROVEMENT IN THE CONDITION OF THE TREES

The entire orchard was very badly rosetted in 1918, and the trees were in such poor condition that it was ready to be abandoned. Photographs of each individual tree taken at that time and again four years later, serve as records of the effect of the soil treatment on the condition of the trees. Girth measurements of the trees were taken each winter, and records of the nut yields have been made from the beginning.

Since the limbs of badly rosetted pecan trees die back each year in proportion to the degree affected, the weight of dead twigs each season was considered an important measure of the improvement or deterioration of a badly rosetted tree. The dead wood from these trees has been removed and weighed during May or June of each year. These data are the most striking of all the records taken. The comparison of photographs of the individual tree, descriptive record, girth growth, and the dead-wood record indicate a most decided improvement in the rosette condition of all the trees in the orchard each year since 1918.

The records fail to show any relationship between the improvement of the trees and the chemical fertilizers used. On the contrary, the controls, or trees not receiving chemical fertilizers, show as great improvement so far as rosette is concerned as do the fertilized ones; in fact, the condition of the entire orchard has improved in the same proportion as have the trees receiving chemical fertilizers. The records do not show that any one chemical fertilizer or fertilizer combination had any advantage over another when used with the intention of curing rosette. As the improvement of the orchard seems to be due to the general improvement of the soil by means of growing and plowing under cover crops as practiced, the records given below are for a total of all the trees under observation. Records for individual trees variously fertilized are omitted.

The condition of the orchard each year is shown in the following tables. Records were kept of 62 Frotscher and 54 Moneymaker pecan trees. The number of trees rosetted and the quantity of dead wood cut from the Frotscher trees annually are given in Table 6.

The Moneymaker trees were budded in 1918 on the old Frotscher stock, and there is no dead-wood record for this variety. The annual girth growth and the yields of both the Frotscher and the Moneymaker trees are given in Table 7.

TABLE 6.—*Dead wood resulting from rosette in Frotscher pecan trees grown on Norfolk fine sandy loam soil at Cairo, Ga., from 1918 to 1923, inclusive*

Year of growth	Number of trees			Weight of dead wood (pounds)	
	Recorded	Dying back	Not dying back [1]	Total	Per tree
1917	62	60	2	1,051	17.5
1918	62	57	5	980	17.2
1919	62	61	1	670	11.0
1920	62	42	20	54	1.3
1921	62	10	52	19	1.9
1922	62	16	46	31	1.9

[1] Trees showing no indication of rosette.

The quantity of dead wood cut from the orchard was very great in 1917, 1918, and 1919, which is a good measure of the prevalence of rosette. This decreased greatly in 1921 and diminished to a very small amount in 1922. In 1923 there was almost no rosette, showing that the orchard had apparently overcome the disease. The trees grew slowly prior to 1918, but made a more rapid growth the following four years, or after the rosette began to decline. In 1918 and prior to that year the orchard yielded few or no nuts. The yields have increased under the treatment given the orchard, and in 1923 the Frotscher trees yielded 576 pounds and the Moneymaker trees 530 pounds per acre.

TABLE 7.—*Annual average girth growth and yields of Frotscher and Moneymaker pecan trees grown on Norfolk fine sandy loam at Cairo, Ga., from 1918 to 1923, inclusive*

Year	Average girth growth (inches)		Annual yields									
			Frotscher					Moneymaker				
			Number of trees			Yield of nuts (pounds)		Number of trees			Yield of nuts (pounds)	
	Frotscher	Moneymaker	Recorded	Bearing	Unproductive	Total	Per acre (20 trees)	Recorded	Bearing	Unproductive	Total	Per acre (20 trees)
1918			62	30	32	43.8	14	54	0	54	0	0
1919	1.9	0.5	62	55	7	1,008.8	324	54	0	54	0	0
1920 [1]	1.25	.4	62					54				
1921	1.2	1.2	62	58	4	908.8	294	54	48	6	890.9	330
1922	1.5	.9	62	59	3	1,018.3	328	54	52	2	513.0	190
1923	2.4	1.0	62	61	1	1,787.3	576	54	53	1	1,430.7	530

[1] Crop destroyed by insects.

In Plate II is shown a typical tree as it appeared in the orchard in 1918 and in 1923. *A* shows tree No. K–15 as it appeared in 1918 and *B* as the same tree appeared in 1923. The two pictures were taken from the same position and at the same distance. The great improvement made is well illustrated here.

GREENVILLE SANDY LOAM

A second study was conducted on another orchard, located in Dougherty County in southern Georgia. This orchard was planted in 1909 to a number of varieties of pecan trees, including Frotscher, Stuart, Van Deman, and Mobile. As in the former case, chemical-fertilizer experiments were undertaken to study the effect of various ratios on the rosette of pecans. Applications were made in 1918, 1919, and 1920, using in the beginning 20 and later 30 pounds of fertilizer per tree, which is equivalent in the latter case to an application of 600 pounds per acre. The same effect was observed here as in the experiments on the Norfolk fine sandy loam of the Cairo orchard; that is, no beneficial results in rosette control were obtained from any of the chemical fertilizers, nor did the cultural system employed in this orchard, which was quite different from that in the former orchard, prove successful.

CULTURAL SYSTEM EMPLOYED

During the first eight years of the life of this orchard farm crops of corn and cotton were grown, and little or no vegetable matter was returned to the soil. No special attention was given to soil improvement; even the native grasses, which produced luxuriant crops of hay, were cut and removed from the fields. The general method of culture of the orchard in 1918 and the four years following has been to disk the soil very shallowly in early spring. In two of these years peas or beans were broadcasted between the tree rows and allowed to grow in competition with the native grasses and weeds. In the fall the vegetation, which was usually luxuriant, was cut and cured for hay and removed from the field. The ground was left bare during the fall and winter and a light disking made again in the spring. At no time during the four years the orchard was under observation was the soil plowed or put in a good condition. It became compact and hard and depleted in organic matter. The fertilizer used in the experiment was spread on the surface and a light disk run over the ground. There was no indication of a beneficial effect of the fertilizer on the trees. However, the grass made a better growth and produced more hay.

In Plate III, *A* and *B*, the orchard is shown as it was in 1919 and in 1922. The condition of the trees as well as the plan of orchard management is seen here. The grass and peas grown during the summer of 1919 and producing a good crop have been cut, piled, and cured, to be removed and used for hay. The picture also shows the scant quantity of material left on the ground. In Plate III, *B*, the weeds and native grass grown during the summer of 1922 are shown. It is seen that the trees have not improved since 1919, as they are here shown to be stunted and badly rosetted.

CHARACTER OF THE SOIL

This orchard is on Greenville sandy loam, which is a reddish brown to red sandy loam 8 to 10 inches deep. The subsoil is invariably red to bright-red friable sandy loam, becoming heavier with depth. The soil is easily cultivated, though care must be exercised in its management, as it is liable to clod if plowed too wet or too dry. Although the subsoil is a heavy sandy clay, no difficulty is experienced in preparing a seed bed or maintaining a favorable moisture content. This soil and the soil type in general have a high agricultural value, are well adapted to and grow good crops of cotton, corn, and oats, and give excellent yields of forage crops and native grasses. Large areas of the Greenville sandy loam are planted to pecan orchards in southern Georgia, and where properly managed and cared for the trees are doing well. As a rule this type of soil is considered better than the Norfolk type for general farm crops and for pecans. The character of this soil is such that its fertility can be more easily improved and maintained by good methods of soil management and fertilization than the Norfolk sandy loam. The mechanical analysis of the Greenville soil is given in Table 8.

TABLE 8.—*Mechanical analysis of Greenville sandy loam from Dougherty County, Ga.*

Soil material	Constituents (per cent)						
	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Soil	0.9	14.5	20.2	32.3	6.8	14.5	10.8
Subsoil	1.0	10.6	19.9	32.4	7.4	13.8	14.9

The orchard on which the chemical-fertilizer experiment was conducted contained about 18 acres. The trees were 9 years of age at the time and very badly rosetted; they produced practically no nuts. The land had been growing general farm crops, and no vegetation was turned under. The plowing which was necessary for the annual crops had been very shallow and the cultivation scant. However, fair yields of farm crops were obtained, and the native grass which was cut for hay yielded well.

In 1918, soil samples, representative of the entire 18 acres, were taken for laboratory work, and the chemical analysis is given in Table 9.

TABLE 9.—*Chemical analysis of soil from a Greenville sandy loam orchard in Dougherty County, Ga., in 1918* [1]

Soil material	Constituents (per cent)					
	Organic matter (C)	Nitrogen (N)	Phosphorus (P_2O_5)	Calcium (CaO)	Potash (K_2O)	Magnesium (MgO)
Soil	0.37	0.022	0.0407	0.182	0.264	0.0598
Subsurface soil	.31	.026	.0230	.128	.298	.0962
Subsoil	.29	.018	.0276	.182	.276	.1179

[1] Analysis by W. R. Leighty, Office of Soil-Fertility Investigations, Bureau of Plant Industry.

A PECAN ORCHARD ON NORFOLK FINE SANDY LOAM IN WHICH COVER CROPS OF VELVET BEANS WERE GROWN AND PLOWED UNDER FOR GREEN MANURING

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PECAN TREES IN A NORFOLK FINE SANDY LOAM ORCHARD

A.—Condition of tree in 1918 before soil-improvement methods were practiced. B.—The same tree in 1923, leguminous cover crops having been grown and plowed under for six years. The quantity of dead wood resulting from rosette each year was as follows: 1918, 65 pounds; 1919, 13 pounds; 1920, 3 pounds; 1922 and 1923 ,none

GENERAL VIEWS OF A ROSETTED ORCHARD ON GREENVILLE SANDY LOAM

A.—The practice of removing all vegetation produced in the pecan orchard is shown here. Note the condition of these 9-year-old pecan trees, photographed in October, 1919. B.—Note the character of vegetation, consisting of weeds and native grasses grown during the summer, and the rosetted condition of the trees. Photographed during the summer of 1922

BADLY ROSETTED PECAN TREE IN A GREENVILLE SANDY LOAM ORCHARD

A.—Photographed in 1918 when the tree was 9 years old. B.—As it appeared four years later. No vegetable matter was added to the soil. Note the character of the natural growth

PECAN TREES 7 YEARS OLD, PLANTED ON GREENVILLE SANDY LOAM, DEWITT, GA.—I

The land had been well farmed and its fertility maintained previous to planting the trees. The insert is a near view of an average-sized tree in this orchard

PECAN TREES 7 YEARS OLD, PLANTED ON GREENVILLE SANDY LOAM, DEWITT, GA. II

The land had been abused and poorly managed previous to planting the trees, which were of the same age and had the same management as those shown in Plate V. The two orchards adjoin each other. The insert is a near view of an average-sized tree in the orchard, which was photographed at the same distance as the insert shown in Plate V

FIVE-YEAR-OLD PECAN TREES ON ORANGEBURG SANDY LOAM, NEAR MONTICELLO, FLA.

A.—Tree in the yard near a chicken house. Its trunk circumference was 21 inches. The soil contains 0.064 per cent nitrogen and 0.98 per cent organic matter (C). B.—An average-sized tree in a field adjoining the chicken yard. Its trunk circumference was 16 inches. The soil contains 0.046 per cent nitrogen and 0.44 per cent organic matter (C)

FROTSCHER PECANS ON NORFOLK SANDY LOAM IN THE LITTLE ORCHARD, THOMASVILLE, GA.

A.—Tree in a field adjoining the house. The soil contains 0.047 per cent nitrogen and 0.40 per cent organic matter (C). B.—A tree near the house almost twice as large as A. It is a much heavier bearer than trees of the same age and variety in the adjoining field. The soil contains 0.65 per cent nitrogen and 1.45 per cent organic matter (C)

The quantity of the nutrients commonly used as food by plants does not vary to any great extent in the Greenville and Norfolk orchards. The sample of Greenville soil obtained in 1918 contained less organic matter, nitrogen, and phosphorus, about the same quantity of calcium, and slightly more potash and magnesium than the Norfolk soil.

The structure of the soil was good; it crumbled easily, and when plowed and harrowed it was easily pulverized. However, it became hard and dry during the summer in times of drought.

Samples of soil collected from the orchard late in 1922, four years after the first sampling was made, contained less nitrogen and organic matter than the samples taken in 1918. The organic matter (carbon) had decreased from 0.37 to 0.29 per cent and the nitrogen from 0.022 to 0.018 per cent. These differences, though slight, tend to show that the soil was losing in the properties which determine fertility and crop-producing power under the cultural system practiced.

CONDITION OF THE TREES

The orchard under observation was in a very poor condition and badly rosetted in 1918. The trees had been in bad condition for two years prior to this date. At the time that they should have begun to produce nuts, rosette appeared and grew steadily worse. This was true of every variety, none escaping the disease.

A record of 107 trees in the 18-acre orchard was kept. Photographs were made in 1918 and the trees photographed again in 1922. Girth measurements to determine the growth of the trees were taken annually, and the quantity of dead wood resulting from rosette was recorded each year.

The dead wood in the 107 trees weighed 453 pounds in 1917, or 4.23 pounds per tree. In 1918 there were 845.5 pounds of rosetted wood, averaging 7.9 pounds per tree. These records were not made in subsequent years.

The average girth growth of the 107 trees was five-eighths inch in 1918 and 1 inch in 1919. The yields in 1918 for the 107 trees totaled about 3.5 pounds of nuts. In 1919 less than 1 pound was harvested, and in 1920 only a few trees bore, the yield being very small. The trees have been in very poor condition since that time and have produced very little. The orchard was practically abandoned by 1923.

A photograph of a typical tree in this orchard is shown in Plate IV, *A* and *B*. It was taken in the summer of 1918 soon after the experiments were begun. The rosetted condition of this tree should be specially noted and compared with its condition four years later, as shown in the photograph taken in the late summer of 1922. In each case the trees were photographed from practically the same position and at the same distance. The trunk has increased in girth measurement, but the top has died back each year, and the condition of the tree appears hopeless.

LABORATORY EXAMINATION OF SOILS FROM ROSETTED AND FROM NONROSETTED PECAN ORCHARDS

The relation between the rosette, the character of tree growth, and the productiveness of pecan trees and soil conditions has been investigated in a number of orchards, and the results are given in this bulletin.

It was found that there is a close correlation of high nitrogen and organic-matter content of soil with productive trees free from rosette and of low nitrogen and organic-matter content with nonbearing rosetted trees. In orchards free from rosette there was invariably a correlation of high nitrogen and organic-matter content of soil with thrifty, productive trees and of low nitrogen and organic-matter content with feeble growth and minimum productiveness. The results indicate that it is immaterial whether the increased organic matter in the soil is brought about by the use of cover crops or the addition of stable manure or is caused by a natural accumulation of litter and débris.

ORCHARD SOILS EXAMINED

The relation of soil conditions to the rosette of pecan trees was investigated in 11 orchards in southern Georgia, northern Florida, and Alabama. The soils of these orchards were examined, because in each it was possible to find under the same management both rosetted and healthy trees of uniform age and variety growing on uniform soil types. In each orchard samples of soils were obtained from a rosetted and from a healthy section of the orchard. Records were made as to the subsoil conditions of the two sections and of the cultural system practiced. In each case soil samples were taken for laboratory determination of their acidity, nitrogen, and organic-matter content. Comparisons were thus made between the soils of rosetted and healthy orchards. The data for the soils of these 11 orchards are given in Table 10.

ORGANIC MATTER

The organic matter of the soils in 9 of the 11 orchards in which these investigations were conducted was greater in the soil from the normal sections than in that from the rosetted sections. In orchards Nos. 3 and 5 the organic matter was greater in the soil from the diseased than from that in the healthy sections. The subsoil was probably responsible, at least in part, for the condition of the trees in the diseased sections of these orchards.

Wide variation was found in the organic matter content in the soils of these 11 orchards. In reading these tables, comparison should only be made between the soil from diseased and from healthy sections of individual orchards and not between soils from different orchards, as the data are not presented to show the amount of organic matter necessary for healthy pecan trees. The humus requirement necessarily varies with different soils, and the data resulting from this work are insufficient to determine that question. They do, however, indicate that the percentage of organic matter in a soil is an important factor in causing or preventing pecan rosette.

NITROGEN

The nitrogen content of soil from healthy sections of each orchard is greater than that from the rosetted sections in 7 cases of the 11 examined. Even where the reverse is the case, the nitrogen content of both soils is very nearly the same. The ratio of nitrogen to organic matter is not exactly the same in any two samples of soil.

ACIDITY

All of the soils examined, except one, were found to be acid in reaction. The acidity is given in terms of P_H values which were determined by the hydrogen-electrode method. There is no apparent relation between the degree of acidity of the soil and the quantity of pecan rosette in the orchards examined. In seven of these orchards the soil from the rosetted sections was found to be slightly more acid than that from the healthy sections, in one orchard the degree of acidity was the same in both soils, and in three the acidity was less. There was no wide variation in the degree of acidity in any of these soils except in orchards Nos. 2, 6, and 11, and from the data procured it would seem that a slight degree of acidity is not a factor in causing rosette.

In orchard No. 2 the soil from the rosetted section was less acid than that from the unrosetted section. The acidity (P_H) value was 5.7 and 4.2, respectively. In orchard No. 6 the soil from the rosetted section was alkaline, having a P_H value of 7.7, and that from the healthy section was slightly acid, having an acidity (P_H) value of 6.1. On the other hand, in orchard No. 11 the soil from the rosetted section was more acid than that from the healthy section, the acidity (P_H) value being 5.4 and 6.1, respectively. There is nothing in these data to show that there is any relation between slight degrees of acidity and rosette.

ORCHARD CULTURE

The growing of leguminous cover crops for green manuring or the application of stable manure has been responsible for the greater organic-matter content of the soil in the healthy sections of most of the orchards examined.

CONDITION OF THE SUBSOIL

The unfavorable character of the subsoil is evidently an important factor in causing rosette of pecan trees, but only a few cases in the 11 orchards examined permit study of this factor. In orchard No. 3 the subsoil from the diseased section was very stiff and hard, which was not the case in the healthy sections and was probably the principal factor in the cause of the rosette. It was also a possible factor in orchard No. 7, where the subsoil was stiffer and harder in the diseased than in the healthy section. The rosetted condition of a section of orchard No. 5 may be due to the deeper and more porous nature of the subsoil. In the other orchards mentioned in Table 10 the subsoil conditions were similar in the rosetted and healthy sections.

TABLE 10.—*Relation of the soil nitrogen, organic matter, acidity, and subsoil condition to rosette of pecans in 11 orchards*

Orchard No.	Soil type and location	Trees set, year	Orchard culture	Orchard condition	Soil condition	Soil constituents (per cent)		Soil acidity (P_H)[2]
						Nitrogen[1] (N)	Organic matter[1] (C)	
1	Norfolk sandy loam, Simpson orchard, Monticello, Fla.	1904	Little vegetation	Good growth, no rosette	Shallow surface soil, sandy clay subsoil.	0.032	0.89	6.7
1A	do	1904	do	Small and rosetted	Deep sandy surface soil, yellow clay subsoil.	.033	.41	5.7
2	Norfolk deep sandy loam, Silver Lake pecan orchard, Monticello, Fla.	1907		No rosette, growing well	Sandy surface soil, yellow sandy clay subsoil.	.034	.66	4.2
2A	do	1907		Badly rosetted and dying	Deep sandy surface soil, sandy clay subsoil.	.035	.45	5.7
3	Norfolk sandy loam, North Florida Pecan Co. orchard, Monticello, Fla.	1902		No rosette, trees large	do	.041	.72	6.3
3A	do	1902		Slight rosette, slow growth	Very deep sandy surface soil, yellow hard sandy clay subsoil.	.055	.79	6.4
3B	do	1902		Badly rosetted and dying	Deep sandy surface soil, stiff red clay subsoil.	.055	.89	6.1
4	Norfolk sandy loam, Durand orchard, Fowl River, Ala.	1907	Manure and straw mulch	Rosetted when young, improved later.	Sandy surface soil, sandy clay subsoil	.093	2.00	6.8
4A	do	1907	Native grass, no culture	Badly rosetted and abandoned.	do	.043	.96	6.4
5	Norfolk sandy loam, Weaver orchard, Fowl River, Ala.	1907	Pasture	Slight rosette	Deep sandy surface soil, yellow clay subsoil.	.044	1.23	6.6
5A	do	1907	Clean culture in spring, native grass in summer.	Badly rosetted and abandoned.	Deep sandy surface soil, sandy yellow clay subsoil.	.067	1.31	6.2
6	Norfolk sandy loam, Betchel orchard, Ocean Springs, Miss.			No rosette	Yellow sandy surface soil, high location.	.057	.91	6.1
6A	do			Badly rosetted	Yellow sandy surface soil, low location	.043	.68	7.7
7	Kalmia fine sandy loam, Jackson orchard, Baconton, Ga.	1906	Cover crop turned under	No rosette	Sandy surface loam, yellow clay subsoil.	.036	.55	5.9
7A	do	1906	do	Badly rosetted	Sandy surface loam, stiff hard clay subsoil.	.033	.48	5.2
8	Norfolk sandy loam, Stone orchard, Thomasville, Ga.	1904	Fertilized well when young	No rosette, good growth and yield.	Gray loam surface soil, yellow sandy clay subsoil.	.065	1.20	5.6
8A	do	1904	Cultivated to corn	Badly rosetted	do	.040	.90	6.0
9	Norfolk sandy loam, Little orchard, Thomasville, Ga.	1907	Legumes grown and turned under, 1918 to 1923.	No rosette, producing well.	Sandy loam surface soil, yellow sandy clay subsoil.	.047	1.31	5.9
9A	do	1907	Pasture	Badly rosetted	do	.042	.90	5.9
10	Norfolk sandy loam, Demaree rosette-experiment orchard, Thomasville, Ga.	1907	Beginning with 1918 green manuring and commercial fertilizer.	No rosette; badly rosetted prior to 1918.	do	.061	1.51	5.5
10A	do	1907	Beginning with 1918 stable manure annually.	do	do	.094	1.84	6.0
10B	do	1907	No fertilizer, no cultivation	Badly rosetted	do	.048	1.29	5.4
11	Norfolk fine sandy loam, Demaree rosette-experiment orchard, Cairo, Ga.	1904	20 tons of stable manure per acre.	No rosette	Sandy loam surface soil, sandy clay subsoil.	.141	2.13	6.1
11A	do	1904	No manure	Badly rosetted	do	.031	.64	5.4

[1] Analysis by P. D. Boone, Office of Soil-Fertility Investigations, Bureau of Plant Industry. [2] Analysis by E. F. Snyder, Office of Soil-Fertility Investigations, Bureau of Plant Industry.

DISCUSSION

In orchards affected with rosette the turning under of leguminous crops has proved a highly successful remedy. It is attended by an increased organic-matter content of the soils, which not only furnishes a steady and gradual supply of nitrogen for the trees but improves the physical condition of the soil and increases its moisture-holding capacity. The data procured in the orchards investigated show a close relation between the humus content of the soil and the rosette of pecans. As the organic matter in the soil increased, the rosette of the orchards decreased and gradually disappeared.

Methods of increasing the humus content of a soil vary, but an easy and inexpensive way is by the use of green-manure crops. The application of large quantities of stable manure would probably give the quickest results, but stable manure is expensive and difficult to obtain. The natural growth of grass and weeds allowed to decompose on the ground would likely help somewhat. Applications of ordinary commercial fertilizers alone apparently do not serve as a remedy for the rosette of pecans.

This statement seems applicable also to the rosette of apples. Morris,[3] working with apples on western soils, obtained no apparent improvement with apple rosette by the application of chemical fertilizer, but orchards in which leguminous cover crops were grown outgrew the diseased condition in three to five years. The practice of good farming methods which maintain a high degree of soil fertility is as essential to successful pecan growing on upland soils as it is in the growing of any farm crop. Fertile soil is necessary to develop normal, healthy trees capable of producing good crops of pecans.

In order to determine the relation of the organic matter of the soil to the general growth of pecan trees and the production of nuts, other rosette-free orchards were examined. The data are given below.

EXAMINATION OF THE SOIL OF GOOD AND OF POOR SECTIONS OF ORCHARDS FREE FROM ROSETTE

The soils of eight orchards containing no rosette in which different cultural methods had been practiced were analyzed for nitrogen and organic matter and their acidity determined, so as to ascertain the relation of these factors to the condition of the orchards. In these orchards, each having a uniform soil type, two cultural methods had been practiced. Each presented an opportunity to study the effect of soil and orchard management or fertilization on the soil and on pecan growth and yield.

The soils examined were from orchards situated in Georgia, Florida, and Alabama and are reported as being well adapted to pecan culture. The soil samples were collected in 1921 and 1922, and the orchard record was made at that time. The data are given in Table 11.

Comparisons should be made between the two sections under different cultural treatments in each orchard (Table 11). The soil types and also the tree varieties in each section of each orchard were the same. The differences shown in tree growth and yield are apparently due to cultural treatment. The effect of the soil treatment on the organic matter and nitrogen of the soil is striking, and invariably the greater organic matter and nitrogen content are correlated with good tree growth and yield.

[3] Morris, O. M. Apple rosette. Wash. Agr. Exp. Sta. Bul. 177, 30 p., illus. 1923.

TABLE 11.—*Laboratory examination of soils from productive and unproductive pecan orchards*

Orchard No.	Soil type and location	Variety	Trees set, year	Tree trunk, circumference (inches)	Nut yield	Cultural practice	Soil constituents (per cent)		Soil acidity [2] (pH)
							Nitrogen [1] (N)	Organic matter [1] (C)	
1	Orangeburg sandy loam, Sawyer orchard, Citronelle, Ala.	Miscellaneous	1916	9.1	Good	10-foot alley used for farm crops, tree rows in peas plowed under.	0.064	1.11	5.6
1A	do	do	1916	6.5	Poor	Asparagus grown for market over entire orchard.	.045	.75	5.5
2	Greenville sandy loam, Patterson orchard, Dewitt, Ga.	do	1914	12.0	Good	High state of cultivation and well farmed previous to 1914; cover crops in orchard after that.	.54	1.14	5.6
2A	do	do	1914	9.1	Poor	Poor cultivation and abused previous to 1914; cover crops in orchard after that.	.031	.96	5.6
3	Orangeburg sandy loam, Davis and Miller orchard, Albany, Ga.	do	1917		Good	Orchard in cover crops and cultivated	.041	1.11	
3A	do	do	1917		Poor	Orchard not cultivated; no vegetative matter turned under.	.031	.77	
4	Orangeburg sandy loam, H. K. Miller orchard, Monticello, Fla.	Frotscher, Stuart	1905	46.0	Good	Trees on fence and ditch rows	.158	2.34	6.7
4A	do	do	1905	33.0	do	Trees in field adjoining	.043	1.35	6.5
5	Norfolk sandy loam, Wight orchard, Cairo, Ga.	Frotscher	1906	46.0	do	Tree on fence row and lower area	.110	2.80	5.8
5A	do	do	1906	30.0	Fair	Average size tree in field adjoining	.047	.89	6.4
5B	do	do	1906		Good	Trees heavily manured	.014	2.30	6.1
6	Norfolk deep fine sandy loam, North Florida Pecan Co. orchard, Monticello, Fla.	Schley	1911	36.0	do	Tree in yard and near house; no cultivation and cover crops.	.084	1.57	
6A	do	do	1911	25.0	Poor	Tree in field near house	.060	.92	
7	Orangeburg sandy loam, Leach orchard, Monticello, Fla.	Stuart	1917	21.0	Good	Tree in yard and near chicken house	.064	.98	6.7
7A	do	do	1917	16.0	do	Average size tree in field; cover crops grown and turned under.	.046	.44	6.4
8	Norfolk sandy loam, Little orchard, Thomasville, Ga.	Frotscher	1911		do	Very large tree in yard near house	.650	1.45	6.7
8A	do	do	1911		Poor	Field adjoining house	.047	.40	5.8

[1] Analysis by P. D. Boone, Office of Soil-Fertility Investigations, Bureau of Plant Industry.
[2] Analysis by E. F. Snyder, Office of Soil-Fertility Investigations, Bureau of Plant Industry.

The data shown for orchard No. 1 are interesting. The entire orchard was fertilized with chemical fertilizer. One section of the orchard, on which asparagus was grown, was cultivated in the spring and no further attention given the soil during the year. In the other section corn was grown on strips 15 or 20 feet wide between the tree rows, and the remainder of the ground was seeded to cowpeas annually. A stunted tree growth resulted where asparagus was grown; these trees came into bearing late, and the yield was small; and the soil was found to contain much less nitrogen and organic matter. Results similar to these are frequently seen where nursery stock is grown in a portion of a pecan orchard, a practice which frequently has a detrimental effect on growth and productiveness.

The results of improving the soil and putting it in a high state of fertility before planting the orchard are shown in orchard No. 2. Previous to setting this land to pecan trees, one section had been well cultivated and its fertility carefully maintained. The other section was poorly farmed for years, and as a result it was in an impoverished condition. The growth of the pecan trees during the first seven years after the orchard was planted was considerably better on the good farm than on the poor one, even though the trees on both farms received the same cultural treatment. The general appearance of the trees on the farm which was well tilled previous to planting is shown in Plate V and that of those on the farm poorly tilled previous to planting in Plate VI. The nitrogen and organic matter of the soil at the time the sample was taken in 1921 were much higher in the soil from the good farm than from the poor one.

The results of growing cover crops for green manuring as compared with no cover crops and no cultivation are shown in orchard No. 3. The trees in the cultivated sections during their first four years of growth had developed a great deal more rapidly than the others. The soil was found to contain 1.11 per cent of organic matter (C) as compared with 0.77 per cent for the uncultivated section. The nitrogen content was also higher.

It is frequently observed that pecan trees growing beside a fence or a ditch bordering an orchard develop more rapidly and yield better than do trees in the orchard adjoining, even though the latter may be well tilled. Illustrations of this were afforded by orchards Nos. 4 and 5. In both cases the two were thrifty and good yielders, but trees adjacent to the fence and ditch were much larger and yielded nearly twice as many nuts. Ordinarily considerable débris accumulates near a fence or ditch and appears to be the cause of improved tree growth. The organic matter and nitrogen were found to be more than twice as great in the soil near the fence and ditch as in adjoining fields. It is also frequently observed that pecan trees in or near barnyards or dwellings do much better than trees in adjoining orchards. Illustrations of this are given in orchards Nos. 6, 7, and 8. The trees in orchard No. 7 are shown in Plate VII, *A* being a large tree near a chicken house and *B* a typical tree in a field adjacent to the yard. A great difference is shown in the size of the two trees. The trees in orchard No. 8 are shown in Plate VIII, in which *A* is typical of the trees in the field and *B* shows the tree near the dwelling, photographed at the same distance. The latter was a much larger tree and a heavier yielder. The organic

matter and nitrogen in the soils under trees growing in the yards near dwellings were much greater than in the adjoining orchards, and the nut yields were correspondingly greater. All of these soils, as shown by hydrogen-ion exponents, were slightly acid, but practically no difference was found between the degree of acidity of the soils producing large and small crops of pecans.

SUMMARY

Two badly rosetted orchards grown on soils low in both organic matter and fertility were subjected to different cultural treatments, one of which included plowing, thorough cultivation, and the growing and turning under of two green-manure crops each year; the second included only a light disking annually and the growing of grasses and weeds with no plowing. In the latter case, the vegetation produced was cut and removed as hay and none turned under. Chemical fertilizers, as used in the experiments, had no influence in decreasing or increasing rosette.

The former treatment was coincident with an increase in the supply of organic matter and nitrogen in the soil, which resulted in a gradual improvement and finally in the apparently complete disappearance of all rosette symptoms on the trees and a return to a normal production of nuts. On the other hand, the second cultural treatment was coincident with a decrease of organic matter and of nitrogen in the soil and a marked increase of rosette symptoms, resulting in the abandonment of the orchard.

Soils from healthy and rosetted sections of pecan orchards of uniform soil type and of uniform tree age and variety were examined in the field and laboratory. There is a close correlation in these orchard soils having a high nitrogen and organic-matter content with healthy productive trees and of soils having a low nitrogen and organic-matter content with unfruitful rosetted trees. There was no correlation of soil acidity with good or poor pecan orchards.

In orchards free from rosette there is a correlation of high nitrogen and organic-matter content of soil with productive trees and of a low nitrogen and organic-matter content with poor tree growth and poor nut yield.

It is apparent that the accumulation of organic matter in the soils, whether acquired by the growing and plowing under of cover crops or by the addition of manures, composts, or débris, is beneficial to pecan trees and stimulates increased growth and yield.

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