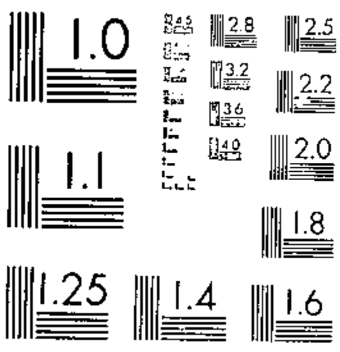
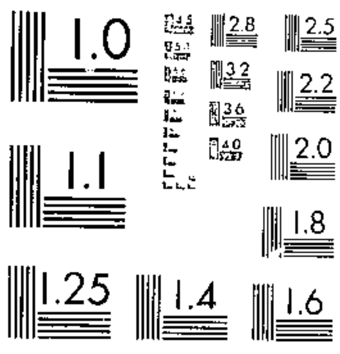
TB 426 (1934) USDA TECHNICAL BULLETINS UPDATA
THE RELATION OF FERTILIZERS TO THE CONTROL OF COTTON ROOT ROT IN TEXAS
JORDAN, H V ; ET AL 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

TECHNICAL BULLETIN NO. 426 AUGUST, 1934

THE RELATION OF FERTILIZERS TO THE CONTROL OF COTTON ROOT ROT IN TEXAS

By

H. V. JORDAN
Associate Soil Technologist

P. R. DAWSON
Associate Biochemist

J. J. SKINNER
Senior Biochemist

and

J. H. HUNTER
Assistant Soil Technologist
Division of Soil Fertility, Soil Investigations
Bureau of Chemistry and Soils

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D.C.

by the Superintendent of Documents, Washington, D.C. Price 10

Technical Bulletin No. 426 — August 1934

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

THE RELATION OF FERTILIZERS TO THE CONTROL OF COTTON ROOT ROT IN TEXAS[1]

By H. V. JORDAN, *associate soil technologist;* P. R. DAWSON,[2] *associate biochemist;* J. J. SKINNER,[3] *senior biochemist,* and J. H. HUNTER, *assistant soil technologist, Division of Soil Fertility, Soil Investigations, Bureau of Chemistry and Soils*

CONTENTS

INTRODUCTION

Cotton root rot is the most destructive plant disease in Texas, in many sections of which it has become an important limiting factor in cotton production. It is also serious in certain portions of other Southwestern States, particularly Arizona, New Mexico, and California; and it occurs in Oklahoma, Arkansas, and Mexico. The causal organism is a soil-inhabiting fungus, *Phymatotrichum omnivorum* which attacks the underground portions of the plants.

[1] The investigations reported herein are a part of correlated studies on this general problem in which the Bureau of Chemistry and Soils and the Bureau of Plant Industry of the U.S. Department of Agriculture, the Texas Agricultural Experiment Station and the University of Texas are cooperating. A number of the experiments were made on substations of some of these organizations and acknowledgment is made of the assistance of H. C. McNamara, superintendent, U.S. Cotton Breeding Field Station, Greenville, Geo. T. Ratliffe, superintendent, U.S. Field Station, San Antonio, Henry Dunlavy, superintendent, substation no. 5, Texas Agricultural Experiment Station, Temple; and other members of the staffs of these stations. Acknowledgment is also made of cooperation of the University of Texas in furnishing premises for laboratory and office use and in extending assistance in many other respects. Valuable assistance in securing field data was rendered by E. R. Collins and W. V. Black, assistant soil technologists, and D. R. Ergle, assistant chemist.

[2] In charge of soil-fertility cotton root-rot investigations, Austin, Tex.

[3] In charge of cotton soil and fertilizer investigations.

While of greatest economic importance in relation to cotton, root rot attacks many other field and truck crops, particularly legumes and root crops; it infects and frequently kills many shade and orchard trees; and it is often a serious menace to ornamental plants and shrubs. Of the field crops only members of the grass family, such as corn, sorghum, and small grains, appear to be free from attack by the disease. It occurs on many species of native vegetation and appears to be indigenous throughout most of the area over which it extends.

The disease has been found in 196 counties in Texas, as reported

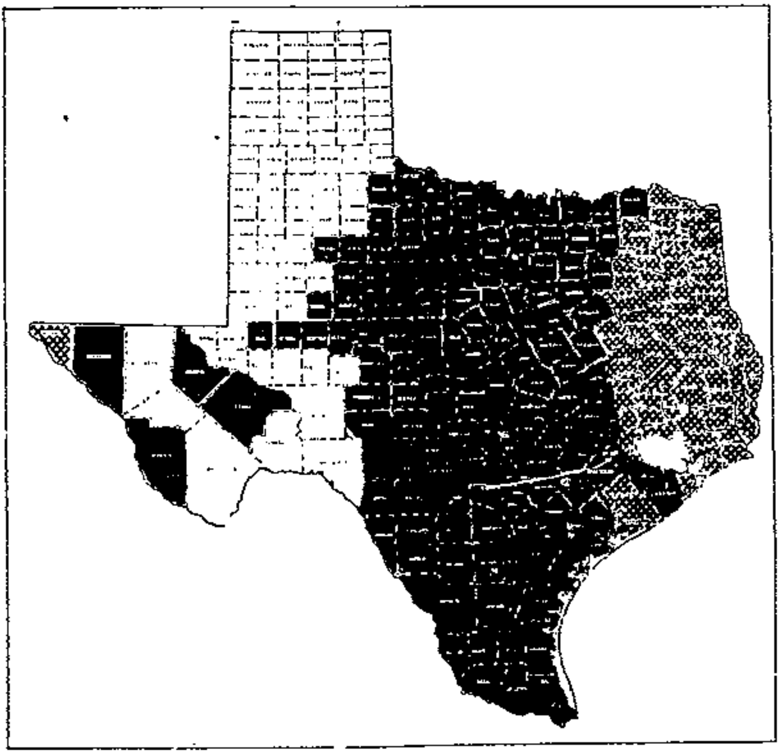


FIGURE 1.—Known distribution of root rot in Texas, black areas indicating counties where it is more prevalent and causes considerable damage, shaded areas counties where the disease is known to be present but is less prevalent, and white areas counties where root rot has not been found, or where no record is available. (Reproduced by permission of the Texas Agricultural Experiment Station, from Bulletin 423 (*66, Fig. 1, p. 6*).)

by Taubenhaus and Ezekiel (*66*).[4] A map showing distribution of root rot in Texas is shown in Figure 1. It is particularly destructive in the black-land prairie section of the State, characterized by heavy clay soils, predominantly calcareous and alkaline in reaction. In light, sandy, acid soils occurring in portions of east Texas, cotton root rot is of minor importance. The annual losses to the Texas cotton crop have been estimated by Taubenhaus and Ezekiel (*66*) at 10 to 15 percent for the State as a whole; but in seasons favorable to root rot the losses in certain localities may greatly exceed these figures. Including the damage to many plants other than cotton affected by the disease, the figure for the average aggregate annual

[4] Italic numbers in parentheses refer to Literature Cited, p. 72.

losses in Texas has been set by the authors cited at approximately $100,000,000.

The damage to cotton is caused by the destruction of plants before maturity of the crop. The fungus infects the roots, destroys the epidermal and cambium layers, and causes the plants to wilt and die

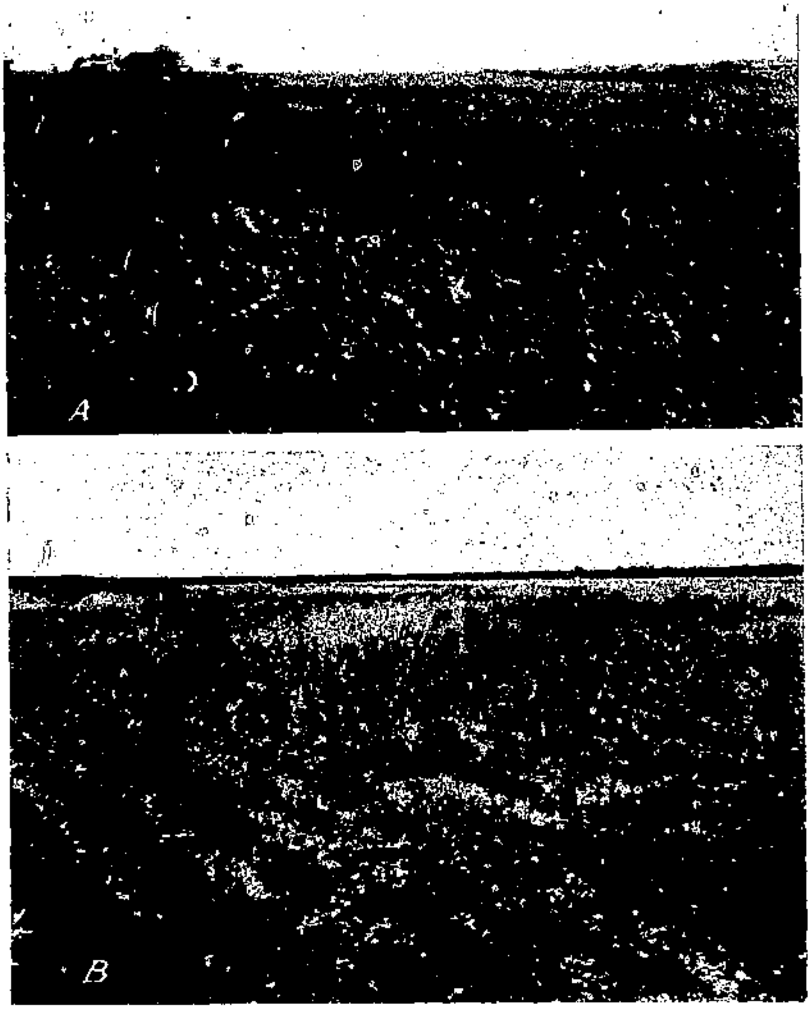


FIGURE 2.—*A*, Root-rot spots in cotton field on Houston clay, Dallas County. *B*, Large field on Houston black clay, Caldwell County, in which cotton has nearly all been killed by root rot. Grass has grown up in places where cotton plants died early in the season. Photographed September 11, 1931.

very quickly. In central Texas the first plants to die usually succumb in June. Killing progresses throughout the crop season at rates varying with the soil moisture, temperature, and other factors not all of which are known. Losses in cotton vary with the proportion of plants which die and their stage of development when death occurs. In Figure 2 are shown root-rot spots in cotton fields and a large field in which nearly all cotton has been killed.

PREVIOUS INVESTIGATIONS

The fungous nature of cotton root rot was first recognized by Pammel in 1888 (*42, 43*). In 1907 Shear (*56*) described the ozonium or vegetative stage of the organism; while Duggar (*10*) in 1916 reported the conidial stage. In recent years numerous studies (*6, 8, 9, 11, 12, 13, 14, 15, 16, 21, 24, 25, 27, 29, 30, 31, 32, 33, 37, 38, 39, 44, 45, 53, 54, 57, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70*) in Texas and Arizona by investigators of the Bureau of Plant Industry and the Texas Agricultural Experiment Station have greatly extended the knowledge of the life history and physiology of the root-rot fungus, the range of cultivated and wild plants affected, the mode of spread and dissemination, means of overwintering and perpetuation, behavior under field crop conditions, and the relation of the fungus to environmental factors.

Investigations by the same agencies on the control of root rot (*1, 6, 11, 12, 13, 14, 20, 21, 22, 23, 26, 27, 28, 29, 31, 32, 40, 46, 47, 48, 49, 54, 58, 59, 63, 66, 70*) have covered a variety of lines of attack. Experiments have been conducted with barriers of sorghum, toxic materials, or open trenches; with soil disinfectants and other toxic materials; and with soil-acidifying agents, such as sulphur and marcasite. Tests have been made of the comparative resistance or susceptibility of different strains, varieties, or species of plants. Extensive trials have been carried out with clean fallows, rotation with nonsusceptible crops, modified tillage, and with application of manure and fertilizers. While no practical means of actually eradicating the disease on a field scale have been forthcoming, measures of control have been developed that offer promise for application under limited conditions.

As far as accumulated evidence indicates, the causal organism of cotton root rot is a soil-inhabiting fungus, and effects its damage through parasitism of the underground portions of susceptible host plants. It should, consequently, be amenable to control through modification of the environmental or soil conditions as they affect the organism or its hosts. Previous experiments on control of the disease by modified tillage or use of soil amendments have had this end in view. Similar approaches to the problem of control have been followed in the case of many other plant diseases, where modification of the soil environment has been accomplished by the application of plant food and soil amendments, or through changed tillage methods. Treatments of this type may be effective either through making the soil less favorable for the causal organism or more favorable for the production of a healthy, disease-resistant plant.

To cite a familiar example, control of the common scab of potatoes has been effected through use of chemical treatments or fertilizer materials which tend to increase or maintain a degree of soil acidity recognized as unfavorable to the disease. The date and character of tillage have been reported to influence the severity of foot rot in wheat, in experiments conducted in Kansas (*55*). The use of liberal quantities of commercial fertilizers has led to material control of the root rot of peas, through delaying onset of the disease and actually decreasing its severity (*18, 19*). The results of investigations in Mississippi (*34, 35, 36*) indicate that potassium salts may be beneficial in reducing damage from Fusarium wilt of cotton; and experiments in Arkansas (*74*) showed definite control of the disease after application of potash-containing fertilizers to soils on which such fertilizer treatment led to stimulation of plant growth and increased yields of seed cotton.

Some previous experiments on the use of fertilizers in relation to control of cotton root rot have been reported. Manure treatments, as described by Scofield (*54*), Taubenhaus and Killough (*70*), and Ratliffe and Atkins (*46*), gave negative or inconclusive results. King and Loomis (*14, 26, 27*), however, have demonstrated a progressive decline in root-rot infestation, following the application of manure and other organic residues over a period of years. Limited trials with commercial fertilizer, reported by Taubenhaus and Killough (*70*) yielded negative or inconclusive results. Later work by the Texas station (*6, Repts. 41, 42, 43; 12; 14; 66*) and by Ezekiel and Neal (*13*) has not shown any direct reduction in root rot, except in pot experiments where the rates of application were excessive. Increases in yield that might offset losses occurred in some instances.

SCOPE OF THE PRESENT INVESTIGATIONS

In 1928, the Division of Soil Fertility undertook a program of investigations in Texas on the relation of soil fertility and the use of fertilizers to the control of cotton root rot. Recognizing that the disease is much more widespread and destructive on certain soil types, or on certain areas of a given type, than on others, studies were directed toward ascertaining what, if any, differences in soil properties are correlated with this unequal distribution. The results have been productive of much fundamental information regarding the characteristics of the prevailing soils; have shed further light upon the soil preferences of the fungus; and have served as a basis upon which to plan and conduct field trials. The data obtained have emphasized the significance of the problem of factors affecting soil fertility.[5]

Other investigations have been concerned with the effects of deep tillage. The most prevalent soils of the black-land prairie section of Texas are characteristically heavy and highly colloidal. Surface drainage is almost everywhere satisfactory, but internal drainage is deficient. Accordingly a modification of soil conditions through deep tillage has been attempted, with striking results in the suppression of root rot.

A further very important phase of the investigations consisted of a series of field fertilizer experiments, inaugurated in 1928 and continued through the succeeding seasons. The object of these experiments was to study the effects of added plant food upon the maturity and yield of the cotton crop growing under conditions of root-rot infestation, and upon the resistance of the plants to the disease. The work has been done exclusively with cotton, and with a few exceptions the experiments have been conducted in fields uniformly infested with root rot.

Detailed reports of the studies on soil characteristics and on the effects of subsoiling are reported elsewhere. This bulletin presents a progress report of the field experiments with fertilizers from 1928 to 1931, inclusive.

---

[5] Members of the staff of the Austin station of the Bureau who rendered valuable assistance in securing data are Prinston Jenkins, H. A. Nelson, John Parker, H. E. Cone, and L. M. Green.

These field experiments have been confined almost entirely to the black-land prairie section of Texas in which cotton root rot is widely prevalent and of great economic importance. The fields have been so located, however, as to cover the range of variations in climatic conditions and soil types characteristic of this section.

CLIMATE

The section in which the investigations were conducted is characterized by a climate distinctly subhumid in the extreme southern part, with rainfall gradually increasing to the north. The mean annual rainfall at San Antonio is 27.18 inches; at Austin, 34.08 inches; at Temple, 33.96 inches; at Waco, 35.26 inches; at Dallas, 36.16 inches; and at Greenville, 37.63 inches.[6] Normally, a period of hot, dry weather occurs during the latter half of June, July, August, and September, and at this time evaporation and transpiration are high. The relatively low rainfall complicates the problem of securing maximum returns from added plant food, and this is made even more acute by its unfavorable distribution.

The season of 1928 was characterized by a wet period in early summer. Rainfall was plentiful in the early part of the growing season of 1929 also. The summer, however, was quite dry in the northern part of the section, although in the southern part rains continued well into July. 1930 was characterized by a comparatively wet spring and a very dry and hot summer, the conditions becoming more extreme in the northern part of the section. 1931 was almost the reverse, with a dry period in the early growing season, followed by fairly well distributed rains and generally less extreme temperatures.

Taubenhaus and Dana (*62*) have shown that rainfall during the growing season is of major importance among the climatic factors influencing the severity of cotton root rot. Rains at this time cause more rapid spread of the disease and consequent increased destructiveness. This correlation is borne out in these experiments. Plant mortality, with its resultant loss from root rot, was high in 1928. In 1929, the disease was much more destructive in the southern part of the section than in the northern. In 1930, losses from root rot were not large on any of the fields occupied by the tests. Losses in 1931 were of considerable magnitude throughout the section.

SOILS

The black-land prairie section of Texas is characterized by its predominant soils of very dark color and heavy clay texture, which when wet assume a waxy, sticky consistency, leading to the common name of "black waxy land." These soils are widely known for their productivity, which has remained at a remarkably high level. Almost no fertilizer and very little manure are used; in many fields cotton is grown practically continuously; and the use of cover or green-manure crops is not common.

The most prevalent soils are those of the Houston series which, according to Carter (*5*), covers about 80 percent of the total upland area of the section. The most important members of this series are Houston black clay and Houston clay. Soils of the Wilson series,

[6] Rainfall figures compiled from U.S. Weather Bureau's Climatological Data, Texas Section (*72*).

including both the clay and the clay loam, are second in extent. The terrace correlatives of the Houston and Wilson soils, classified in the Bell and Irving series, respectively, are important in local areas. Other soil types of minor extent occur in the general section. Experiment fields were located on representative areas of these soil types.[7]

DETAILED PLANS OF THE EXPERIMENTS

These experiments were planned according to the well-known triangle system for fertilizer experimentation (*52*). The triangular diagram was originally suggested by Schreinemakers in 1893 (*50*) and again by Bancroft (*2*) in 1902 for application in physical chemistry where graphic representation of percentage composition of three component parts is involved. Its application to plant-nutrient studies was originated by Schreiner and Skinner (*51*) in a study involving nutrient solutions; and it has since been used extensively in aqueous culture investigations (*60, 71*). Its first application to field fertilizer experiments was in a rotation experiment at Arlington Experiment Farm, Va., and at Pennsylvania State College (*41*); it has since been used extensively in field experiments with many crops throughout the United States. The scheme has proved valuable as a basis for preparing fertilizer mixtures, charting data, and interpreting results. Its application in the fertilizer industry has been suggested by Bear (*3*).

The fertilizer analyses [8] used in the present work are shown in the diagrams in figure 3. It will be noted that all mixtures contain a total of 15 percent of plant food. Those represented at the apexes of the triangle contain only 1 of the usual components of a fertilizer mixture, namely, nitrogen, phosphoric acid, and potash. Those represented along the boundary lines contain 2, and those in the interior of the triangle 3, of the components of a complete fertilizer.

It will be noted further that the mixture represented at the top apex contains 15 percent of nitrogen; those on the line just beneath contain 12 percent; and those on successively lower cross lines contain 9, 6, and 3 percent, and no nitrogen, respectively. A similar arrangement for phosphoric acid will be noted when reading from the lower left; and for potash when reading from the lower right. Thus any proportion of the fertilizer elements can be plotted in a triangular representation such as this, although those actually used differed from each other in steps of 3 percent.

Such a series of fertilizer analyses is of special value because of the facility with which the results can be interpreted. In a field which shows major response to phosphoric acid, for example, response would be of a low order to ratios containing none of this constituent. The response would be progressively greater to ratios containing respectively, 3, 6, 9, 12, and 15 percent. An actual example of such an instance is furnished by the results of the Craig experiment for 1928, represented diagrammatically in figure 20, *A*. The trend of response here is unmistakable. A similar trend, differing only in the location of maximum response, is shown in the plotted results from other field experiments.

[7] Acknowledgment is made of the assistance of W. T. Carter, senior soil scientist, Division of Soil Survey Bureau of Chemistry and Soils, in correlating the soil types on which the experiments were conducted.

[8] Throughout this bulletin the figures in a fertilizer analysis refer, respectively, to the percentages of nitrogen, available phosphoric acid, and potash.

The complete series of 21 ratios was applied in only two of the experiments reported here, namely, those on the Craig and Oscar Nelson fields. For the other experiments a selection was made of 9 fertilizers, including those at the apexes of the triangle and others at interior key points. These analyses are represented by figure 3, *B*.

The restriction of most of the experiments to 9 ratios was found necessary in order to confine the plots to areas as uniform as possible in respect to soil and root-rot infestation, without too greatly reducing the size of individual plots. The map of a typical experiment field indicating by black lines the distribution of dead cotton when the field was selected is shown in figure 4. Root rot spreads characteristically in all directions from initial centers of infection. Invasion of narrow plots by infection originating in adjacent plots might partially or completely mask any effect of a given plot treatment upon the disease. Accordingly, in most of the experiments, the plots were from 6 to 8 rows in width and from 200 to 250 feet in length. One exception was the Craig experiment, where 21 ratios were employed with but two-row plots. In this case limitation to narrow plots was necessary in order that all should transect an area of relatively uniform root-rot infestation. The plots were, however, approximately 500 feet in length, about half of which was in noninfested ground. In the experiment at the United States Cotton Breeding Field Station at Greenville, two-row plots, 400 feet in length, were replicated three times. The Oscar Nelson experiment, comprising 21 fertilizer ratios, was on noninfested ground and was laid out with four-row plots.

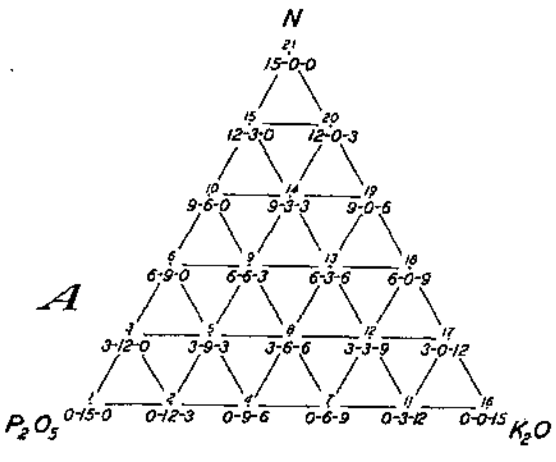


FIGURE 3.—Triangle diagrams of 21 fertilizer analyses (*A*), and of the 9 fertilizer ratios used in most of the experiments (*B*).

The plots were arranged in series in which at least every fourth plot received no fertilizer and served as a check plot. In making

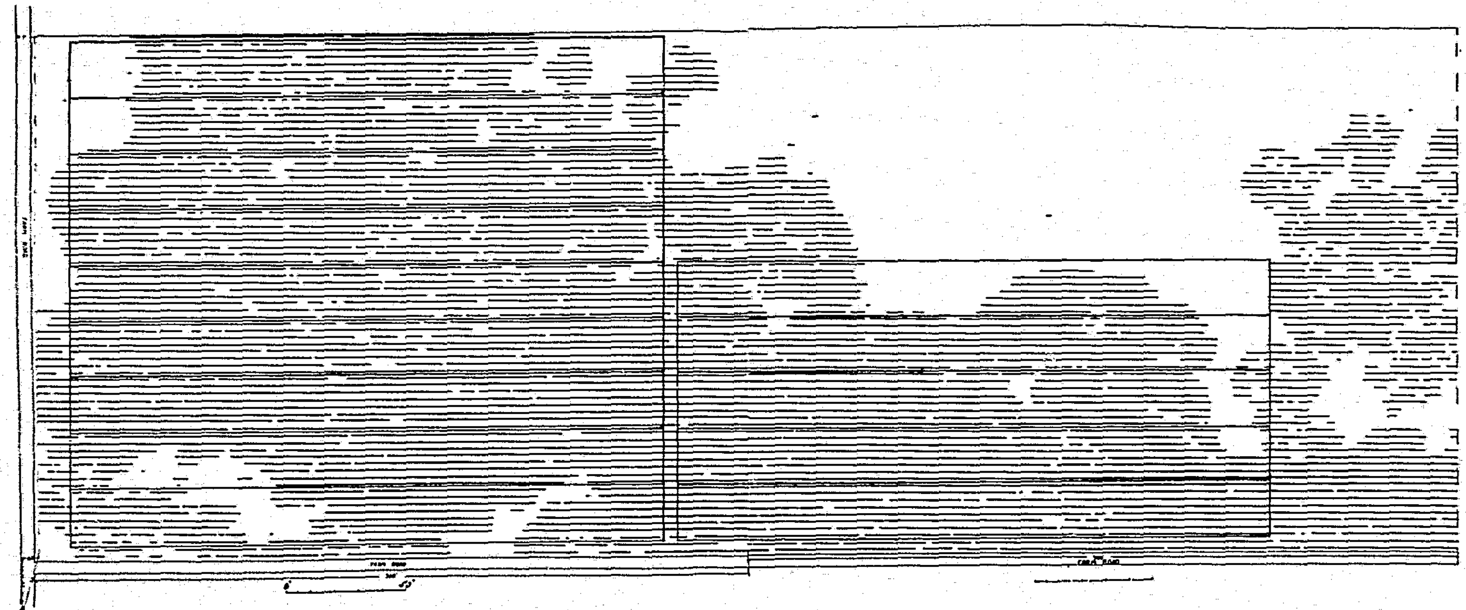


FIGURE 4.—Diagram of a typical experiment field, the black lines showing the distribution of dead cotton at the time the ground was selected and before experimental treatments began; J. W. Jones field, series 1, November 4, 1928.

comparisons of yields, treated plots adjoining check plots were compared with those checks, and the interior one of three adjacent treated plots with the average of the two nearest checks. Such a method of comparison reduces to a minimum the errors arising from soil variations and unequal distribution of root rot. A different arrangement was followed at substation no. 5 of the Texas Agricultural Experiment Station at Temple. Here the plots were grouped in three tiers, the center one of which was untreated. Accordingly, there was a check plot adjacent to each treated plot. Each treatment was replicated eight times in 1929, but owing to a reduction in the area of the experiment in the succeeding years only four replications were retained. Plots in this experiment were 9 rows by 44 feet.

The fertilizer mixtures employed in the triangle ratio experiments were compounded from the commonly used commercial materials.

FIGURE 5.—Method employed in applying fertilizer to experiment plots in most of the experiments.

Except where specific statement to the contrary is made, nitrogen was derived from one third each nitrate of soda, sulphate of ammonia, and cottonseed meal; phosphoric acid was from superphosphate, and potash from sulphate of potash. These experiments were supplemented by comparative tests of various sources of nitrogen and phosphoric acid; and many of the newer, highly concentrated fertilizers were compared with the more commonly used lower grade goods. The fertilizers were applied in most cases at the rate of 600 pounds of 15-percent goods per acre, or the equivalent. In a few experiments lower rates of application were compared with this standard rate.

Applications in most of the experiments to be described were made a week to 10 days in advance of planting, and bedded on. A type of distributor was used which deposited the fertilizer in a rather concentrated stream and about an inch below the bottom of the furrow as shown in figure 5. The placement was thus directly beneath where the seed was eventually planted.

The experiment fields were under close observation throughout the season; and map records of the distribution of cotton killed by root rot were made at frequent intervals.

Most of the experiments were conducted in cooperation with representative farmers and landowners of the section. A number

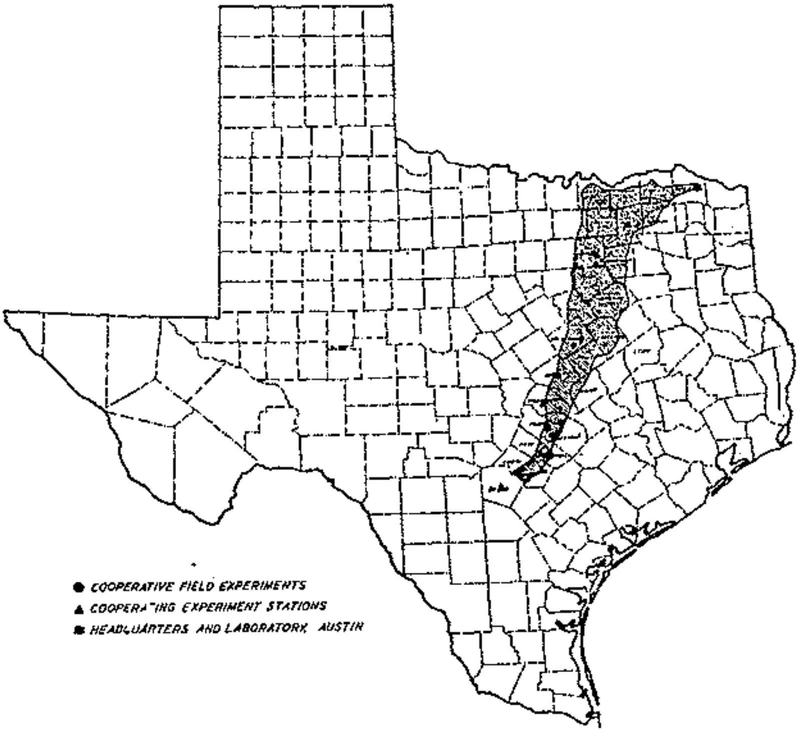


FIGURE 6.—Location of field experiments in Texas, the shaded area representing the major black-land prairie section, according to Carter (*5*).

were carried out with the cooperation of field stations of the Bureau of Plant Industry and of the Texas Agricultural Experiment Station. The geographical distribution of the work is indicated on the map in figure 6. Further information with regard to the fields is given in table 1.

TABLE 1.—*Location of experiment fields, soil types, and duration of experiment*

Name of field [1]	County	Soil type	Duration of experiment	Remarks
R. W. Craig	Hunt	Wilson clay loam	1928–31	
United States Cotton Breeding Field Station.	do	Wilson clay	1928–31	
A. J. King	Dallas	Houston black clay, flat phase.	1929–31	
E. B. Rango [2]	do	Houston black clay, noncalcareous phase.	1929–31	
W. E. Jones [2]	do	Houston black clay	1930–31	Results in 1930 not comparable due to irregular planting.
J. W. Jones (White estate, owner).	do	Bell clay	1929–31	First planting of 1930 crop destroyed by hail; replanted crop severely damaged by bollworm.
J. B. Earle	McLennan	Miller silty clay loam, heavy-subsoil phase.	1929–31	
J. J. Cooper	do	Houston clay	1931	
Substation no. 5, Texas Agricultural Experiment Station.	Bell	Houston black clay	1929–31	
Carl Stried [4]	Williamson	Denton clay	1931	
A. Peterson (Nelson estate, owner).	do	do	1929–31	
O. Nelson [3] (C. E. Nelson estate, owner).	do	Irving clay	1929–31	Yields in 1929 not comparable due to insect injury.
W. F. Voelker	Travis	Houston black clay, flat phase.	1929–31	Poor stand on part of field in 1930. Yields not comparable.
W. H. A. Nelson, experiment no. 1.[5]	do	Houston black clay, gravelly phase.	1929–31	
W. H. A. Nelson, experiment no. 2.[5]	do	do	1931	
W. C. Blanks [2]	Caldwell	Houston black clay, flat phase.	1930–31	
Blanks plantation, experiment no. 1.[5]	do	Houston clay, flat phase	1931	
United States San Antonio Field Station.	Bexar	Houston clay loam	1929–31	

[1] Names given the fields are those of owners or operators of the farms on which the experiments were conducted. The authors acknowledge here the valuable assistance rendered by these farm owners and operators in connection with the conduct of experiments on their land.
[2] Primarily a test of acidifying agents and special fertilizer materials. Results considered here only in connection with concentrated fertilizers.
[3] Fields not infested with root rot. The experiments were conducted to test fertilizer effect without the variations introduced by an unequal distribution of root rot.
[4] Rotation and fallow experiment under the supervision of H. C. McNamara, superintendent, U.S. Cotton Breeding Field Station at Greenville. Fertilizer supplements applied in 1931 only.
[5] Primarily deep-tillage experiments, a number of fertilizer supplements included.

RELATION OF FERTILIZERS TO COTTON ROOT ROT

Two well-defined effects of fertilizers in crop production, both of which should have value as means of evading or offsetting cotton root-rot losses, are respectively, accelerated maturity and increased yields. Acceleration of maturity is of particular significance in relation to a progressive disease such as root rot; while increased yields, if of sufficient magnitude, would fully compensate for resultant losses.

It was shown (*6, Rept. 42, p. 116*) for the season of 1929, at the Temple substation of the Texas station, that cotton which died of root rot in July was practically a total loss in so far as the crop was concerned. Plants dying in August produced 41 percent of a crop; in September, 85 percent; and in October a full crop. The proportion of a crop produced under like conditions will probably vary somewhat from these figures in other seasons and at other locations, but such variations will not be great. It follows, therefore, that a gain of 2 or 3 weeks as a result of accelerating maturity through fertilizers should result in materially larger yields of cotton.

Such an acceleration of maturity must of necessity be reflected in final yields under conditions where a progressive dying of plants occurs throughout the season. It will not be such an important factor in fields free of root rot; or, as is sometimes the case, where cotton does not die until practically mature. It would afford, therefore, insurance against excessive losses from the disease.

Any increase in yield from fertilizer will of course tend to counterbalance the loss from root rot. The extent of loss in any individual field can be estimated only approximately; accordingly, the magnitude of fertilizer effect needed, completely to counterbalance the loss, is necessarily indefinite.

Acceleration of maturity will probably contribute in a very substantial way to increased yields in many cases where root-rot infestation occurs. These two effects of fertilizers are manifestly more or less correlated. Combined they will constitute what might be termed indirect control of the disease.

Other effects of fertilizers in relation to plant disease may lead to more direct control. Accelerated growth and enhanced vigor of plants resulting from adequate supplies of readily available plant food may reduce their susceptibility to attack by root rot or may prolong their period of survival even after infection. Consideration should also be given to a diminished virulence of the disease as a consequence of the influence of fertilizer treatments on the soil environment of the causal organism or upon the activity of competing organisms.

The extent to which such effects have been revealed in the experimental results and their significance in relation to cotton root-rot losses will be developed in the data herein reported.

RESULTS FROM FERTILIZERS ON THE SEVERAL SOIL TYPES

RESULTS ON HOUSTON BLACK CLAY

Houston black clay is one of the most fertile and highly prized soils of the Texas black-land section. It occurs usually in less-eroded situations. The surface soil is a black, highly colloidal clay, which grades into a brown or yellowish-brown clay subsoil. The parent material is marl or chalk. Both soil and subsoil are calcareous, although in this respect the soil differs in degree in different locations.

Experimental data from fertilizer tests on this soil type include 3 years' results on the King field in Dallas County and on the experiment in cooperation with substation no. 5 of the Texas station at Temple, Bell County. Two years' results are included on the Voelker field [9] in Travis County and on the Blanks field in Caldwell County. One year's data are presented on the W. E. Jones field [10] in Dallas County. Summaries of the detailed results are given in tables 2 to 6 and the data are shown graphically in figures 7 to 11.

[9] A poor stand of cotton was obtained on a portion of this field in 1930. The results are accordingly not comparable for the entire experiment; and are not included here.

[10] The results on this field in 1930 were not comparable, owing to irregular planting.

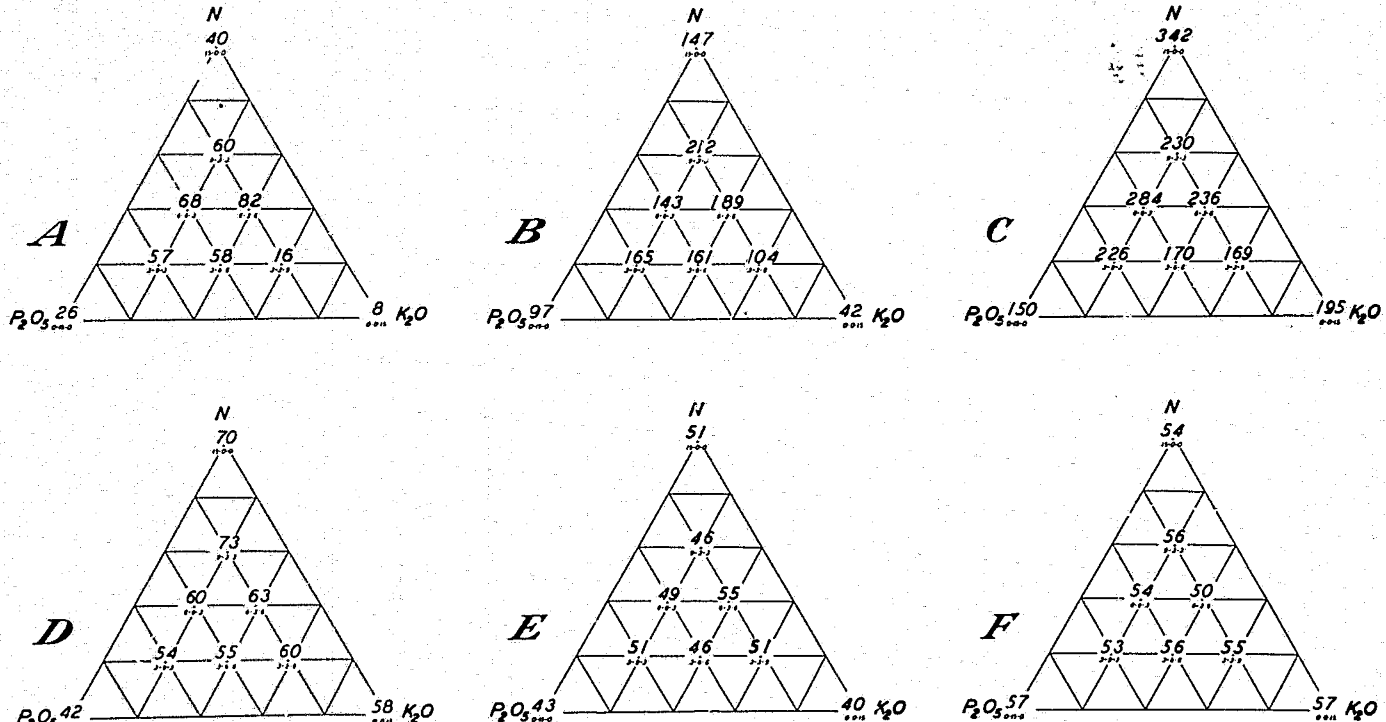


FIGURE 7.—Increases in yield of seed cotton in pounds per acre (*A–C*) and percentages of total yield obtained at first picking (*D–F*) from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Houston black clay, A. J. Kingfield, Dallas County, Tex.: *A*, increases in yields obtained in 1929 over average for check plots of 634 pounds per acre; *B*, increases in yields obtained in 1930 over average for check plots of 500 pounds per acre; *C*, increases in yields obtained in 1931 over average for check plots of 703 pounds per acre; *D*, percentages obtained at first picking in 1929, average for check plots 51 percent; *E*, percentages obtained at first picking in 1930, average for check plots 39 percent; *F*, percentages obtained at first picking in 1931, average for check plots 54 percent.

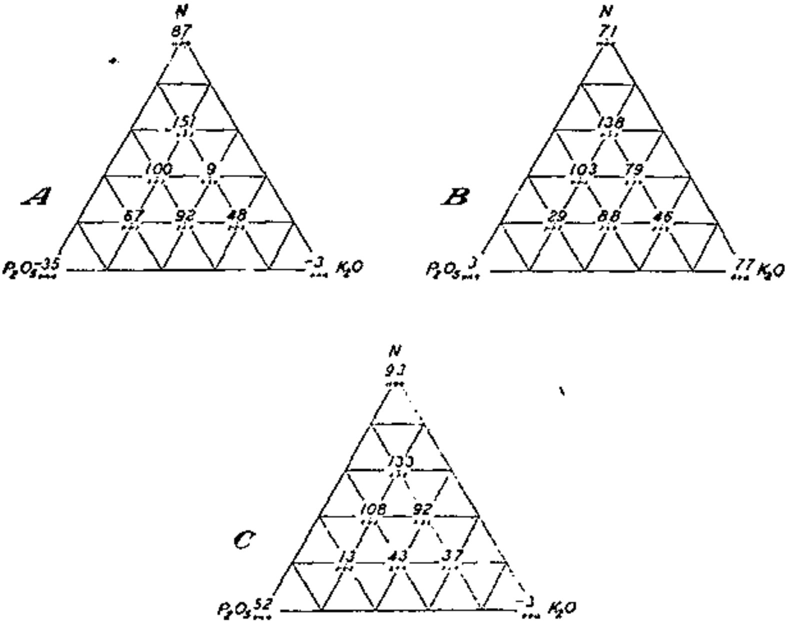


FIGURE 8.—Increases in yield of seed cotton in pounds per acre from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Houston black clay, at substation no. 5, Texas Agricultural Experiment Station, Temple, Bell County: *A*, increases in yields obtained in 1929 over average for check plots of 502 pounds per acre; *B*, increases in yields obtained in 1930 over average for check plots of 502 pounds per acre; *C*, increases in yields obtained in 1931 over average for check plots of 533 pounds per acre.

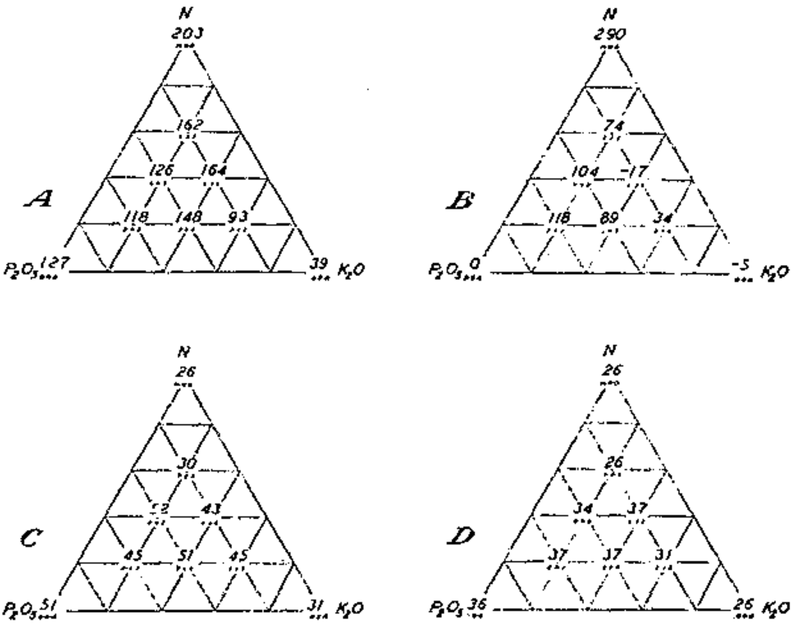


FIGURE 9.—Increases in yield of seed cotton in pounds per acre (*A–B*) and percentages of total yield obtained at first picking (*C–D*) from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Houston black clay, W. F. Voelker field, Travis County, Tex.: *A*, increases in yields obtained in 1929 over average for check plots of 612 pounds per acre; *B*, increases in yields obtained in 1931 over average for check plots of 604 pounds per acre; *C*, percentages obtained at first picking in 1929, average for check plots 39 percent; *D*, percentages obtained at first picking in 1931, average for check plots 30 percent.

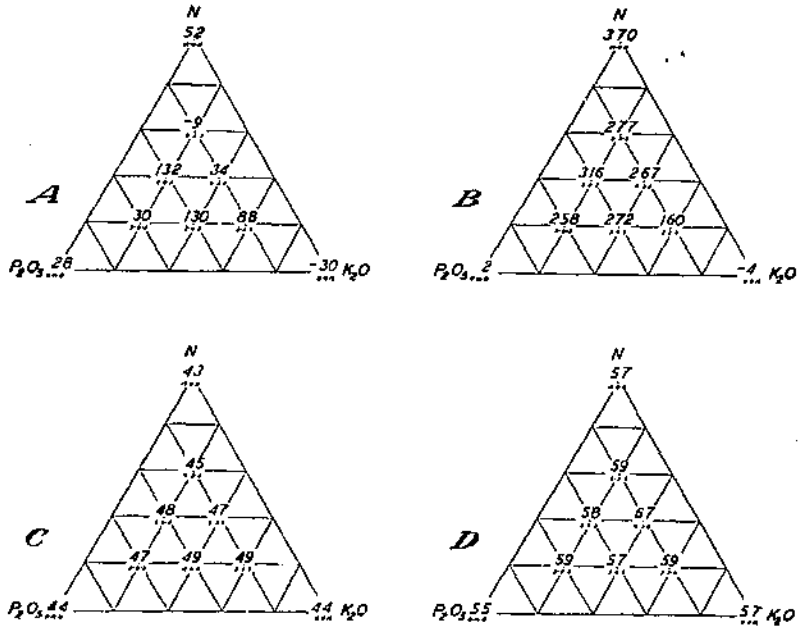


FIGURE 10.—Increases in yield of seed cotton in pounds per acre (*A–B*) and percentages of total yield obtained at first picking (*C–D*) from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Houston black clay, W. C. Blanks field, Caldwell County, Tex.: *A*, increases in yields obtained in 1930 over average for check plots of 763 pounds per acre; *B*, increases in yields obtained in 1931 over average for check plots of 695 pounds per acre; *C*, percentages obtained at first picking in 1930, average for check plots 30 percent; *D*, percentages obtained at first picking in 1931, average for check plots 50 percent.

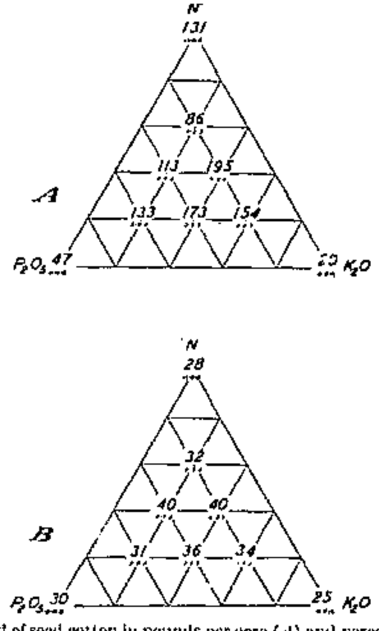


FIGURE 11.—Increases in yield of seed cotton in pounds per acre (*A*) and percentages of total yield obtained at first picking (*B*) from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Houston black clay, W. E. Jones field, Dallas County, Tex.: *A*, increases in yields obtained over average for check plots of 924 pounds per acre; *B*, percentages obtained at first picking, average for check plots 27 percent.

TABLE 2.—*Yields and increases in yield of seed cotton per acre on Houston black clay, flat phase, on A. J. King field, Dallas County, 1929–31*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1929				
		First picking, Aug. 28		Total		Cotton open at first picking
		Yield	Increase[1] from fertilizer	Yield	Increase[1] from fertilizer	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check		193		550		35
1	0-15- 0	244	51	576	26	42
5	3- 9- 3	352	102	646	57	54
8	3- 6- 6	376	69	686	58	55
Check		307		628		49
9	6- 6- 3	419	112	696	68	60
12	3- 3- 9	391	47	654	16	60
13	6- 3- 6	459	78	729	82	63
Check		381		647		59
14	9- 3- 3	519	138	707	60	73
16	0- 0-15	397	15	688	8	58
21	15- 0- 0	528	85	752	40	70
Check		443		712		62

Plot no.[1]	Fertilizer analyses ($N-P_2O_5-K_2O$)	1930					1931				
		First picking, Aug. 21		Total		Cotton open at first picking	First picking, Sept. 23		Total		Cotton open at first picking
		Yield	Increase[1] from fertilizer	Yield	Increase[1] from fertilizer		Yield	Increase[1] from fertilizer	Yield	Increase[1] from fertilizer	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*
Check		208		501		42	338		611		55
1	0-15- 0	255	47	598	97	43	432	94	701	150	57
5	3- 9- 3	340	150	667	165	51	457	113	855	226	53
8	3- 6- 6	306	135	684	161	46	453	103	816	170	56
Check		171		503		34	350		646		54
9	6- 6- 3	318	147	646	143	49	506	156	930	284	54
12	3- 3- 9	299	134	585	104	51	473	111	861	109	55
13	6- 3- 6	357	190	648	189	55	491	118	974	236	50
Check		158		459		34	373		738		51
14	9- 3- 3	312	154	671	212	46	543	170	968	230	56
16	0- 0-15	216	18	539	42	40	552	143	973	195	57
21	15- 0- 0	340	108	682	147	51	629	185	1,160	342	54
Check		238		535		44	444		818		54

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

TABLE 3.—*Yields and increases in yield of seed cotton per acre on Houston black clay at substation no. 5, Texas Agricultural Experiment Station, 1929–31*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1929			1930			1931		
		Yield of plot	Yield of adjoining check plot	Increase from fertilizer[1]	Yield of plot	Yield of adjoining check plot	Increase from fertilizer[1]	Yield of plot	Yield of adjoining check plot	Increase from fertilizer
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	0-15- 0	509	544	−35	556	553	3	664	612	52
5	3- 9- 3	594	527	67	582	553	29	629	616	13
8	3- 6- 6	571	479	92	567	479	88	623	580	43
9	6- 6- 3	581	481	100	573	470	103	533	425	108
12	3- 3- 9	548	500	48	525	479	46	510	473	37
13	6- 3- 6	509	500	9	558	479	79	565	473	92
14	9- 3- 3	632	481	151	608	470	138	558	425	133
16	0- 0-15	476	479	−3	556	479	77	577	580	−3
21	15- 0- 0	614	527	87	624	553	71	709	616	93

[1] Calculated by comparison with adjoining check plot. This experiment involved a test of varieties and planting dates in addition to the fertilizer-analyses comparison. The above data for 1929 are for 3 varieties (Lone Star, Kasch, Delfos) and 2 planting dates. The data for 1930 are for 3 varieties (Bennett, Kasch, and Delfos) and 2 planting dates. The 1931 data involve only a single variety (Qualla) and a single planting date. The table above summarizes the essential data pertaining to fertilizer effect.

Table 4.—*Yields and increases in yield of seed cotton per acre on Houston black clay, flat phase, on W. F. Voelker field, Travis County, 1929 and 1931*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1929					1931[2]				
		First picking, Aug. 10		Total		Cotton open at first picking	First picking, Aug. 18		Total		Cotton open at first picking
		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*
Check		260		542		48	150		549		33
1	0-15-0	344	84	669	127	51	167	17	549	00	36
8	3-6-6	393	103	774	148	51	241	70	652	80	37
5	3-9-3	369	50	827	118	45	255	106	695	118	37
Check		319		709		45	149		577		26
9	6-6-3	432	113	835	126	52	230	81	681	104	34
12	3-3-0	356	85	784	93	45	231	28	747	34	31
13	6-3-6	362	139	837	104	43	307	50	832	−17	37
Check		223		673		33	257		849		30
14	0-3-3	254	31	835	102	30	238	−19	923	74	26
16	0-0-15	201	14	638	39	31	164	−31	639	−5	26
21	15-0-0	186	35	728	203	26	192	59	729	290	26
Check		151		525		29	133		439		30

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

[2] Fertilizer placement was shallow in this experiment for 1931. It is probable that the mineral elements of the fertilizers were not fully effective for this reason (p. 13).

Table 5.—*Yields and increases in yield of seed cotton per acre on Houston black clay, flat phase, on W. C. Blanks field, Caldwell County, 1930–31*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1930					1931				
		First picking, Aug. 15		Total		Cotton open at first picking	First picking, Sept. 11		Total		Cotton open at first picking
		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*
Check		305		540		36	372		773		48
1	0-15-0	384	79	868	28	44	425	53	775	2	55
5	3-9-3	388	115	823	30	47	584	239	989	258	59
8	3-6-6	431	191	875	130	49	545	227	960	272	57
Check		240		745		32	318		688		46
9	6-6-3	419	179	877	132	48	581	263	1,004	316	58
12	3-3-0	405	147	831	88	49	486	156	829	160	59
13	6-3-6	362	86	775	34	47	617	276	917	267	67
Check		276		741		37	341		650		53
14	0-3-3	329	53	732	−9	45	545	204	927	277	59
16	0-0-15	312	29	703	−30	44	372	31	655	−4	57
21	15-0-0	334	45	776	52	43	595	254	1,038	370	57
Check		289		724		40	341		668		51

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

TABLE 6.—*Yields and increases in yield of seed cotton per acre on Houston black clay, on W. E. Jones field, Dallas County, 1931*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	First picking, Sept. 1		Total		Cotton open at first picking
		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check		325		1,022		32
1	0-15-0	323	−2	1,069	47	30
5	3-0-3	323	60	1,051	133	31
8	3-6-6	358	158	986	173	36
Check		200		813		25
9	6-6-3	368	168	926	113	40
12	3-3-9	339	121	1,005	154	34
13	6-3-6	430	104	1,084	195	40
Check		236		889		27
14	9-3-3	314	78	975	86	32
16	0-0-15	238	6	951	20	25
21	15-0-0	309	82	1,104	131	28
Check		227		973		23

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

As indicated in figures 7, 8, 9, 10, and 11, the most effective fertilizer for Houston black clay has consistently been one rather high in nitrogen content. In the King and Blanks experiments for 1931 and the Voelker experiment for both years the 15–0–0 fertilizer has given the greatest increase in total yield. In all other cases, however, a fertilizer with 6 to 9 percent of nitrogen, 3 to 6 percent of available phosphoric acid, and about 3 percent of potash has given the best returns. Such a ratio has also proved well adapted, even where nitrogen alone has been most effective. A 1:1, to 3:1, ratio between nitrogen and phosphoric acid, with perhaps a small proportion of potash, is accordingly indicated.

Both phosphoric acid and nitrogen have accelerated maturity in the experiments on this soil type, with high-phosphate ratios the more effective in most instances. However, high-nitrogen ratios, such as the 9–3–3 and 15–0–0, have been very effective in this respect in all except the Voelker experiment. This is shown in figures 7, *D–E*; 9, *C*, *D*; 10, *C*, *D*; and 11, *B*. Such maturity acceleration has undoubtedly contributed to the higher yields on fertilized plots. As judged by their combined effect on maturity and yields, therefore, the high-nitrogen ratios seem best adapted.

The maximum increases in yield range from 13 percent in the King experiment in 1929 to 53 percent on the Blanks field in 1931. A cumulative effect of fertilizer is evident in the results, as shown by the generally greater response in each successive year. The maximum increases in yield on the King field in the 3 successive years were 82, 212, and 342 pounds, respectively, of seed cotton per acre. The greatest increase in yield on the Blanks experiment in 1930 was 132 pounds and in 1931 it was 370 pounds. Thus the effectiveness of a given treatment should be judged by the average results over a term of years. The effect of fertilizer on cotton plants in several fields of Houston black clay is shown in figure 12.

In the Blanks and W. E. Jones experiments there were included series of plots which received the same fertilizer ratios at 300 pounds per acre, or half the standard rate. Summaries of the results are given in tables 7 and 8, and shown graphically in figures 13 and 14, *A*, *B*.

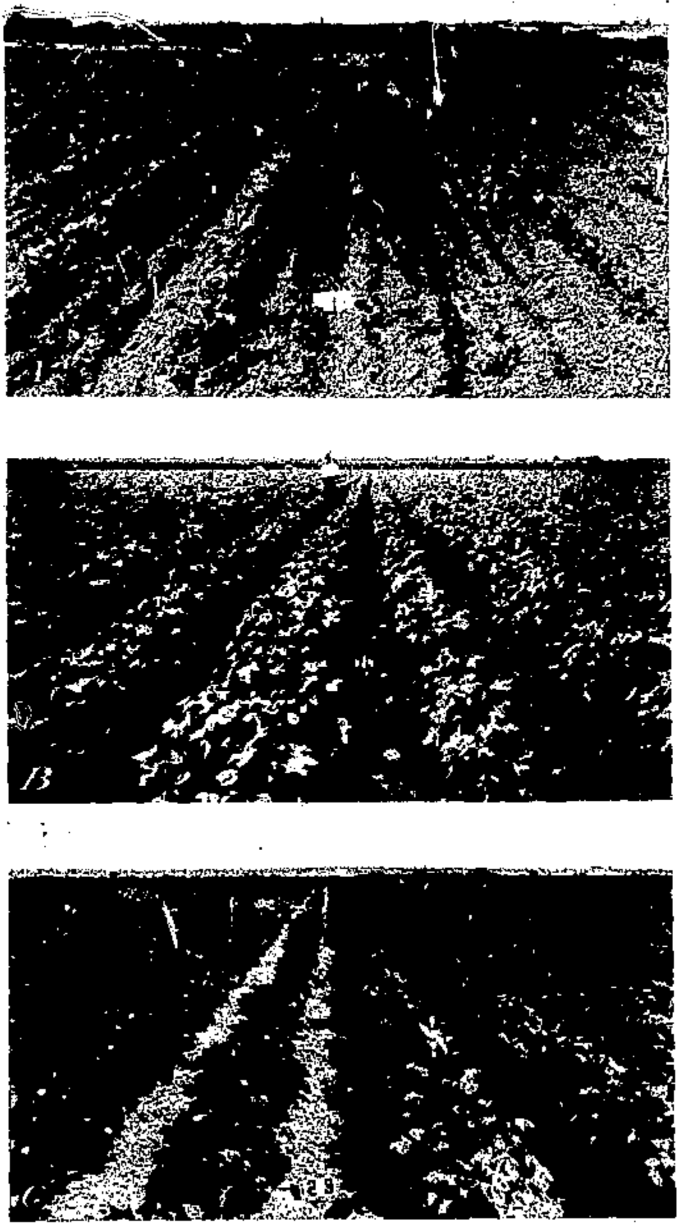


FIGURE 12.—Effect of fertilizers on the growth of cotton on Houston black clay in Texas: *A*, Very young cotton, Range field, Dallas County, June 10, 1931, plot at left treated with 6-10-4 fertilizer at 600 pounds per acre, unfertilized plot at right; *B*, young cotton, W. E. Jones field, Dallas County, plot at left treated with 15-30-15 fertilizer at 150 pounds per acre, unfertilized plot at right; *C*, growth of cotton on W. F. Voelker field, Travis County, photographed July 17, 1930, plot at right treated with 6-6-3 fertilizer at 600 pounds per acre, unfertilized plot at left.

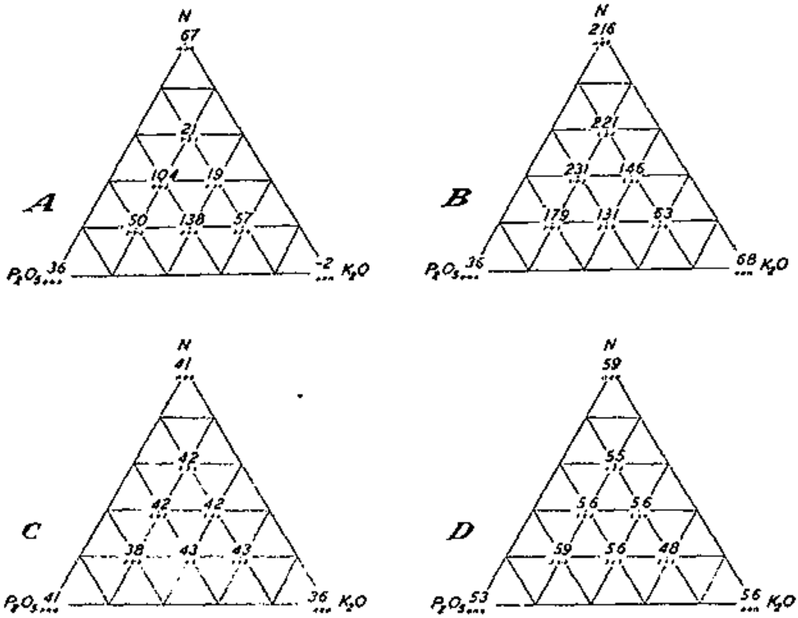


FIGURE 13.—Increases in yield of seed cotton in pounds per acre (*A–B*) and percentages of total yield obtained at first picking (*C–D*) from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Houston black clay, W. C. Blanks field, Caldwell County, Tex., using 300 pounds fertilizer per acre: *A*, increases in yields obtained in 1930 over average for check plots of 705 pounds per acre; *B*, increases in yields obtained in 1931 over average for check plots of 614 pounds per acre; *C*, percentages obtained at first picking in 1930, average for check plots 33 percent; *D*, percentages obtained at first picking in 1931, average for check plots 47 percent.

TABLE 7.—*Yields and increases in yield of seed cotton per acre on Houston black clay, flat phase, on W. C. Blanks field, Caldwell County, when fertilizers were used at the rate of 300 pounds per acre, 1930–31*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1930					1931				
		First picking, Aug. 15		Total		Cotton open at first picking	First picking, Sept. 11		Total		Cotton open at first picking
		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*
Check		226		742		30	310		632		49
1	0-15- 0	319	93	778	30	41	358	40	668	36	53
5	3- 9- 3	294	68	764	50	38	472	184	799	170	59
8	3- 6- 6	354	128	824	138	43	416	151	739	131	58
Check		220		686		33	265		606		44
9	6- 6- 3	330	104	790	104	42	472	207	839	231	58
12	3- 3- 9	323	94	750	57	43	314	56	650	63	48
13	6- 3- 6	301	60	718	19	42	401	150	711	146	56
Check		232		699		33	251		565		44
14	9- 3- 3	304	72	720	21	42	436	185	786	221	55
16	0- 0-15	253	10	695	−2	36	378	82	677	68	56
21	15- 0- 0	314	60	761	67	41	512	171	808	216	59
Check		254		694		37	341		652		52

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with these checks. Intermediate plots are compared with the average of 2 nearest checks.

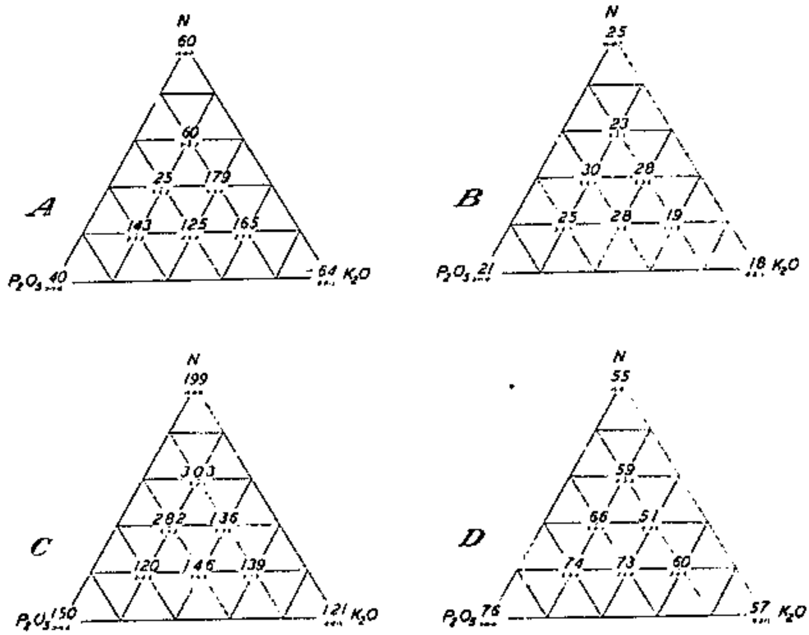


FIGURE 14.—*A*, *B*, Results from using 300 pounds of fertilizer per acre on Houston black clay, W. E. Jones field, Dallas County, 1931: *A*, increases in yield in pounds of seed cotton per acre over average yields from check plots of 971 pounds; *B*, percentages of yield obtained at first picking, average of check plots 23 percent; *C*, *D*, results from using 600 pounds of fertilizer per acre on Houston clay, J. J. Cooper field, McLennan County, 1931: *C*, increases in yield over average yield from check plots of 571 pounds; *D*, percentages of yield obtained at first picking, average of check plots 54 percent.

TABLE 8.—*Yields and increases in yield of seed cotton per acre on Houston black clay, on W. E. Jones field, Dallas County, 1931, when fertilizers were used at the rate of 300 pounds per acre*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	First picking, Sept. 1		Total		Cotton open at first picking
		Yield	Increase from fertilizer [1]	Yield	Increase From fertilizer [1]	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check		298		1,000		30
1	0-15-0	216	−82	1,010	40	21
5	3-9-3	276	28	1,094	143	25
8	3-6-0	290	92	1,027	125	28
Check		198		902		22
9	6-6-3	276	78	927	25	30
12	3-3-0	200	31	1,078	165	19
13	6-3-6	305	165	1,103	179	28
Check		140		924		15
14	9-3-3	227	87	984	60	23
16	0-0-15	163	−27	927	−64	18
21	15-0-0	280	40	1,118	60	25
Check		240		1,058		23

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

When these data are compared with the corresponding results from fertilizers applied at 600 pounds per acre, it is seen that cotton has responded to the same ratios. On the Blanks field the magnitude of response in the two series was about equal in 1930, and only of moderately lower order from the 300-pound rate in 1931. On the W. E. Jones field the increases in yield from the lower acre rate were only a little less than those from the higher rate. In all cases the increase per pound of fertilizer was very much in favor of the 300-pound application. In accelerating maturity the lower rate was also quite effective. These results suggest that lower acre rates than 600 pounds might be more economical on this soil type.

RESULTS ON HOUSTON CLAY

Houston clay is a brown, grayish-brown, or dark-brown clay, with a brown or yellowish-brown clay subsoil. Soil, subsoil, and the parent material are calcareous. The Cooper field in McLennan County is the only one on soil of this type; and only the 1931 results are available, as the experiment was inaugurated in that season. Yield data are presented in table 9 and shown graphically in figure 14, *C*, *D*.

TABLE 9.—*Yields and increases in yield of seed cotton per acre on Houston clay on J. J. Cooper field, McLennan County, 1931*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	First picking, Sept. 3		Total		Cotton open at first picking
		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check		269		473		57
1	0-15-0	473	204	627	150	76
5	3-9-3	440	171	593	120	74
8	3-6-6	452	183	619	146	73
Check		269		473		57
9	6-6-3	499	230	755	282	66
12	3-3-9	423	125	701	139	60
13	6-3-6	398	71	787	136	51
Check		327		651		50
14	9-3-3	563	236	954	303	59
16	0-0-15	447	100	791	121	57
21	15-0-0	484	117	887	199	55
Check		367		688		53

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

It is evident that cotton on this field responded to a fertilizer ratio similar to those that were most effective on Houston black clay. The magnitude of response, however, was much greater. The 9:3:3 ratio gave an increase in yield of 303 pounds of seed cotton per acre, which is 53 percent of the basic yield of the field as indicated by check plots. The 6–6–3 fertilizer was nearly as effective, with an increase in yield of 282 pounds.

The results show that the degree of acceleration of maturity varied directly with the percentage of phosphoric acid in the fertilizer. Even with the 9–3–3 fertilizer, however, maturity acceleration was appreciable. Fifty-nine percent of the total crop was secured at the first picking, as against 54 percent from check plots.

RESULTS ON BELL CLAY

Bell clay is an old alluvial soil occupying a second-bottom or terrace position. The surface soil is a black, highly colloidal clay, similar to the Houston black clay in chemical and physical properties. This grades beneath into dark-gray or brown clay. This soil differs from those of the Houston series in that the depth of the surface soil generally is greater, and especially the depth to parent material. The relief varies from flat to gently undulating. The soil is calcareous throughout the profile.

The J. W. Jones field is representative of this soil type. The experiment comprises two series of plots (designated as series 1 and 2), located at opposite ends of the same 8-acre field. Identical treatments have been used in both series. Series 1 is in an area where root rot is uniformly distributed, although in the years covered by these experi-

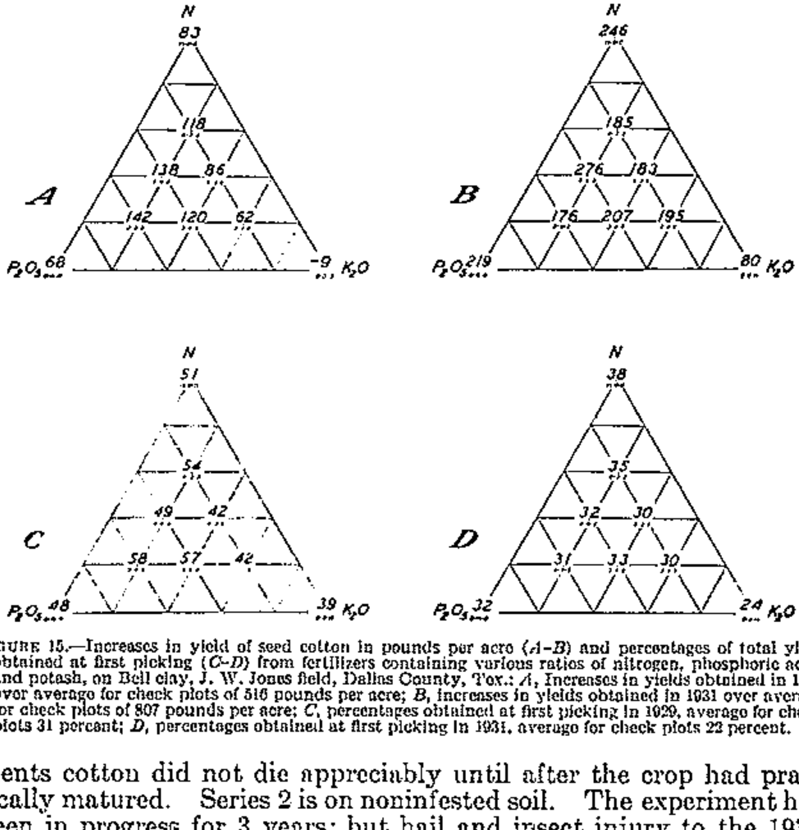


FIGURE 15.—Increases in yield of seed cotton in pounds per acre (*A–B*) and percentages of total yield obtained at first picking (*C–D*) from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Bell clay, J. W. Jones field, Dallas County, Tex.: *A*, Increases in yields obtained in 1929 over average for check plots of 516 pounds per acre; *B*, increases in yields obtained in 1931 over average for check plots of 807 pounds per acre; *C*, percentages obtained at first picking in 1929, average for check plots 31 percent; *D*, percentages obtained at first picking in 1931, average for check plots 22 percent.

ments cotton did not die appreciably until after the crop had practically matured. Series 2 is on noninfested soil. The experiment has been in progress for 3 years; but hail and insect injury to the 1930 crop made the results for that year unreliable.

The soil on which both series of plots are located responded to the same fertilizer ratios. However, the soil of series 2 proved a little more responsive in 1929 and very appreciably more so in 1931. This area has suffered a little more from erosion than the location of series 1, and this may account for the difference, at least in part. Complete data for both series are given in table 10. The essential data were averaged, and these averages are shown graphically in figure 15, which probably represents most accurately what might be expected on this soil type.

TABLE 10.—*Yields and increases in yield of seed cotton per acre on Bell clay on J. W. Jones field, Dallas County, Tex., 1929–31*

SERIES 2

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1930					1931				
		First picking, Aug. 21		Total		Cotton open at first picking	First picking, Sept. 2		Total		Cotton open at first picking
		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*
1	0-15- 0	275	39	559	69	40	340	178	1,150	305	30
Check		236		490		48	168		845		20
5	3- 9- 3	305	160	602	112	66	285	117	1,083	238	26
8	3- 6- 6	408	225	595	142	69	231	114	980	293	24
9	6- 6- 3	381	252	614	198	62	245	180	964	435	25
Check		129		419		31	65		529		12
12	3- 3- 0	300	171	511	95	59	240	175	850	321	28
13	6- 3- 6	314	204	532	117	59	213	134	830	263	25
14	9- 3- 3	205	114	562	149	36	240	148	800	243	28
Check		91		413		22	92		617		15
16	0- 0-15	111	20	414	1	27	123	31	716	99	17
21	15- 0- 0	250	159	566	153	44	314	222	954	337	33

SERIES 1

Plot no.	Fertilizer analyses	1930 Yield	Increase	Total Yield	Increase	Cotton open	1931 Yield	Increase	Total Yield	Increase	Cotton open
Check		201		608		33	318		975		33
1	0-15- 0	315	114	675	67	47	365	47	1,109	133	33
5	3- 9- 3	386	215	775	172	60	399	113	1,097	114	30
8	3- 6- 6	307	160	696	98	44	469	216	1,112	121	42
Check		141		598		24	253		991		26
9	6- 6- 3	239	98	675	77	35	417	164	1,108	117	38
12	3- 3- 0	151	42	630	28	24	344	91	1,063	69	32
13	6- 3- 6	158	80	660	55	24	385	132	1,100	103	35
Check		76		605		13	253		997		25
Check		285		651		44	303		900		33
14	9- 3- 3	522	237	738	87	71	424	121	1,033	127	41
16	0- 0-15	284	82	555	−10	51	282	35	955	60	30
21	15- 0- 0	290	172	510	13	57	440	250	1,037	154	43
Check		118		497		21	190		883		22

AVERAGE

Plot no.	Fertilizer analyses	1930 Yield	Increase	Total Yield	Increase	Cotton open	1931 Yield	Increase	Total Yield	Increase	Cotton open
1	0-15- 0		77		68	48		113		219	32
5	3- 9- 3		187		142	58		115		176	31
8	3- 6- 6		160		120	57		105		207	33
9	6- 6- 3		175		135	49		172		276	32
12	3- 3- 0		107		62	42		133		135	30
13	6- 3- 6		142		86	42		133		183	30
14	9- 3- 3		176		118	54		135		185	35
16	0- 0-15		51		−9	30		33		80	24
21	15- 0- 0		166		83	51		239		246	38

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

There is a tendency for the results on Bell clay to show two major peaks in response as indicated in figure 15, *A*, *B*. High-nitrogen fertilizers have given excellent returns, especially in 1931. The other peak, and in general the more favorable response, has been obtained with a fertilizer containing 3 to 6 percent of nitrogen and 6 to 9 percent of available phosphoric acid. The importance of potash is difficult to establish where only the nine ratios are included, but indications are that it is small. Accordingly a 1 : 3 : 1 or a 2 : 2 : 1 ratio of nitrogen, phosphoric acid, and potash seems best adapted.

An appreciable acceleration of maturity resulted from all fertilizers containing either nitrogen or phosphoric acid alone, or the two in combination. This is shown in figure 15, *C*, *D*. The 3–9–3 analysis gave 58 percent of the total crop at first picking in 1929,

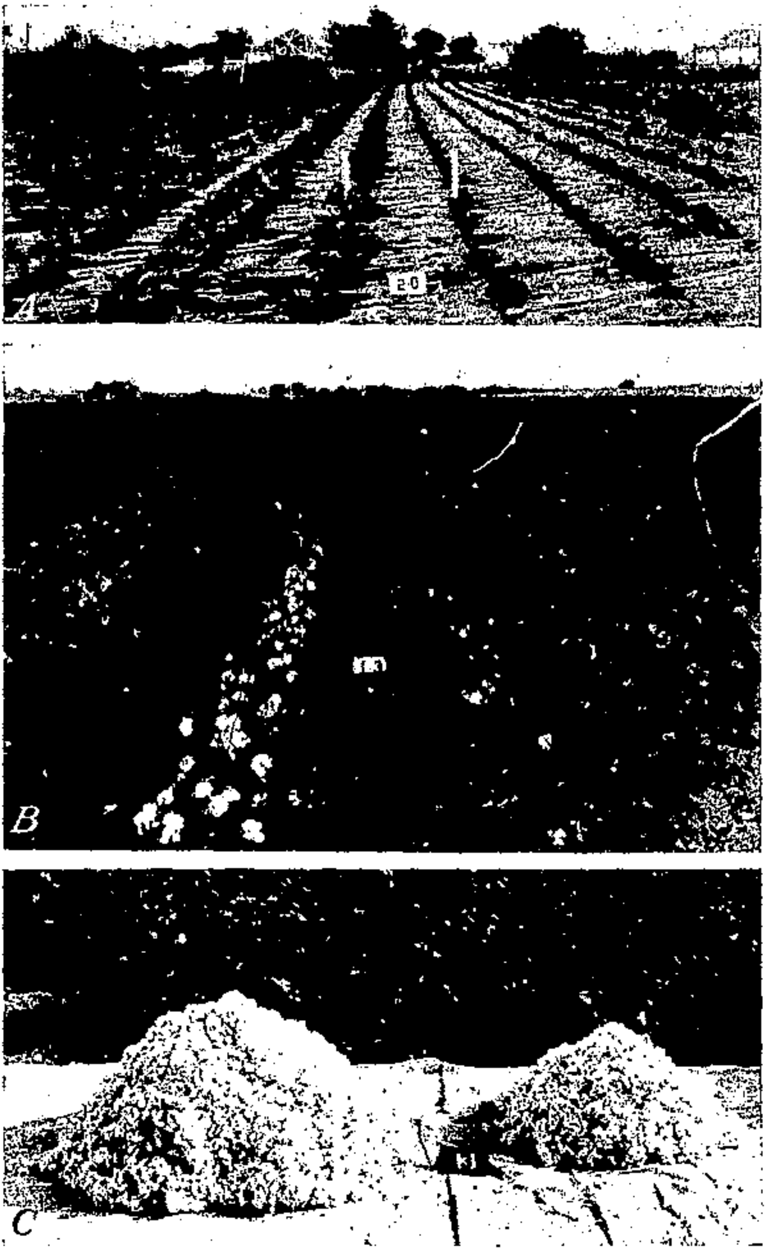


FIGURE 10.—*A*, Effect of fertilizer on early growth of cotton on Bell clay, J. W. Jones field, Dallas County, Tex.; plot at left treated with 3-9-3 fertilizer at 600 pounds per acre; unfertilized plot at right, photographed June 23, 1931. *B*, Effect of fertilizer on the maturity of cotton; rows at left treated with 0-6-3 fertilizer at 600 pounds per acre had an average of 3 times as many mature bolls as the unfertilized rows at the right; leaves plucked in foreground to show open bolls; photographed at date of first picking August 21, 1929. *C*, Effect of fertilizer on early yield. Cotton at left picked from plot treated with 6-8-3 fertilizer yielded at the rate of 381 pounds of seed cotton per acre at first picking on August 21, 1929; cotton at right picked on same date from unfertilized plot yielded at the rate of 129 pounds per acre.

as opposed to 31 percent for the checks. Corresponding figures in 1931 were 31 and 22 percent, respectively. Potash alone accelerated maturity in 1929.

The effects of fertilizer on early growths of cotton, on early maturity, and on yield on Bell clay, are shown in figure 16.

RESULTS ON WILSON CLAY

The surface soil of Wilson clay is dark-gray to nearly black, stiff, heavy clay. Beneath the surface horizon is dark-gray clay; and the substratum below 3 to 5 feet is calcareous clay or marl, light gray to brownish yellow in color. Soil and subsoil are noncalcareous. In small areas the lower subsoil approaches the surface.

The United States Cotton Breeding Field Station at Greenville, Hunt County, is on soil of this type. Four years' data from the experiments conducted here are presented in table 11 and figures 17 and 18.

TABLE 11.—*Yields and increases in yield of seed cotton per acre on Wilson clay at United States Cotton Breeding Field Station, Hunt County, 1928–31*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1928, total		1929				
				First picking, Aug. 26		Total		Cotton open at first picking
		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check		494		137		571		24
1	0-15- 0	515	21	109	−28	553	−18	20
5	3- 9- 3	591	71	166	35	626	57	27
8	3- 6- 6	557	12	163	38	640	74	25
Check		545		125		566		22
9	6- 6- 3	568	23	176	51	659	93	27
12	3- 3- 9	581	66	168	37	628	60	27
13	6- 3- 6	613	128	192	55	671	101	29
Check		485		137		570		24
14	9- 3- 3	602	117	182	45	678	108	27
16	0- 0-15	535	48	127	−8	609	34	21
21	15- 0- 0	548	60	144	12	680	101	21
Check		488		132		579		23

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1930					1931				
		First picking, Aug. 26		Total		Cotton open at first picking	First picking, Sept. 11		Total		Cotton open at first picking
		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*
Check		294		548		54	294		960		31
1	0-15- 0	336	42	563	15	60	375	81	937	−23	40
5	3- 9- 3	404	119	662	120	61	457	135	1,040	82	44
8	3- 6- 6	391	116	650	114	60	452	103	1,045	80	43
Check		275		536		51	349		950		37
9	6- 6- 3	410	135	687	151	60	410	61	1,125	169	36
12	3- 3- 9	398	120	635	109	63	352	34	1,046	127	34
13	6- 3- 6	401	121	645	130	62	350	63	1,086	204	32
Check		280		515		54	287		882		33
14	9- 3- 3	389	109	661	146	59	379	92	1,129	247	34
16	0- 0-15	312	32	549	34	57	302	15	938	56	32
21	15- 0- 0	322	42	566	51	57	310	23	1,069	187	29

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

The most effective fertilizer for this soil is one with from 6 to 9 percent of nitrogen, 3 to 6 percent of available phosphoric acid, and about 3 percent of potash, as will be noted in figure 17. Maximum

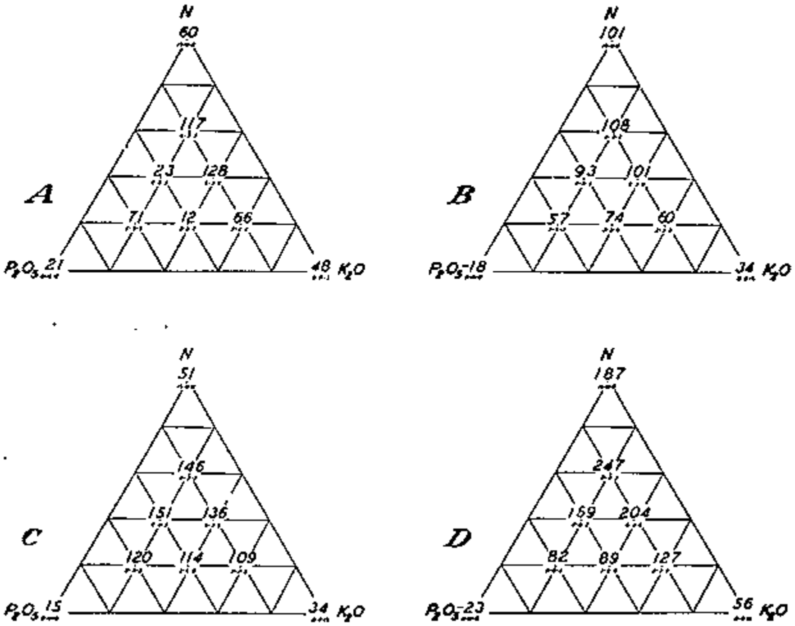


FIGURE 17.—Increases in yield of seed cotton in pounds per acre from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Wilson clay, United States Cotton Breeding Field Station, Greenville, Tex.: *A*, Increases in yields obtained in 1928 over average for check plots of 503 pounds per acre; *B*, increases in yields obtained in 1929 over average for check plots of 572 pounds per acre; *C*, increases in yields obtained in 1930 over average for check plots of 533 pounds per acre; *D*, increases in yields obtained in 1931 over average for check plots of 933 pounds per acre.

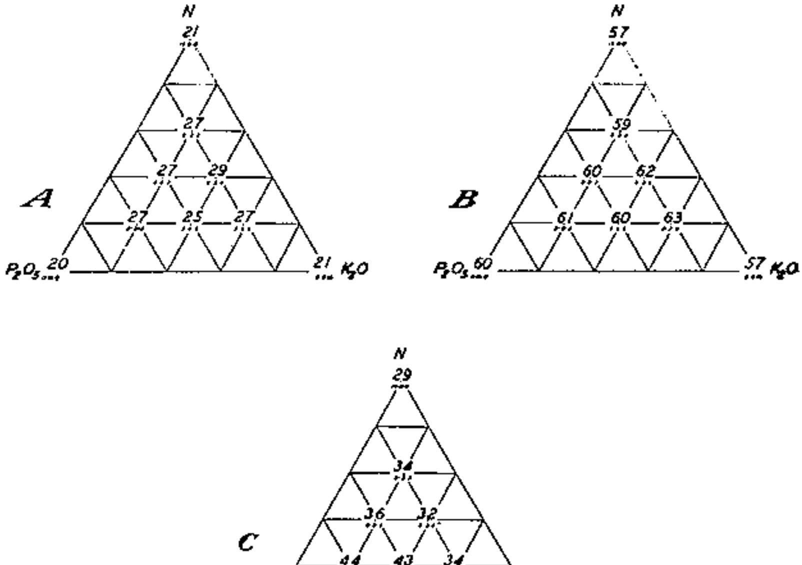


FIGURE 18.—Percentages of total yield of seed cotton obtained at first picking from use of fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Wilson clay, United States Cotton Breeding Field Station, Greenville, Tex.: *A*, Percentages obtained at first picking in 1929, average for check plots 23 percent; *B*, percentages obtained at first picking in 1930, average for check plots 53 percent; *C*, percentages obtained at first picking in 1931, average for check plots 34 percent.

FIGURE 19.—Effect of fertilizers on the growth and yield of cotton on Wilson clay, United States Cotton Breeding Field Station, Greenville, Tex.: *A*, Very young cotton, plot at left treated with 15-0-0 fertilizer at 600 pounds per acre but without visible response, and plot at right treated with 15-30-15 fertilizer at 150 pounds per acre, photographed June 7, 1930; *B*, plot at left treated with 9-3-3 fertilizer at 600 pounds per acre, and plot at right treated with 0-0-15 fertilizer and comparable to unfertilized plots, photographed July 17, 1929; *C*, rows at left treated with 6-6-3 fertilizer at 600 pounds per acre, rows at right unfertilized, leaves plucked in foreground to show open bolls September 27, 1928.

increases in yield varying from 108 pounds of seed cotton per acre in 1929 to 247 pounds in 1931 were obtained from such ratios applied at the rate of 600 pounds per acre.

Data showing the effect of fertilizers on maturity acceleration are lacking for 1928. In the 3 years for which data are shown in figure 18 practically all combinations of nitrogen and phosphoric acid were effective in this respect.

The effects of fertilizers on early growth of young cotton, on growth in midseason, and on yield on Wilson clay are shown in figure 19.

RESULTS ON WILSON CLAY LOAM

The surface soil of Wilson clay loam is a dark-gray to dark-brown, noncalcareous clay loam. Below 6 or 8 inches this grades into stiff

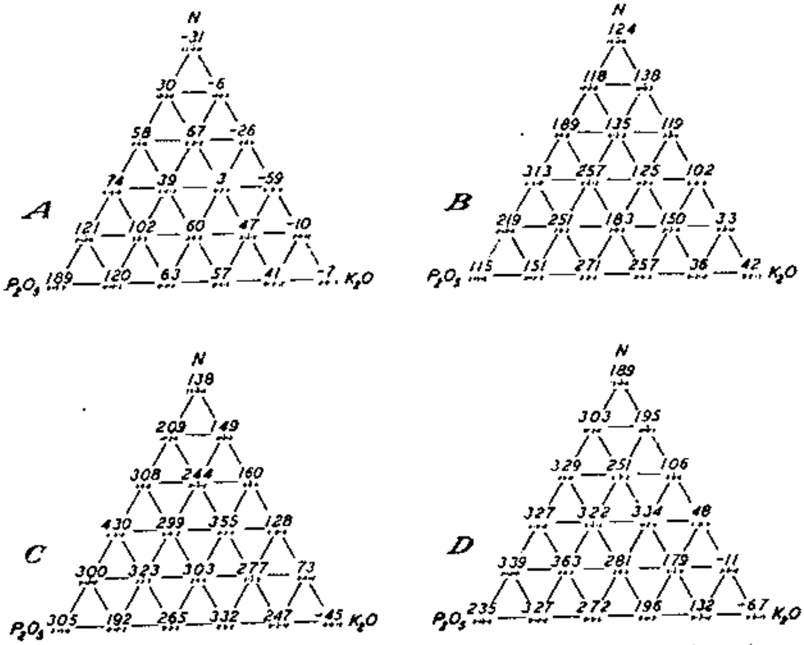


FIGURE 20.—Increases in yield of seed cotton in pounds per acre from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Wilson clay loam, R. W. Craig field, Hunt County, Tex.: *A*, Increases in yields obtained in 1928 over average for check plots of 279 pounds per acre; *B*, increases in yields obtained in 1929 over average for check plots of 454 pounds per acre; *C*, increases in yields obtained in 1930 over average for check plots of 369 pounds per acre; *D*, increases in yields obtained in 1931 over average for check plots of 343 pounds per acre.

brown to grayish-brown clay. The subsoil is yellowish-brown clay, calcareous and filled with concretions of calcium carbonate. The soil mantle in the Craig field, which is representative of this type, is of variable thickness. The subsoil lies at the immediate surface in bands extending diagonally across the field. Between, in areas of deeper soil, it lies at a depth exceeding 3 feet. This soil condition with its effect upon the distribution of the root disease is to be made the subject of a separate paper.

Four years' results of experiments on the Craig field are summarized in table 12, and are shown graphically in figures 20 and 21.

TABLE 12.—*Yields and increases in yield of seed cotton per acre on Wilson clay loam, on R. W. Craig field, Hunt County, 1928–31*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	1928					1929					1930					1931				
		First picking, Sept. 12		Total		Cotton open at first picking	First picking, Aug. 27		Total		Cotton open at first picking	First picking, Aug. 19		Total		Cotton open at first picking	First picking, Aug. 25		Total		Cotton open at first picking
		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*
Check		130		295		44	159		610		26	125		382		33	61		353		17
1	0-15- 0	224	94	484	189	46	332	173	725	115	46	283	158	687	305	41	126	65	588	235	21
2	0-12- 3	196	86	407	120	48	322	179	679	151	47	284	159	574	192	49	189	128	680	327	28
3	3-12- 0	198	108	399	121	50	247	121	664	219	37	322	197	682	300	47	165	104	692	339	24
Check		90		278		32	126		445		28	125		382		33	61		353		17
4	0- 9- 6	140	50	341	63	41	298	172	716	271	42	306	181	647	265	47	211	150	625	272	34
5	3- 9- 3	175	81	376	102	47	277	161	682	251	41	332	221	669	323	50	244	183	716	303	34
6	6- 9- 0	155	56	344	74	45	284	179	730	313	39	348	251	739	430	47	237	176	680	327	35
Check		99		270		37	105		417		25	97		309		31	61		353		17
7	0- 6- 9	142	43	327	57	43	214	109	674	257	32	242	145	641	332	38	148	87	549	196	27
8	3- 6- 6	138	42	344	60	40	227	120	607	183	37	286	198	627	303	46	191	130	634	281	30
9	6- 6- 3	133	41	336	39	40	258	150	688	257	38	260	181	638	299	41	211	150	675	322	31
Check		92		297		31	108		431		25	79		339		23	61		353		17
10	9- 6- 0	156	64	355	58	44	201	93	620	189	32	257	178	647	308	40	242	181	682	329	35
11	0- 3-12	100	11	322	41	31	139	37	474	36	29	217	137	581	247	37	155	96	455	132	34
12	3- 3- 9	118	33	311	47	38	177	82	594	150	30	224	143	605	277	37	162	106	472	179	34
Check		85		264		32	95		444		21	81		328		25	56		293		19
13	6- 3- 6	99	14	267	3	37	172	77	569	125	30	229	148	683	355	34	143	87	627	334	23
14	9- 3- 3	131	50	322	67	41	159	58	589	135	27	194	121	619	244	31	114	58	566	251	20
15	12- 3- 0	114	37	275	30	41	140	34	582	118	24	181	116	631	209	29	133	77	639	303	21
Check		77		245		31	106		464		23	65		422		15	56		336		17
16	0- 0-15	66	−11	238	−7	28	92	−14	506	42	18	59	−6	377	−45	16	39	−17	269	−67	14
17	3- 0-12	82	−3	261	−10	31	85	−17	482	33	18	78	10	477	73	16	51	−11	324	−11	16
18	6- 0- 9	73	−19	238	−59	31	85	−12	535	102	16	113	43	513	128	22	70	2	382	48	18
Check		92		297		31	97		433		22	70		385		18	68		334		20
19	9- 0- 6	91	−1	271	−26	34	99	2	552	119	18	110	40	545	160	20	73	5	440	106	17
20	12- 0- 3	103	1	287	−6	36	87	−1	550	138	16	103	25	545	149	19	92	25	547	105	17
21	15- 0- 0	99	−12	258	−31	38	81	2	515	124	16	90	4	545	138	17	85	20	559	189	15
Check		111		289		38	79		391		20	86		407		21	65		370		18

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

It is apparent from figure 20 that the maximum increase in yield in 1928 was obtained from the 0–15–0 fertilizer. In 1929 and 1930 the most effective ratio was the 6–9–0, and in 1931 the 3–9–3. Evidently cotton on this soil responds chiefly to phosphoric acid, but the presence of some nitrogen, and perhaps a small proportion of potash, in the fertilizer increases its effectiveness. Accordingly, the need for a fertilizer having a 2:3:1 or 2:3:0 ratio of nitrogen, phosphoric acid, and potash is indicated.

The acceleration of maturity by fertilizers has been very marked, as shown in figure 21. The ratio most effective in increasing yields has also been very effective in this respect.

Wilson clay loam is the most responsive soil included in these experiments. The increase due to the most effective fertilizer was for

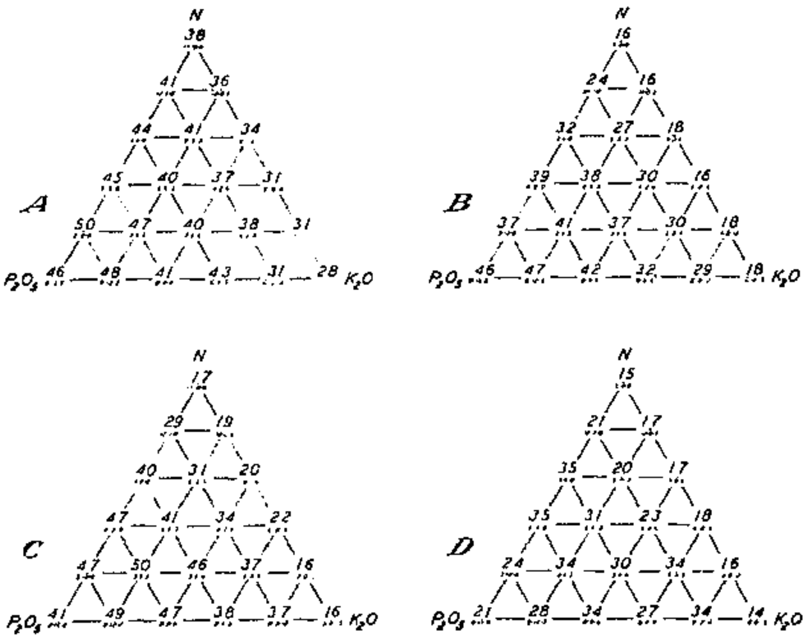


FIGURE 21.—Percentages of total yield of seed cotton obtained at first picking from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Wilson clay loam, R. W. Craig field, Hunt County, Tex.: *A*, Percentages obtained at first picking in 1928, average for check plots 35 percent; *B*, percentages obtained at first picking in 1929, average for check plots 24 percent; *C*, percentages obtained at first picking in 1930, average for check plots 25 percent; *D*, percentages obtained at first picking in 1931, average for check plots 18 percent.

1928, 68 percent; for 1929, 69 percent; for 1930, 117 percent; and for 1931, 106 percent. Incidentally 1930, when the maximum increase in yield was obtained, was the most unfavorable year for fertilizer response of the four. Conditions approaching drought prevailed throughout most of the summer.

The effect of fertilizers on growth, maturity, and yield of cotton on Wilson clay loam is shown in figure 22.

RESULTS ON IRVING CLAY

Soils of the Irving series are the terrace correlatives of the Wilson soils. The Irving clay resembles the Wilson clay closely, differing

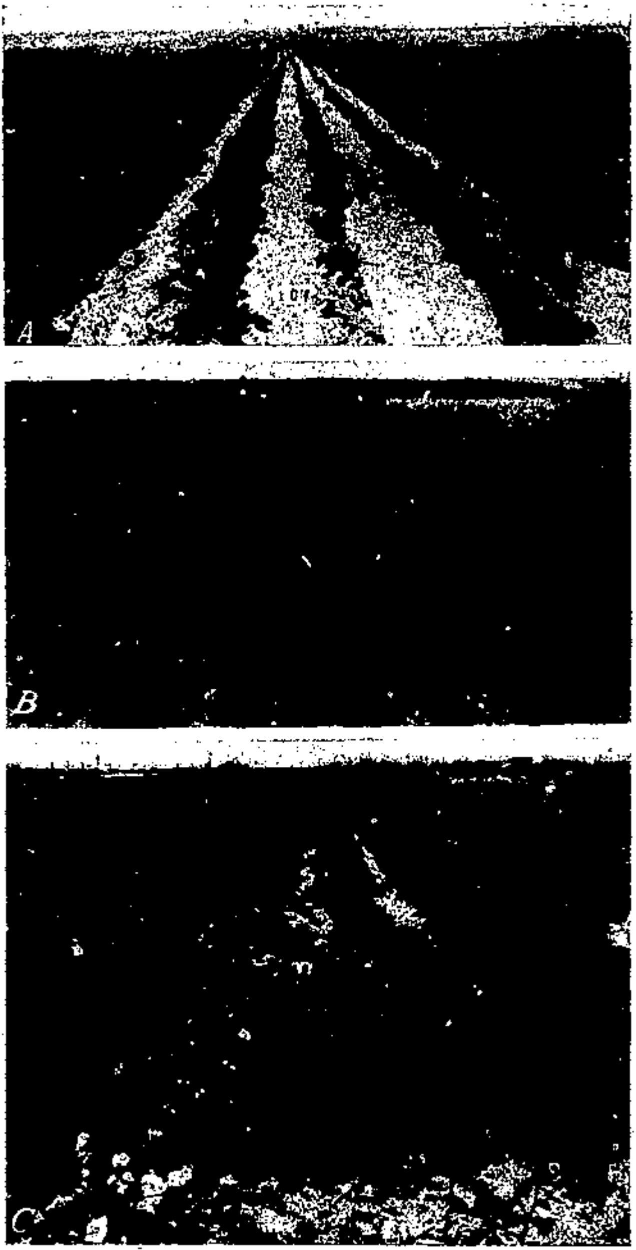


FIGURE 22.—Effect of fertilizers on the growth, maturity, and yield of cotton on Wilson clay loam, R. W. Craig field, Hunt County, Tex.: *A*, Young cotton, the two rows at left of middle treated with 6-9-0 fertilizer at 600 pounds per acre, the two rows at right of middle unfertilized, photographed June 25, 1930; *B*, cotton, the four rows at left of middle unfertilized, the four rows at right of middle treated with 15-30-15 and 11-48-0 fertilizers at 150 pounds per acre, photographed August 19, 1930; *C*, maturity and yield of cotton, rows at left treated with 15-30-15 fertilizer at 150 pounds per acre, rows at right unfertilized, leaves plucked in foreground to show open bolls August 19, 1930.

48579—34——5

from it principally in position and in its greater depth to soil-forming material. Soil and subsoil are noncalcareous.

The Oscar Nelson field is representative of this soil. The field is not infested with root rot, and the results are considered as those of a

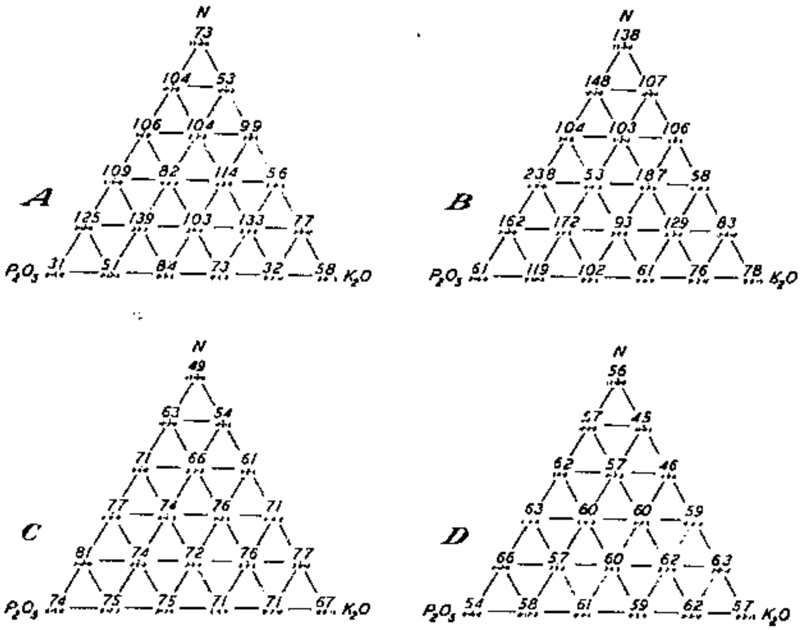


FIGURE 23.—Increases in yield of seed cotton in pounds per acre (*A–B*) and percentages of total yield obtained at first picking (*C–D*) from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Irving clay, O. Nelson field, Williamson County, Tex.: *A*, Increases in yields obtained in 1930 over average for check plots of 592 pounds per acre; *B*, increases in yields obtained in 1931 over average for check plots of 511 pounds per acre; *C*, percentages obtained at first picking in 1930, average for check plots 67 percent; *D*, percentages obtained at first picking in 1931, average for check plots 57 percent.

fertilizer-ratio test, in which experimental complications arising from root rot are eliminated. However, not all areas of this soil type are free from root rot, and these results could probably at least be duplicated in infested fields. Data for 1930 and 1931[11] are presented in table 13 and shown graphically in figure 23.

[11] The results for 1929 are unreliable as a result of a severe and irregular infestation by bollworms.

TABLE 13.—*Yields and increases in yield of seed cotton per acre on Irving clay on O. Nelson field, Williamson County, 1930–31*

Plot no.	Fertilizer analyses N-P₂O₅-K₂O)	1930					1931				
		First picking, Aug. 18		Total		Cotton open at first picking	First picking, Aug. 31		Total		Cotton open at first picking
		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]		Yield	Increase from fertilizer[1]	Yield	Increase from fertilizer[1]	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*
Check		477		630		75	310		547		57
1	0-15- 0	496	19	670	31	74	327	17	608	61	54
2	0-12- 3	494	51	658	51	75	366	55	634	110	58
3	3-12- 0	560	160	669	125	81	424	112	644	102	66
Check		400		574		74	312		482		65
4	0- 9- 6	401	82	658	84	75	356	44	581	102	61
5	3- 9- 3	537	134	726	130	74	306	80	647	172	57
6	6- 9- 0	547	150	700	100	77	446	187	705	238	63
Check		307		600		66	259		467		55
7	0- 6- 9	470	82	673	73	71	310	51	528	61	59
8	3- 6- 6	490	105	690	103	72	344	68	574	93	60
9	6- 6- 3	484	94	656	82	74	327	34	547	53	60
Check		390		574		68	293		494		59
10	9- 6- 0	484	91	680	106	71	373	80	598	104	62
11	0- 3-12	428	50	605	32	71	340	82	559	76	62
12	3- 3- 9	532	167	704	133	76	375	135	601	120	62
Check		365		571		64	240		472		51
13	6- 3- 6	520	155	685	114	76	305	155	659	187	60
14	9- 3- 3	445	69	680	104	66	334	70	581	103	57
15	12- 3- 0	431	30	655	101	63	363	75	632	148	57
Check		392		581		68	288		484		60
16	0- 0-15	431	39	639	58	67	322	34	562	78	57
17	3- 0-12	523	91	682	77	77	395	59	627	83	63
18	6- 0- 9	480	21	685	56	71	390	7	661	58	59
Check		465		629		74	383		603		64
Check		344		603		57	252		516		40
19	9- 0- 6	431	87	702	99	61	288	36	622	106	46
20	12- 0- 3	341	10	634	53	54	280	8	630	107	45
21	15- 0- 0	312	—5	632	73	49	375	72	698	138	56
Check		317		559		57	303		530		57

[1] Plots occur in the field in the same order as they are presented above. In calculating "increase from fertilizer" treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

It is evident from figure 23, *A*, *B* that cotton on this soil responds to fertilizers high in phosphoric acid. Some nitrogen seems essential to maximum response, and perhaps a small percentage of potash. The 3–9–3 mixture was most effective in 1930 and the 6–9–0 mixture in 1931. Accordingly a 1:3:1, 2:3:0 or 2:3:1 ratio is indicated. The maximum increase in yield in 1930 amounted to 23 percent and in 1931 to 47 percent.

Fertilizers high in phosphoric acid have accelerated the maturity of the crop. This is not reflected in final yields to the degree that would obtain if root rot were prevalent, however. The effect of fertilizers on growth of young cotton on Irving clay and on maturity and yield are shown in figure 24.

RESULTS ON DENTON CLAY

Denton clay is an important soil of the Grand Prairie section, which lies to the west of the black-land prairies, and in portions of which root rot is a serious problem. The surface soil is a brown to dark-brown friable clay. The subsoil is also a friable clay, but varies to yellowish brown in color. In the experiment field (Peterson) representing this type the substratum is encountered below 30 inches, and

FIGURE 24.—Effect of fertilizers on growth, maturity, and yield of cotton on Irving clay, O. Nelson field, Williamson County, Tex.: *A*, Very young cotton, rows at left treated with 6–10–4 fertilizer at 600 pounds per acre, those at right unfertilized, photographed June 8, 1929; *B*, young cotton, rows at left unfertilized, rows at right treated with 6–10–4 fertilizer at 600 pounds per acre, photographed June 25, 1929; *C*, maturity and yield of cotton, plot at left unfertilized, plot at right treated with 6–10–4 fertilizer at 600 pounds per acre, leaves plucked in foreground to show open bolls August 18, 1930.

is pale-yellow to white chalky clay loam. Soil, subsoil, and substratum are calcareous.

Three years' results from the Peterson experiment are given in table 14 and are shown graphically in figures 25 and 26.

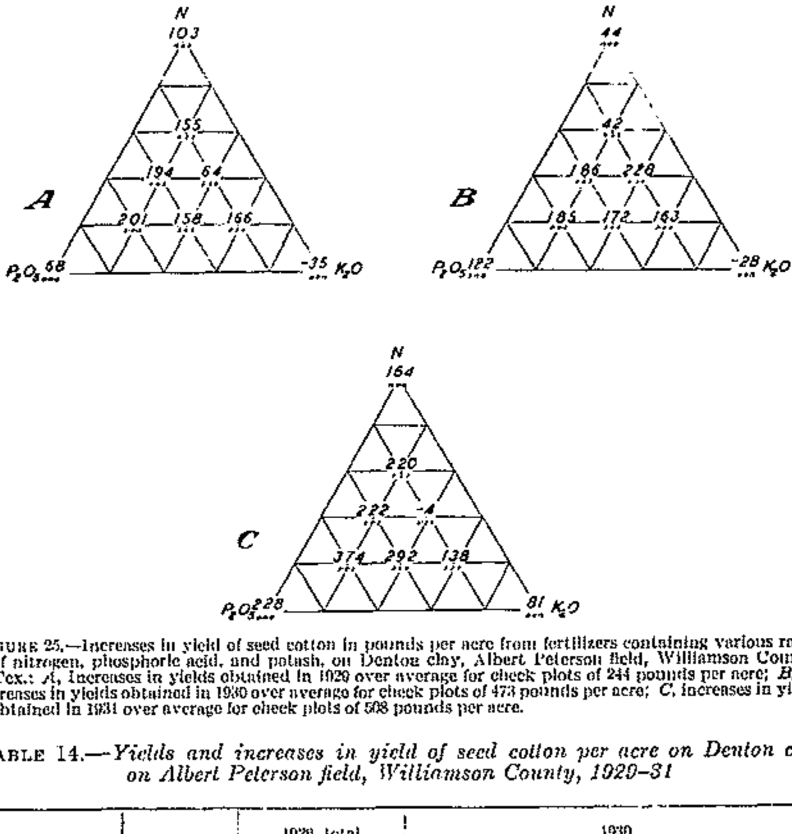


FIGURE 25.—Increases in yield of seed cotton in pounds per acre from fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Denton clay, Albert Peterson field, Williamson County, Tex.: *A*, Increases in yields obtained in 1929 over average for check plots of 244 pounds per acre; *B*, increases in yields obtained in 1930 over average for check plots of 473 pounds per acre; *C*, increases in yields obtained in 1931 over average for check plots of 508 pounds per acre.

TABLE 14.—*Yields and increases in yield of seed cotton per acre on Denton clay on Albert Peterson field, Williamson County, 1929–31*

Plot no.	Fertilizer analyses $N-P_2O_5-K_2O$	1929, total		1930				
		Yield	Increase from fertilizer [1]	First picking, Aug. 19		Total		Cotton open at first picking
				Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
1	0-15- 0	309	68	382	129	522	122	73
5	3- 9- 3	442	201	445	192	585	185	70
8	3- 6- 6	390	158	396	143	572	172	69
Check [2]		241		253		400		63
9	6- 6- 3	435	194	306	143	586	186	68
12	3- 3- 9	407	166	378	125	563	163	67
13	6- 3- 6	305	64	388	135	628	228	62
14	9- 3- 3	402	155	437	113	587	42	74
10	0- 0-15	212	−35	375	51	517	−28	73
21	15- 0- 0	50	103	307	73	589	44	67
Check [2]		247		324		545		60

[1] Plots in this experiment are in 2 tiers. Because of arrangement the "increase from fertilizer" in each tier was calculated from the average yield of check plots in that tier.

[2] Average of 2.

TABLE 14.—*Yields and increase in yield of seed cotton per acre on Denton clay on Albert Peterson field, Williamson County, 1929–31*—Continued

Plot no.	Fertilizer analyses $N-P_2O_5-K_2O$	1931				
		First picking Aug. 23		Total		Cotton open at first picking
		Yield	Increase from fertilizer [1]	Yield	Increase from fertilizer [1]	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*
1	0-15-0	262	90	694	228	38
5	3-0-3	342	170	840	374	41
8	3-0-0	303	131	758	292	40
Check [2]		172		466		37
9	0-0-3	274	102	688	222	40
12	3-3-6	212	40	604	138	35
13	6-3-6	162	−10	462	−4	35
14	9-3-3	373	209	769	220	49
16	0-0-15	311	147	630	81	49
21	15-0-0	281	117	713	164	39
Check [2]		164		549		30

[1] Plots in this experiment are in 2 tiers. Because of arrangement the "Increase from fertilizer" in each tier was calculated from the average yield of check plots in that tier.
[2] Average of 2.

From the data in figure 25 it is apparent that this soil responds to applications of both phosphoric acid and nitrogen. Maximum returns, however, are obtained only when the two are in combination. Response to potash alone is clearly negligible, although its importance in the fertilizer ratio is difficult to establish with the data from only nine ratios at hand. In 2 of the 3 years the 3–9–3 fertilizer gave the greatest increase in yield; and in 1930 also this treatment was among the most effective. A 1:3:1 ratio of nitrogen, phosphoric acid, and potash is accordingly indicated. This ratio was also highly effective in accelerating maturity, as shown in figure 26. Data of this kind were not obtained for the 1929 crop.

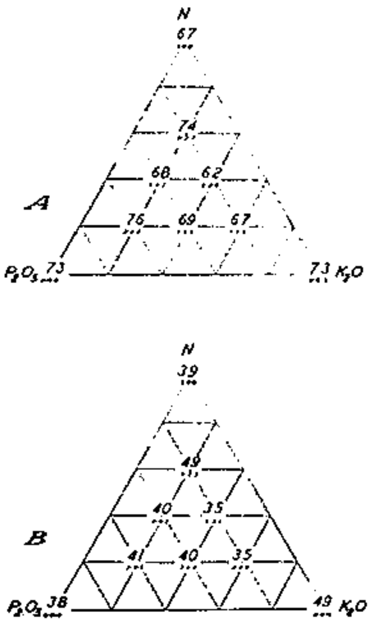


FIGURE 26.—Percentages of total yield of cotton obtained at first picking from use of fertilizers containing various ratios of nitrogen, phosphoric acid, and potash, on Denton clay, Albert Peterson field, Williamson County, Tex.: *A*, Percentages obtained at first picking in 1930, average for check plots 61 percent; *B*, percentages obtained at first picking in 1931, average for check plots 34 percent.

The effect of fertilizers on the growth, maturity, and yield of cotton on Denton clay, and the response of young cotton to nitrogen are shown in figures 27 and 29, *A*.

RESULTS ON MILLER SILTY CLAY LOAM

Miller silty clay loam is an alluvial soil, which, with related types, covers a rather extensive area in the Brazos River Valley. The experiment field, on the Earle farm in McLennan County, represents a heavy subsoil phase of this soil type. At the surface is a brown silty clay loam, and the subsoil is a brown to dark-brown clay loam.

The experiment field, like most other areas of this type, is occasionally subject to overflow.

Experiments were conducted in 1929, 1930, and 1931. The field used in 1929 had been in alfalfa during the 2 preceding years. The

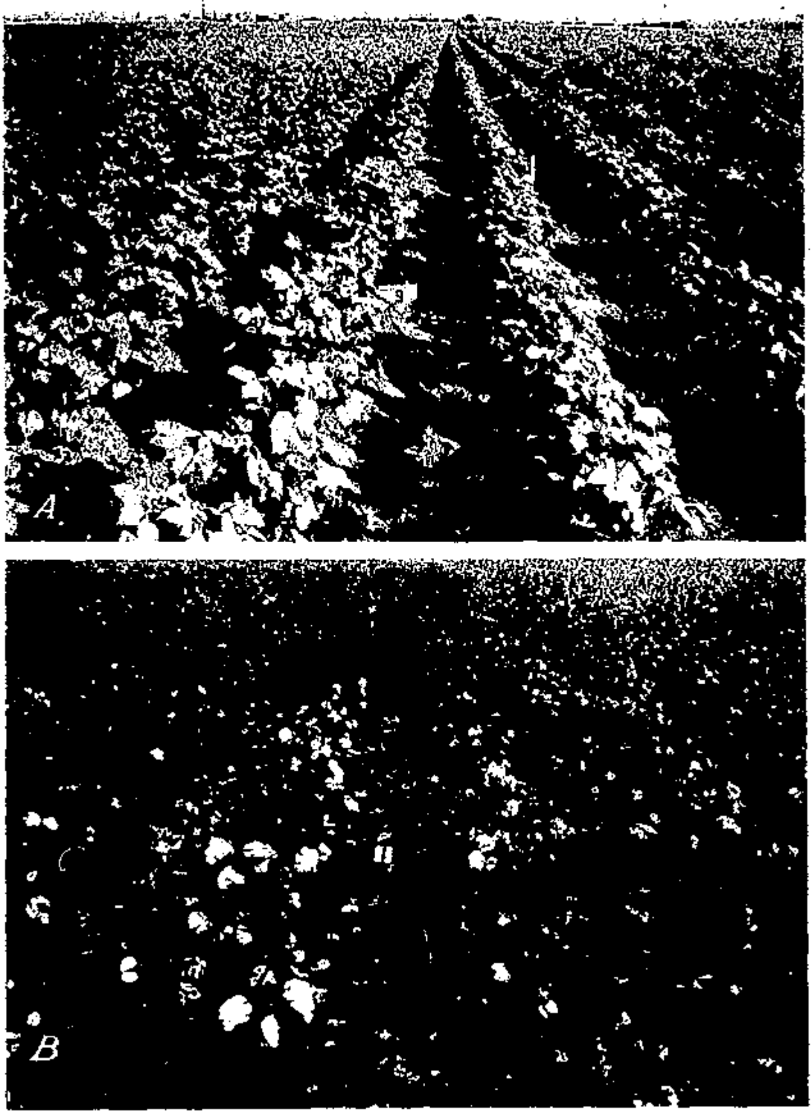


FIGURE 27.—Effect of fertilizers on the growth and early yield of cotton on Denton clay, Albert Peterson field, Williamson County, Tex.: *A*, Plot at left treated with 0-6-3 fertilizer at 600 pounds per acre, plot at right unfertilized, photographed July 10, 1930; *B*, early yield of cotton, rows at left of middle treated with 9-3-3 fertilizer at 600 pounds per acre, rows at right unfertilized, leaves plucked in foreground to show open bolls August 29, 1929.

same nine fertilizers used in other experiments were applied. No consistent increases in yield were obtained.

In 1930 and 1931 a field was used which had been almost continuously in cotton for 20 years. The cotton responded to high-nitrogen ratios, as indicated by greater vegetative growth and darker green color. However, this was not consistently translated into increased

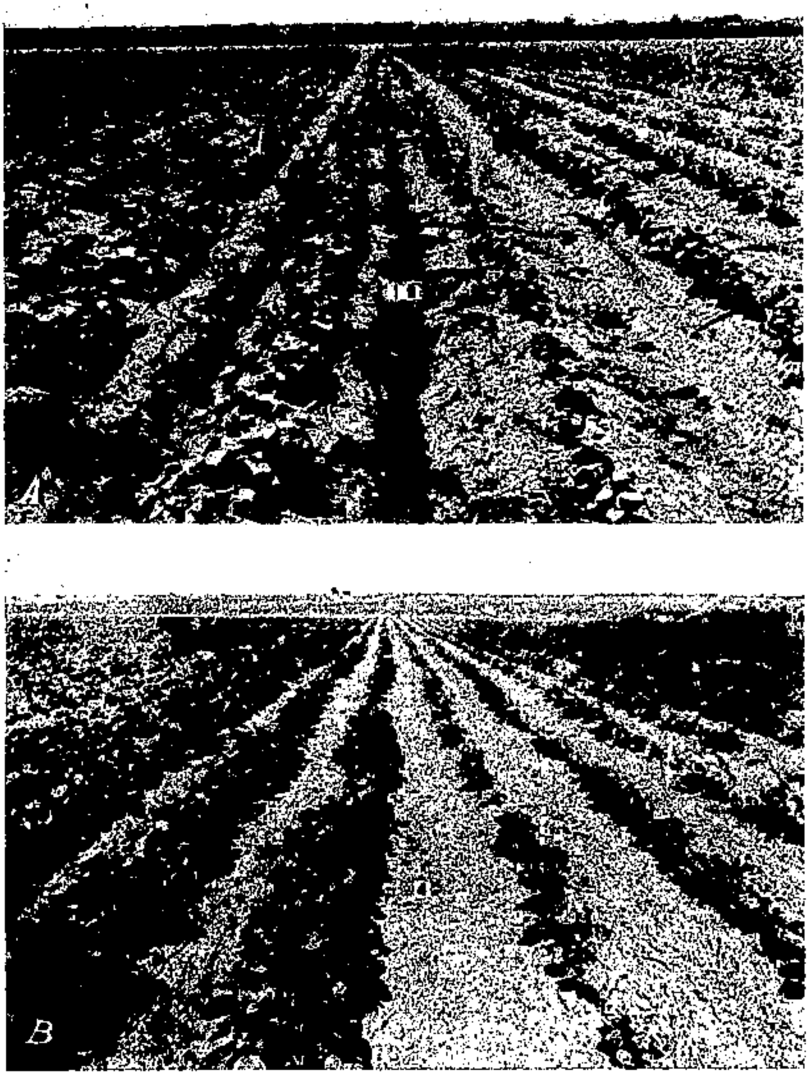


FIGURE 28.—*A*, Effect of concentrated fertilizer on the early growth of cotton on Houston black clay, W. E. Jones field, Dallas County, Tex.; rows at left treated with commercial 15–30–15 fertilizer at 75 pounds per acre, rows at right unfertilized, photographed June 20, 1931; *B*, effect of fertilizer prepared from concentrated materials on the growth of young cotton on Wilson clay loam, R. W. Craig field, Hunt County, Tex.; plot at left treated with 6–10–4 fertilizer, compounded largely from potassium-ammonium phosphate, at 450 pounds per acre, plot at right unfertilized. Photographed June 25, 1930.

yields, although fertilizers did to a limited extent accelerate maturity. Indications are that this soil type is among the least responsive of those covered by these experiments.

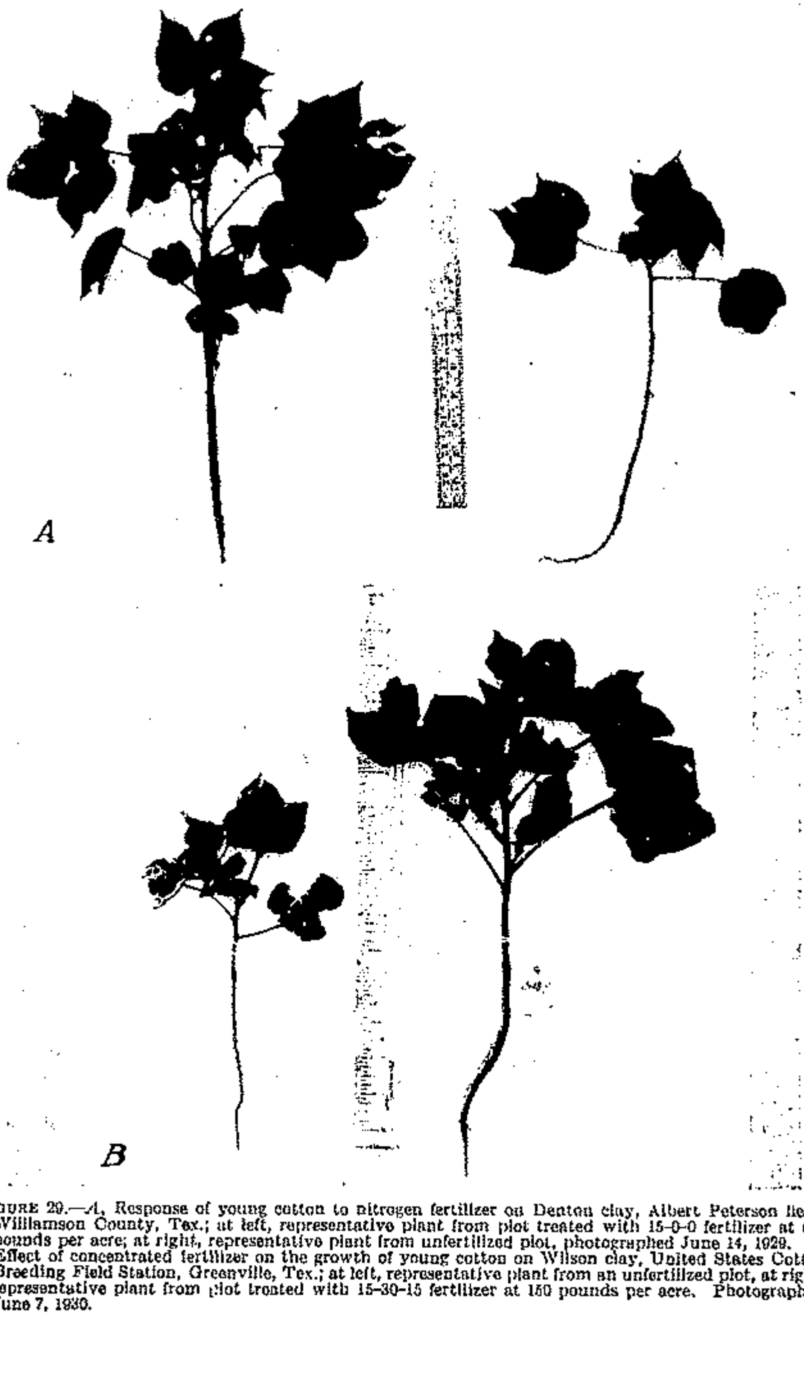


FIGURE 29.—*A*, Response of young cotton to nitrogen fertilizer on Denton clay, Albert Peterson field, Williamson County, Tex.; at left, representative plant from plot treated with 15-0-0 fertilizer at 600 pounds per acre; at right, representative plant from unfertilized plot, photographed June 14, 1929. *B*, Effect of concentrated fertilizer on the growth of young cotton on Wilson clay, United States Cotton Breeding Field Station, Greenville, Tex.; at left, representative plant from an unfertilized plot, at right, representative plant from plot treated with 15-30-15 fertilizer at 150 pounds per acre. Photographed June 7, 1930.

EXPERIMENTS AT THE UNITED STATES FIELD STATION, SAN ANTONIO

Experiments have been in progress at the United States field station of the Bureau of Plant Industry at San Antonio, for 3 years. The prevailing soil type is Houston clay loam. The soil differs from the other Houston soils, here described, in the texture of the surface horizon. Furthermore, having developed in a distinctly subhumid environment, it is less leached of mineral and organic plant food.

The same nine fertilizer ratios used in other experiments were applied to this field. Yields data are lacking for 1929 and 1931, owing to severe damage by bollweevil and bollworm. The 1930 figures do not show a consistent trend toward increased yields from any ratio. Little or no effect of fertilizer could be seen in the vegetative development of the crop in either of the two earlier years of the experiments. In 1931, however, the cotton showed small, though definite, response to fertilizers combining nitrogen and phosphoric acid.

The high native fertility of soils developed in areas of deficient rainfall, together with the limitations imposed on crop production by such a climate, make this field distinct from the others here treated. The annual precipitation on the San Antonio station was 29.45 inches in 1929, 23.93 inches in 1930, and 29.39 inches in 1931. Probably moisture was the limiting factor rather than available plant food.

RESIDUAL EFFECTS OF FERTILIZERS

In all of these experiments, except that on the Earle field, the same treatments were applied to identical plots in successive years. A study of the data shows that the magnitude of reponse on most of the soils increases in general with each successive application. That this is due to the residual effect of the fertilizer seems evident, because of a total lack of correlation with seasonal conditions. Response from fertilizer was generally greater in 1930 than in 1929, although seasonal conditions were much less favorable for fertilizer effect in 1930. Correspondingly, response was generally greater in 1931 than in 1930. Data showing such effects are represented in table 15.

TABLE 15.—*Increases in yield of seed cotton per acre from fertilizers on several soil types, showing progressive cumulative effect*

MAXIMUM INCREASES IN YIELD FROM OPTIMUM FERTILIZER EACH YEAR

Year	Houston black clay, King field		Houston black clay, Voelker field		Wilson clay, United States Cotton Breeding Station		Wilson clay loam, Craig field		Bell clay, J. W. Jones field		Irving clay, O. Nelson field		Denton clay, Peterson field	
	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increase	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increase	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increase	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increase	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increase	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increase	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increase
		Lb.		*Lb.*		*Lb.*		*Lb.*		*Lb.*		*Lb.*		*Lb.*
1928	----	----	----	----	6-3-0	128	0-15-0	180	----	----	----	----	----	----
1929	6-3-6	82	15-0-0	203	9-3-3	108	6-9-0	313	3-9-3	142	----	----	3-9-3	201
1930	9-3-3	212	----	----	6-6-3	151	6-9-6	430	----	----	3-9-3	130	6-3-6	228
1931	15-0-0	342	15-0-0	200	9-3-3	247	3-9-3	383	6-6-3	270	6-9-0	238	3-9-3	374

TABLE 15.—*Increase in yield of seed cotton per acre from fertilizers on several soil types, showing progressive cumulative effect*—Continued

INCREASES IN YIELD EACH YEAR FROM SAME FERTILIZER ANALYSIS

Year	Houston black clay, King field 6-6-3 fertilizer	Houston black clay, Voelker field 15-0-0 fertilizer	Wilson clay, United States Cotton Breeding Station, 9-3-3 fertilizer	Wilson clay loam, Craig field 6-9-0 fertilizer	Bell clay, J. W. Jones field 6-6-3 fertilizer	Irving clay, O. Nelson field 6-9-0 fertilizer	Denton clay, Peterson field, 0-15-0 fertilizer
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1928	----------	----------	117	74	----------	----------	----------
1929	68	203	108	313	138	----------	68
1930	143	----------	146	430	----------	109	122
1931	284	290	247	327	276	236	228

Because of this residual effect the current year's increase in yield in these experiments cannot be considered the full measure of benefit of a single fertilizer application. Rather the average results over a period of years would seem the best criterion. Furthermore, owing to this factor, some improvement in soil conditions of a more than transient nature may be anticipated. Differences in plant growth between fertilized and nonfertilized plots in the experiments were at times rather striking. There was a corresponding increase in the amount of plant residue returned to the soil of the fertilized plots. This would tend to build up the organic matter in the soil, increase the water-holding capacity, and decrease susceptibility to erosion—all of which are of paramount importance. While improvement of this kind is of too low magnitude to be measured during the duration of these experiments, it must, nevertheless, be considered among the advantages of fertilizer use.

GENERAL TREND OF RESULTS

Viewing these results collectively, for the region as a whole, the greatest response has been secured from the combined application of nitrogen and phosphoric acid. Nitrogen alone has usually shown a marked effect on early plant growth and color of foliage; but only in a few cases has such fertilizer given the greatest increase in yield. A few fields have shown response to phosphoric acid alone. For maximum effect on the majority of the soils, however, these two constituents must be present in combination. There has been relatively little response to potash alone, insofar as plant growth and yields are concerned; and in such respects this element is apparently of minor importance on the black-land soils. It has been repeatedly noted, however, that potash in the fertilizer ratio tends to promote seedling vigor. In the case of fields where the stand was reduced in the early stages of growth by seedling diseases or by a combination of unfavorable conditions the mortality of plants on plots treated with potash alone was frequently the lowest of any in the field.

Increases in yields were obtained in all of the experiments except those on the J. B. Earle field and at the United States San Antonio Field Station. With these reservations, increases ranging from 13 to 82 percent were obtained in 1929. In 1930 the increase on the least responsive field amounted to 17 percent and on the most responsive field to 117 percent; corresponding figures for 1931 are 21 and 106 percent, respectively.

SUPPLEMENTARY EXPERIMENTS

EXPERIMENTS WITH CONCENTRATED FERTILIZERS

Some of the newer concentrated fertilizer materials possess properties which should theoretically render them advantageous for use under Texas black-land conditions. Many of these fertilizers contain 2, or even 3, of the nutritive elements combined in a single salt. These elements are released to the soil solution and to the plant in the proportions in which they occur in the salt. This would appear to be an advantage in many of these soils, in which, as indicated by observation and laboratory investigations, fixation of added phosphoric acid seems to be a problem of considerable importance. The granular structure of a number of the commercial concentrated fertilizers, permitting slower solution than in the case of finely divided materials, offers an added advantage.

Accordingly, the fertilizer-ratio experiments, in which mixtures compounded of the more common commercial materials were used, have in many instances been supplemented by tests of the newer concentrated sources of nitrogen and phosphoric acid. Particular attention has been given the ammonium phosphates. These have been applied directly in their original concentrated form at rates equivalent in plant-food content to the lower analysis fertilizers, and with or without supplements to modify their plant-food ratios, or they have been used as the major sources of plant food in compounding lower analysis mixtures.

Table 16 presents some results from such fertilizers, prepared largely from the ammonium phosphates, in fields on which response to phosphoric acid has been appreciable. For ready comparison, results with the most favorable ratio compounded of ordinary commercial goods and with ratios of such fertilizers most nearly comparable in analysis to the concentrated mixtures are included.

TABLE 16.—*Increases in yield from fertilizers compounded from concentrated materials as compared with those from fertilizers compounded of ordinary commercial materials 1930–31*

1930

Soil type and experiment field	Ordinary commercial materials [1]						Concentrated materials [2]				
	Optimum ratio			Ratios most nearly comparable to concentrated ratios			Fertilizer		Major constituent of fertilizer	Increased yield of seed cotton per acre	Proportion of total crop at first picking
	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increased yield of seed cotton per acre	Proportion of total crop at first picking	Fertilizer analyses ($N-P_2O_5-K_2O$)	Increased yield of seed cotton per acre	Proportion of total crop at first picking	Mixture no.	Analyses ($N-P_2O_5-K_2O$)			
		Pounds	*Percent*		*Pounds*	*Percent*				*Pounds*	*Percent*
Houston black clay, King	9-3-3	212	46	3-6-6	161	46	30	6-10-4	Ammonium phosphate	129	50
				6-6-3	143	49	31	6-10-4	Potassium ammonium phosphate	91	58
							NPK	15-30-15	Diammonium phosphate	—4	53
Houston black clay, noncalcareous phase, Range	3-3-9	53	46	3-9-3	35	58	NPK	15-30-15	do	62	61
				3-3-9	53	46					
Houston black clay, Voelker	6-6-3	88	65	3-6-6	86	60	30	6-10-4	Ammonium phosphate	144	56
				6-6-3	88	65	31	6-10-4	Potassium ammonium phosphate	152	74
							NPK	15-30-15	Diammonium phosphate	94	72
Houston black clay, Blanks	6-6-3	132	48	3-6-6	130	49	NPK	15-30-15	do	79	45
Wilson clay, United States Cotton Breeding Station	6-6-3	151	60	3-6-6	114	60	NPK	15-30-15	do	165	71

[1] Nitrogen from one-third each, sulphate of ammonia, nitrate of soda, and cottonseed meal; phosphoric acid from 18 percent superphosphate; potash from sulphate of potash. Fertilizers applied at rate of 600 pounds per acre.

[2] Mixtures compounded as follows; constituents given in order of importance:

Mixture no.	Components
50	Ammonium phosphate (Ammo-Phos "A"), sulphate of potash, urea, cottonseed meal.
30	Ammonium phosphate (Ammo-Phos "A"), urea, sulphate of potash, cottonseed meal.
31	(1930) Potassium ammonium phosphate, ammonium sulphate, potassium nitrate, cottonseed meal.
	(1931) Diammonium phosphate, sulphate of ammonia, sulphate of potash.
33	Nitrophoska (15-30-15), sulphate of ammonia.
34	Diammonium phosphate, sulphate of ammonia.
41	Ammonium phosphate (Ammo-Phos "A"), sulphate of ammonia, sulphate of potash, cottonseed meal.
43	Diammonium phosphate, sulphate of ammonia, sulphate of potash, cottonseed meal.
45	Ammo-Phos-Ko, Ammo-Phos "B", cottonseed meal.
NPK	Nitrophoska, 15-30-15.

Except where noted, 6-10-4 ratios were applied at rate of 450 pounds per acre; 15-30-15 at rate of 150 pounds per acre.

TABLE 16.—*Increases in yield from fertilizers compounded from concentrated materials as compared with those from fertilizers compounded of ordinary commercial materials 1930–31*—Continued

1930

Soil type and experiment field	Ordinary commercial materials: Optimum ratio: Fertilizer analyses ($N-P_2O_5-K_2O$)	Optimum ratio: Increased yields seed cotton per acre	Optimum ratio: Proportion of total crop at first picking	Ratios most nearly comparable to concentrated ratios: Fertilizer analyses ($N-P_2O_5-K_2O$)	Ratios most nearly comparable: Increased yield of seed cotton per acre	Ratios most nearly comparable: Proportion of total crop at first picking	Concentrated materials: Fertilizer: Mixture no.	Fertilizer: Analyses ($N-P_2O_5-K_2O$)	Major constituent of fertilizer	Increased yield of seed cotton per acre	Proportion of total crop at first picking
		Pounds	*Percent*		*Pounds*	*Percent*				*Pounds*	*Percent*
Wilson clay loam, Craig	6-9-0	430	47	6-9-0	430	47	30	6-10-4	Ammonium phosphate	232	40
				3-6-6	303	46	31	6-10-4	Potassium ammonium phosphate	261	44
							NPK	15-30-15	Diammonium phosphate	268	65
Irving clay, O. Nelson	3-9-3	139	74	6-9-0	109	77	30	[3] 6-10-4	Ammonium phosphate	210	83
				3-6-6	103	72	31	[3] 6-10-4	Potassium ammonium phosphate	169	85
				3-9-3	139	74	NPK	[4] 15-30-15	Diammonium phosphate	186	87
							5C	[5] 3-9-3	Ammonium phosphate	126	71

1931

Soil type and experiment field	Optimum ratio: Fertilizer analyses ($N-P_2O_5-K_2O$)	Optimum ratio: Increased yields seed cotton per acre	Optimum ratio: Proportion of total crop at first picking	Comparable ratios: Fertilizer analyses ($N-P_2O_5-K_2O$)	Comparable ratios: Increased yield of seed cotton per acre	Comparable ratios: Proportion of total crop at first picking	Mixture no.	Analyses ($N-P_2O_5-K_2O$)	Major constituent of fertilizer	Increased yield of seed cotton per acre	Proportion of total crop at first picking
Houston black clay, noncalcareous phase, Range.	9-3-3	340	41	3-9-3	278	52	33	[6] 16-24-12	Diammonium phosphate	393	37
				3-3-9	307	58	34	[7] 15-30-0	do	181	38
							NPK	15-30-15	do	313	42
Houston black clay, Blanks	15-0-0	370	57	3-6-6	272	57	NPK	15-30-15	do	241	64
	6-6-3	316	58								
Bell clay, J.W. Jones	6-6-3	276	32	6-6-3	276	32	30	6-10-4	Ammonium phosphate	217	30
				3-6-6	207	33	NPK	15-30-15	Diammonium phosphate	259	27
Wilson clay, United States Cotton Breeding Field Station.	9-3-3	247	38	3-6-6	89	43	NPK	15-30-15	do	207	38
Wilson clay loam, Craig	3-9-3	363	34	6-9-0	327	35	30	6-10-4	Ammonium phosphate	223	32
				3-6-6	281	30	31	6-10-4	Diammonium phosphate	249	27
							NPK	15-30-15	do	213	35
Irving clay, O. Nelson	6-9-0	238	63	6-9-0	238	63	30	6-10-4	Ammonium phosphate	189	65
				3-6-6	103	72	31	6-10-4	Diammonium phosphate	148	64
							41	6-10-4	Ammonium phosphate	203	64
							43	6-10-4	Diammonium phosphate	223	67
							45	6-10-4	Ammonium phosphate	186	64
							NPK	15-30-15	Diammonium phosphate	126	67

[3] Applied at rate of 600 pounds per acre.
[4] Applied at rate of 200 pounds per acre.
[5] Applied at rate of 600 pounds per acre.
[6] Applied at rate of 186 pounds per acre; equivalent to application of a 20-30-15 fertilizer at a rate of 150 pounds an acre.
[7] Applied at rate of 150 pounds per acre.

The marked advantage of the concentrated fertilizers in accelerating maturity in 1930 is apparent. That year was characterized by a rather wet spring and a very dry summer. The advantage was not so great in 1931, in which season rainfall was better distributed. There is experimental evidence to indicate a greater mobility of concentrated fertilizers, and this may account, at least in part, for the difference in behavior with varying seasonal conditions. It has been observed in a number of the experiments that a marked advantage of fertilizers compounded from ammonium phosphates over those from ordinary materials, in favoring early plant growth and increasing the yields at first picking, has been materially reduced or has disappeared with advance of the season. The total yields in such cases were little or no higher, or even lower, than those resulting from use of ordinary materials.

The effect of concentrated fertilizers on early growth of cotton on Houston clay, Wilson clay loam, and Wilson clay is shown in figures 28 and 29, B.

In general, the increases in yield from the concentrated materials compare favorably with those from ordinary commercial goods. This is noteworthy in view of the fact that the analyses of the concentrated fertilizers differ materially in some cases from those of the commercial mixtures and particularly from those found most effective in the fertilizer-ratio trials. The results have not, however, been entirely consistent. Concentrated fertilizers with formulas better suited to the prevailing soil and crop needs seem to offer possibilities in this section.

One of the problems encountered in the use of these fertilizers in districts having lighter textured soils has been the risk of injury to germination and early growth. Little tendency in this direction has been encountered in these experiments, notwithstanding the fact that the materials have been applied at relatively high rates and in close proximity to the seed. Freedom from injury of this kind is probably due to the high absorptive capacity of the prevailing soils.

While the results so far obtained have not consistently demonstrated the advantages of concentrated fertilizer materials over those of lower analysis that might be anticipated on theoretical grounds, there is promise that selection of more appropriate ratios and materials, and more effective placement may permit fuller realization of such advantages. Experiments in this direction are in progress.

EXPERIMENTS WITH VARIOUS NITROGEN SOURCES

A number of comparative tests of various sources of nitrogen have been made. The nitrogen carriers were combined in 6–10–4 fertilizer and applied on several of the soil types covered by these experiments. The results do not indicate decided advantage for any of the older and more commonly used nitrogen carriers. Some of the newer, concentrated materials, which carry nitrogen alone or combined with other plant-food constituents, have given more favorable results on yields. This is particularly the case with the ammonium phosphates. However, it appears likely that the advantage is to be attributed in part to the combined source of nitrogen and phosphoric acid, rather than to the nitrogen source alone.

EXPERIMENTS WITH FERTILIZERS ON COTTON FOLLOWING CLEAN FALLOW

For a number of years the Division of Cotton, Rubber, and other Tropical Plants of the Bureau of Plant Industry has been conducting at its Greenville station a program of experiments on the relation of clean fallowing to cotton root-rot control. A material reduction in root-rot infestation after 2 years of such fallow treatment has been reported by McNamara (*31*) and McNamara and Hooton (*32*).

In connection with their experiments these investigators noted that cotton following clean fallow on the Wilson clay soil of the Greenville station generally made an abnormally rank vegetative growth as compared with that on land in continuous cotton, but that the yields were not increased in proportion. This behavior indicated an excess supply of moisture or available nitrogen, or both, and suggested the probable value of fertilizer supplements, especially those containing phosphoric acid. Another observation frequently made was that the initial growth of young cotton on land previously in clean fallow was appreciably retarded, although this condition disappeared later in the season.

As supplements to the fertilizer experiments on Wilson clay at the Greenville station described above, advantage was taken of the opportunity afforded for making applications of certain fertilizers to cotton immediately following different periods of clean fallow. Four such experiments have been conducted at Greenville, 1 in 1929 following 2 years' fallow, 1 in 1930 following 3 years' fallow, and 2 in 1931 following 3 and 4 years' fallow, respectively. With one exception, that of the experiment after 4 years' fallow in 1931, there have been pronounced responses to phosphatic fertilizers. The initial retardation of growth was overcome, marked acceleration of maturity resulted, and considerable increases in yield were obtained. Additional applications of nitrogen or potash were ineffective in producing any further increases. The results are presented in table 17 and the effects on early growth are illustrated in figure 30, *A* and *B*. The lack of response to phosphoric acid in the case of the one exception noted, that of cotton following 4 years' fallow, is difficult to explain in the light of present information.

TABLE 17.—*Results of fertilizer application to cotton following clean fallow on Wilson clay, United States Cotton Breeding Field Station, Greenville, Tex., 1929–31*

Plot treatment	1929, following 2-year fallow		1930, following 3-year fallow		1931, following 3-year fallow		1931, following 4-year fallow
	Yield of seed cotton per acre	Proportion of total yield at first picking	Yield of seed cotton per acre	Proportion of total yield at first picking	Yield of seed cotton per acre	Proportion of total yield at first picking	Yield of seed cotton per acre
	Pounds	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*
Superphosphate [1]	1,053	43	904	59	1,338	63	1,444
Check	870	29	675	46	810	34	1,510
Superphosphate+potash [2]	996	48	870	60	----------	----------	1,497
Superphosphate+nitrogen [3]	905	40	830	66	----------	----------	1,617
Dicalcium phosphate [4]	----------	----------	----------	----------	1,285	58	----------

[1] Superphosphate (18 percent P_2O_5) at 400 pounds per acre.
[2] Superphosphate (18 percent P_2O_5) at 400 pounds per acre; sulphate of potash at 40 pounds per acre.
[3] Superphosphate (18 percent P_2O_5) at 400 pounds per acre; nitrate of soda at 100 pounds per acre.
[4] Dicalcium phosphate (40 percent P_2O_5) at 180 pounds per acre.

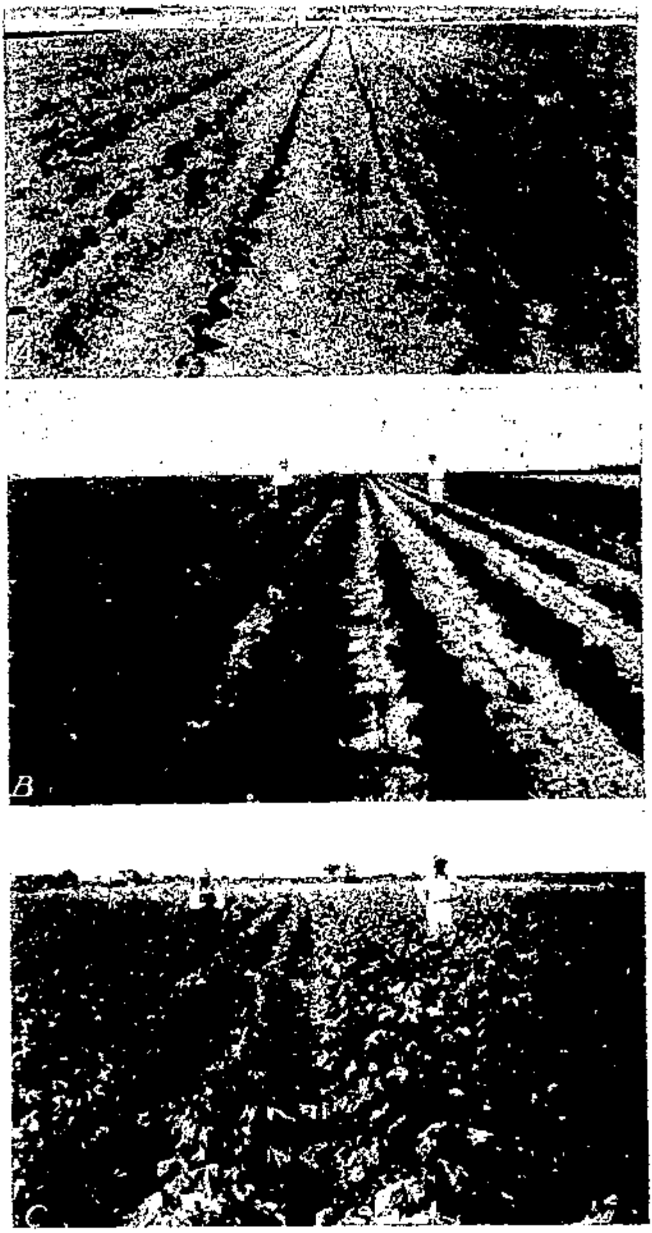


FIGURE 30.—*A*, Effect of phosphatic fertilizer on very young cotton following 3-year fallow on Wilson clay, United States Cotton Breeding Field Station, Greenville, Tex.; rows at left treated with 40-percent dicalcium phosphate at 180 pounds per acre, rows at right unfertilized; photographed June 9, 1931. *B*, Effect of phosphatic fertilizer on growth of cotton following 3-year fallow on Wilson clay, United States Cotton Breeding Field Station; rows at left treated with 18-percent superphosphate at 400 pounds per acre, rows at right unfertilized; photographed July 10, 1931. *C*, Effect of nitrogen fertilizer on cotton following sorghum on Houston black clay, W. H. A. Nelson field, Travis County, Tex.; rows at left unfertilized, rows at right treated with 15-0-0 fertilizer at 600 pounds per acre; photographed July 16, 1930.

McNamara and Hooton (*32*) have discussed the value of clean fallow in root-rot control. The treatments reported here, which are a part of a series that they are studying, have all been consistent with the results of their work reported earlier. Root-rot infestation was reduced to a minimum in the cotton crop following the fallow, and in most instances this reduction has carried over in the second and third succeeding crops. As pointed out by these authors, however, clean fallows are expensive to maintain and their use can be recommended only in a limited way.

The results with fertilizer supplements indicate that, from an economic standpoint, the admittedly limited scope in which such methods might find practical application may be considerably broadened by the use of phosphatic fertilizers. The yield from the phosphate plot following 2 years' fallow in 1929 (1,053 pounds of seed cotton an acre) would represent a yield nearly equal to the average[12] for this section if divided among the 3 years that the plot was under treatment.

EXPERIMENTS WITH FERTILIZERS FOR COTTON FOLLOWING SORGHUM

Grain sorghums are important feed crops in the Texas black-land section, particularly in the southern portion. On many farms they are the principal source of hay and furnish a considerable proportion of the grain consumed. The crop is frequently introduced into a rotation with cotton on land badly infested with root rot as a means of checking further spread and partially controlling the disease. For this purpose it is probably the most effective crop available.

The depressing effect of sorghums on crops which follow in rotation is well recognized. Breazeale (*4*), in some early work, attributed this to toxic properties in roots and stubble which interfered with normal biological soil processes. Later Conrad (*7*) demonstrated that sorghum roots and stubble, because of high soluble carbohydrate content, encouraged activity and reproduction of micro-organisms to such a degree that they competed with succeeding crops for nitrates. He further demonstrated that nitrogen fertilizers offset the depressing effect to a large extent. His conclusions are substantiated by the work of Wilson and Wilson (*73*).

Such effects of sorghum on succeeding crops are frequently pronounced in this section. During progress of the experiments described herein supplementary tests of fertilizers for cotton following sorghum were made in a number of instances. Such applications were made on Houston black clay, Houston clay, Bell clay, and Denton clay. Without exception there was excellent response to nitrogen fertilizers. The results from two such experiments are given in table 18 as representative. Data from the Nelson experiment were obtained on the W. H. A. Nelson farm in Travis County on Houston black clay, gravelly phase. Broadcast sorghum had been grown for hay in 1929 and the experimental results were obtained with the cotton crop of 1930. The other experiment was conducted in 1931 on the Blanks plantation, Caldwell County, on Houston clay. The field had been cropped to hegari (in rows) in 1929 and 1930.

[12] The average yield of lint cotton in the black-land section for the years 1916 to 1922, inclusive, is reported as 151 pounds per acre. (Tex. Agr. Expt. Sta. Bul. 365, *35*, p. 6.)

TABLE 18.—*Effect of fertilizer on cotton following sorghum*

NELSON EXPERIMENT NO 1, 1930

Fertilizer treatment [1]	Yield of seed cotton per acre	Increased yield of seed cotton per acre	Proportion of total yield at first picking
	Pounds	*Pounds*	*Percent*
Check	330		21
15-0-0	716	380	47
3-9-3	486	82	45
3-3-9	472	-5	35
Check	477		32
9-3-3	617	140	46
Yield, continuous cotton	609		

BLANKS EXPERIMENT NO. 1, 1931

Fertilizer treatment	Quantity per acre	Yield of seed cotton per acre	Increased yield of seed cotton per acre	Proportion of total yield at first picking
	Pounds	*Pounds*	*Pounds*	*Percent*
6-10-4 [2]	300	589	292	67
Check		297		68
Sulphate of ammonia	100	463	166	78
6-10-4 [2]	600	584	269	66
Check		315		67
Sulphate of ammonia	200	645	330	68

[1] 600 pounds fertilizer per acre.
[2] 90 percent of the nitrogen from sulphate of ammonia, 10 percent from cottonseed meal.

NOTE.—Plots occur in the field in the same order as they are presented above. In calculating increases from fertilizer, treated plots adjoining check plots are compared with those checks. Intermediate plots are compared with the average of 2 nearest checks.

In the Nelson experiment, while three of the treatments increased yields, ratios high in nitrogen were by far the most effective. Further, nitrogen alone (15–0–0) was more effective than an equivalent application of plant food in a 9–3–3 fertilizer. The yield recorded in table 18 as obtained in continuous cotton was secured in the same field with all cultural conditions identical except that no sorghum crop intervened. It is apparent that both the 9:3:3 and 15:0:0 ratios completely offset the harmful effect of the sorghum crop, and that nitrogen alone gave a further increase of approximately 100 pounds of seed cotton an acre. The effect of nitrogen on growth of cotton on Houston black clay previously cropped to sorghum is shown in figure 30, *C*.

The data of the Blanks experiment are arranged in order as the treatments supply increasing amounts of nitrogen. In general the response to fertilizer is in the same order and nitrogen was the element most effective in increasing yields under these conditions. The heaviest application of nitrogen was the most effective. Increases in yield of considerable magnitude were obtained from all treatments. While yields from comparable land cropped continuously to cotton are not available for comparison in this experiment, it is probable that even the least effective treatment fully counterbalanced the depressing effect of the sorghum crop.

These results suggest that sorghum, followed by a nitrogen fertilizer for the succeeding crop, might profitably find a wider use in rotations designed to effect partial control of the root-rot disease. Some further applications of such treatment are discussed under the heading Relation of Fertilizers to the Control of Cotton Root Rot (p. 57).

INDIRECT CONTROL OF COTTON ROOT ROT THROUGH USE OF FERTILIZERS

The experimental results presented above furnish repeated evidence of accelerated maturity and increased yields of cotton as a consequence of fertilizer application. In direct proportion as these two well-defined effects of fertilizers are exerted they will favor evasion or offsetting, respectively, of losses normally occasioned by root rot. The ultimate result may properly be termed "indirect control."

EVASION OF LOSSES THROUGH ACCELERATED MATURITY

Hastening of maturity has been very marked and is of particular significance. An example is furnished by the Craig experiment of 1930 on Wilson clay loam. On a plot treated with (concentrated) 15-30-15 fertilizer (at 150 pounds per acre), 65 percent of the total crop was secured at the first picking on August 19; while on the same date only 25 percent of the crop was secured from unfertilized plots. Obviously cotton plants dying of root rot after August 19 would not cause nearly so great a crop loss on fertilized land as on untreated areas, and even where cotton dies earlier than this the loss would be appreciably diminished. Similarly in 1931, on the W. E. Jones field on Houston black clay, 40 percent of the total crop was secured at first picking September 1 from a 6-3-6 plot, as compared with 27 percent from check plots. In 1929 in the J. W. Jones experiment (series 2) on Bell clay, a plot treated with 6-6-3 fertilizer yielded at the rate of 381 pounds of seed cotton per acre at the first picking on August 21. An adjoining unfertilized plot yielded at the rate of 129 pounds on the same date. These two plots are shown in figure 16, to which reference has already been made.

The experiments furnish many instances in which the early harvest from fertilized plots approached or even exceeded the total yield on unfertilized ground. In figure 31 are presented graphically the yields of fertilized plots at first picking, as compared with the total yields of check plots, for the Craig field in 1930 and the King field in 1931. The better fertilized plots yielded almost as much cotton at the first picking as did check plots for the entire season. Under conditions of severe root-rot infestation yields at early pickings frequently constitute the major part of the crop. The importance of early maturity is accordingly obvious, and fertilizers which favor it offer a means of evading, or insuring against, excessive losses. Likewise, the higher the proportion of the total crop that can be harvested at an early date, the lower will be the loss from insect damage or crop deterioration in the later season.

OFFSETTING LOSSES THROUGH INCREASED YIELDS

While no exact method of estimating losses from root rot in a given field is known, it seems that increases in yield of the magnitude secured in these experiments should counterbalance losses in most cases. The results on several of the fields offer concrete evidence on this point.

When the Cooper field was selected November 8, 1930, 96 percent of the cotton was dead. During 1931, when fertilizer applications were made, 84 percent of the cotton died. Accordingly the results were obtained under conditions of extreme root-rot infestation. Yet the most favorable fertilizer ratio increased the yield by 303

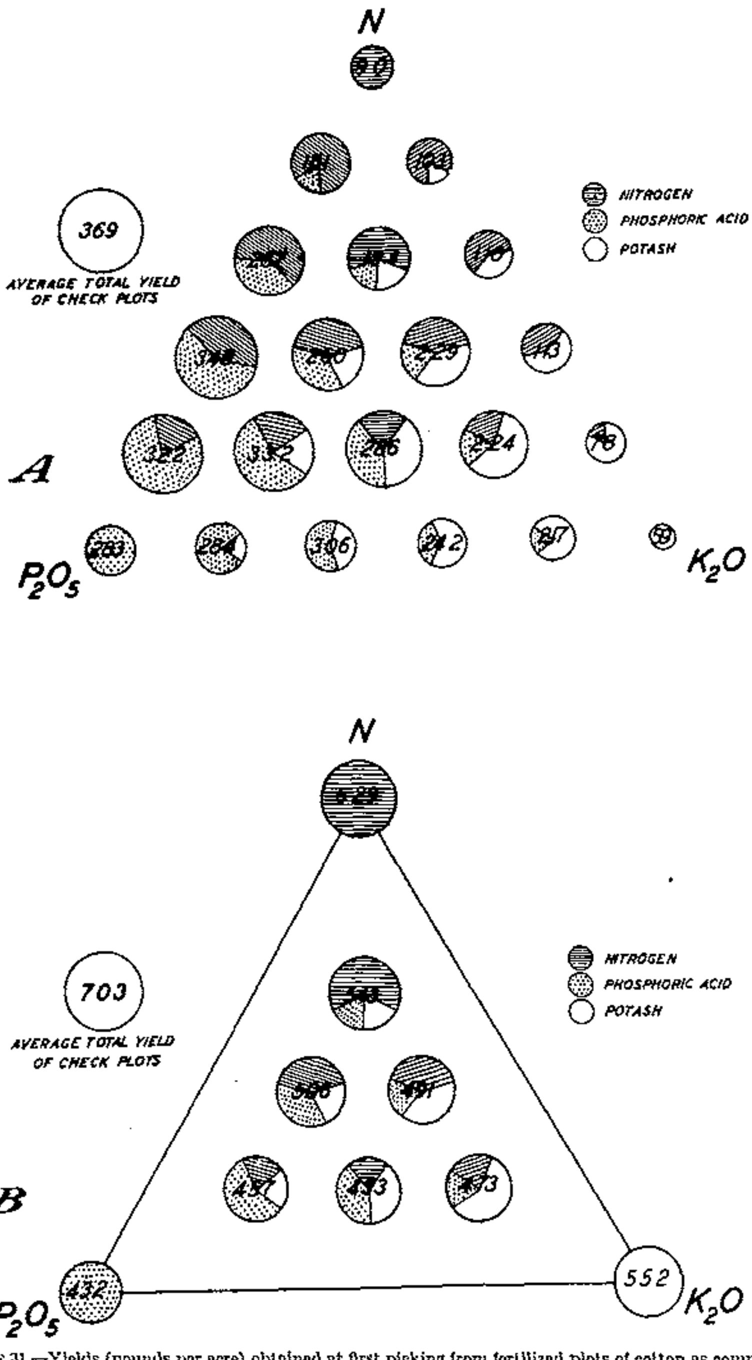


FIGURE 31.—Yields (pounds per acre) obtained at first picking from fertilized plots of cotton as compared with total yield of the check plot for the Craig experiment August 19, 1930 (*A*), and the King experiment September 23, 1931 (*B*). Areas of circles are proportional to yields of seed cotton per acre.

pounds of seed cotton an acre, which must be well in excess of any probable loss by root rot. Other fertilizers produced increases of almost equal magnitude. A considerable proportion of these increases can undoubtedly be attributed to acceleration of maturity. It is highly significant that the yield of the 9–3–3 plot at first picking on September 3 was 563 pounds of seed cotton an acre, which is only 8 pounds less than the average yield of check plots for the entire season.

The area in which the fertilizer-ratio experiment on the Craig field lies is all infested with the root-rot disease. Just a little to the south and in the same field is an area in which no cotton dies. This area has been utilized for some supplementary experiments, and yields data for a four-row check plot, practically noninfested with the disease, are available for 1929, 1930, and 1931. The location of this plot (*B*) with respect to the main experiment (*A*) is shown in figure 32 which also shows the distribution of root rot in the field September 13, 1928.

TABLE 19.—*Yields of seed cotton per acre of infested 6–9–0 plot compared with noninfested check plot, Craig experiment*

Year	Yield of check plot noninfested with root rot	Yield of 6–9–0 plot infested with root rot	Yield increases in excess of root-rot loss
	Pounds	*Pounds*	*Pounds*
1929	500	730	230
1930	406	739	333
1931	358	680	322

Table 19 gives the yields of this noninfested check plot for the 3 years of record. There are also shown yields of the 6–9–0 plot in which root rot was prevalent. Considering the proximity of the two plots and the fact that both were in the same experiment and subjected to the same cultural treatments except for the fertilizer, a direct comparison of their yields should be reasonably accurate. Such a comparison shows (table 19) that the 6–9–0 fertilizer entirely offset losses due to the disease, and in addition produced increases ranging from 230 pounds of seed cotton per acre in 1929 to 333 pounds in 1930.

Ezekiel and Taubenhaus (*14, p. 988*) suggest, as a result of 6 years' measurements, that the reduction in yield as a consequence of root rot may be estimated roughly as averaging about 50 percent of the percentage of plants killed by the disease prior to first picking. Some of these plants will produce a partial crop; on the other hand there will be some loss from cotton dying subsequent to first picking. A method of estimating losses, such as that suggested by the above authors, takes account of these losses which vary with the maturity of the crop. While such a method can at best be only an approximation, it is interesting to use it as a basis for computing losses of crops from root rot in the infested fields occupied by these experiments. The pertinent data are presented in table 20.

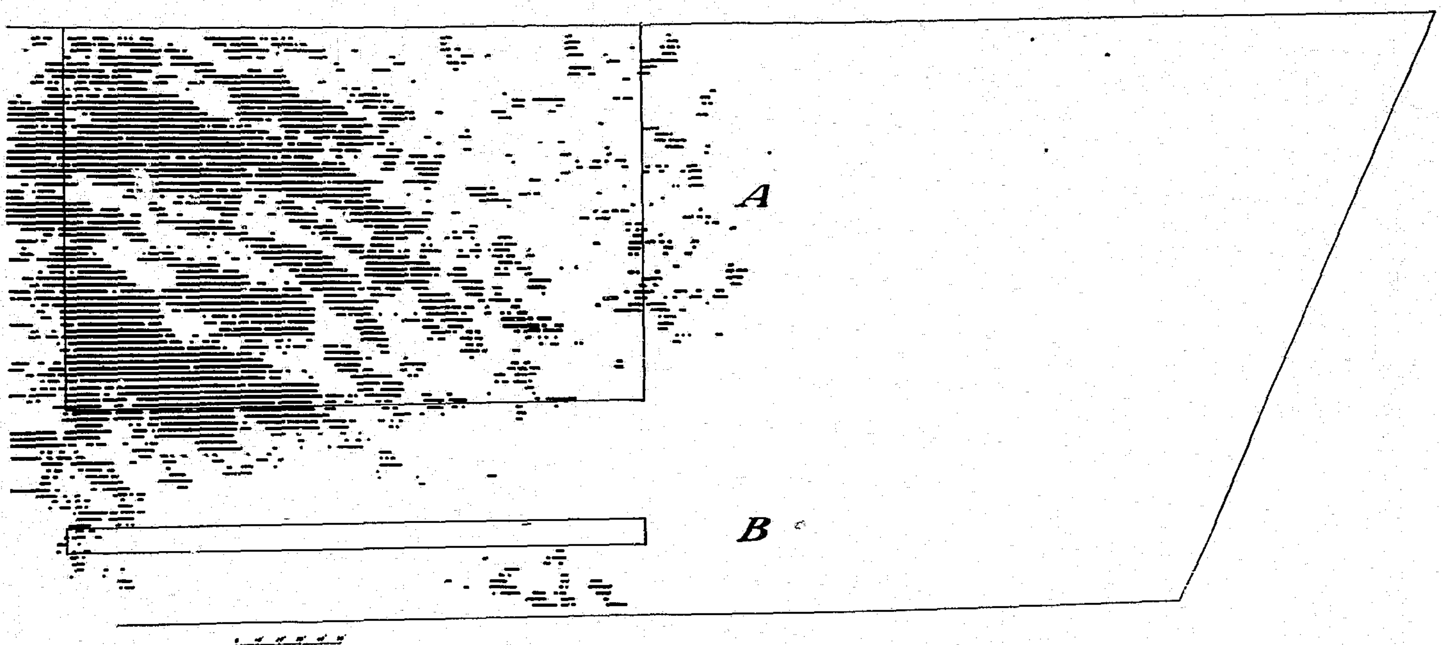


FIGURE 32.—Distribution of dead cotton in the Craig field September 13, 1923: *A*, Area of fertilizer-ratio experiment included in the calculation of percentage of dead cotton; *B*. check plot that was very slightly infested.

TABLE 20.—*Yields of seed cotton per acre of check plots corrected for root-rot losses compared with uncorrected yields from fertilized plots*

Soil type and field	Year	Date of first picking	Dead cotton on check plots at first picking: Date of record	Dead cotton on check plots at first picking: Percent	Reduction in yield due to root rot [1]	Yield of check plots (average): Actual	Yield of check plots (average): Corrected [2]	Yield of fertilized plot	Fertilizer ratio ($N-P_2O_5-K_2O$)	Dead cotton on fertilized plot
					Percent	*Lb.*	*Lb.*	*Lb.*		*Percent*
Houston black clay:										
King	1929	Aug. 28	Oct. 29	7.1	3.6	634	658	720	0-3-6	7.1
	1930	Aug. 21	Oct. 24	4.0	2.0	500	510	671	9-3-3	3.4
	1931	Sept. 23	Oct. 21	30.8	10.9	703	878	930	6-6-3	28.8
Substation no. 5, Texas Agricultural Experiment Station	1931	Sept. 22	Oct. 7	56.4	28.2	533	742	558	9-3-3	63.3
Voelker	1929	Aug. 19	Nov. 4	22.8	11.4	612	691	774	3-9-6	19.0
	1931	Aug. 18	Oct. 22	73.2	36.6	604	953	729	15-0-0	72.3
Houston clay:										
Cooper	1931	Sept. 3	Sept. 10	78.0	39.0	571	936	954	9-3-3	56.0
Bell clay:										
J. W. Jones [3]	1929	Aug. 21	Sept. 14	3.4	1.7	592	602	775	3-9-3	1.6
	1931	Sept. 2	Oct. 22	0.7	0.4	950	954	1,108	6-6-3	0.3
Wilson clay:										
United States Cotton Breeding Station	1928	Oct. 9	Nov. 8	24.9	12.5	503	575	613	6-3-0	25.3
	1929	Aug. 28	Sept. 18	0.6	0.3	572	574	678	9-3-3	1.2
	1930	Aug. 28	July 17[4]	0.7	0.4	533	535	657	6-6-3	0.3
	1931	Sept. 11	Sept. 9	10.7	5.4	933	986	1,086	6-3-0	10.4
Wilson clay loam:										
R. W. Craig	1928	Sept. 12	Sept. 13	45.0	22.5	279	360	378	3-9-3	50.0
	1929	Aug. 27	Sept. 19	29.2	14.6	454	532	698	6-6-3	28.6
	1930	Aug. 19	Oct. 27	8.3	4.2	360	385	739	6-9-0	4.0
	1931	Aug. 25	Sept. 8	34.5	17.8	343	415	675	6-6-3	32.1
Denton clay:										
Peterson	1929	Aug. 29	Nov. 5	17.0	8.5	244	267	442	3-9-3	13.9
	1930	Aug. 19	Oct. 30	6.5	3.3	473	489	628	6-3-6	6.7
	1931	Aug. 23	Oct. 10	21.5	10.8	508	570	688	6-6-3	22.1
Average				24.2			631	726		22.4

[1] One-half of the percentage of dead cotton at first picking is taken as the percentage reduction in yield due to root rot.

[2] The corrected yields represent the actual yields corrected by the estimated amount of root-rot loss shown. For example: With a loss of crop estimated at 20 percent, an actual yield of 400 pounds of seed cotton per acre represents 80 percent of the total yield that would have been obtained in the absence of such loss; and the corrected yield accordingly amounts to $\frac{400}{80}\times 100=500$ pounds.

[3] Records are from series 1 only of this experiment. Series 2 is noninfected.

[4] Later records from this field lost in a fire.

The percentages of dead cotton in table 20 were computed from map records made periodically for each of the fields. The dates of these maps do not in all instances coincide with the dates of first picking, but where this is not the case later records were used. The percentage reduction in yield due to root rot was calculated from the percentage of dead cotton on check plots. The average yield of check plots was then corrected by the amount of this factor. The corrected average yield of check plots should therefore be a close approximation to the potential yield of the field if root rot had not been present, within, of course, the limits of accuracy of the method. For comparison there are presented the yields of plots in each experiment which have been treated with a favorable fertilizer.

There are only two instances in which the yield of the fertilized plot is not in excess of the corrected average yield of check plots, or the potential yield of the field without root rot. In the remaining 18 cases in table 20 fertilizers not only completely offset the calculated loss from root rot but increased the yields by a further considerable margin. As an average for all fields fertilizers counterbalanced losses and produced an added increase in yield amounting to 95 pounds of seed cotton an acre. The percentage of root rot on fertilized and check plots compared is very nearly the same as an average and very nearly the same in most of the individual comparisons. In this connection it was necessary to eliminate from table 20 certain plots of certain experiments treated with optimum fertilizer because of a somewhat lower percentage of root rot than occurred in check plots, due probably to direct control of the disease which is discussed in a subsequent paragraph.

The data are rather conclusive in demonstrating the value of fertilizer usage as a means of indirectly controlling the root-rot disease. By accelerating maturity, losses which the disease might cause tend to be evaded and by increasing yields they have in these experiments been more than offset.

RELATION OF FERTILIZERS TO THE CONTROL OF COTTON ROOT ROT

The effects of fertilizers favoring evasion and compensation of losses from cotton root rot as a consequence of accelerated maturity and increased yields of crop are essentially indirect in nature. Another and more direct effect of such treatments in actually reducing the rate of plant mortality resulting from the disease has been indicated in the course of the experiments.

While the evidence of such an effect in a number of instances is definite the fundamental factors involved have not as yet been fully determined. Whether the increased vigor of the plant increases its resistance is as yet an open question. Much of the evidence seems to support this view. Regardless of the cause, however, the more effective fertilizers in many of these experiments have actually decreased the proportion of plants which have succumbed to the disease.

In a field thoroughly infested with root rot significant reduction in its severity has not been noted following a single fertilizer application, but only as a result of the cumulative action of repeated applications. However, in a number of instances, where the apparent infestation was first reduced by growing nonsusceptible rotation crops, or by a combination of rotation and subsoiling significant further reduction has followed single fertilizer treatments.

A striking example of such behavior was encountered in 1930 in a supplementary fertilizer experiment with cotton on the W. H. A. Nelson field (no. 1), Houston black clay, gravelly phase. Here the level of root-rot infestation had been greatly lowered by combination of a sorghum crop and subsoiling in 1929. The percentages of dead cotton, calculated from map records of the several plots during the 1930 season, are shown in table 21, together with similar figures secured on the same area in the cotton of 1928, before any treatment. A graphic representation of the data for the subsoiled area is given in figure 33 *A*.

TABLE 21.—*Effect of fertilizers on root rot and yield of cotton W. H. A. Nelson experiment no. 1, 1930*

SUBSOILED

Plot no.[1]	Fertilizer analyses ($N-P_2O_5-K_2O$)	Percentages of dead cotton: Oct. 4, 1928, before treatment	Percentages of dead cotton: Oct. 31, 1930, following sorghum grown in 1929	Increased or decreased yield of seed cotton per acre due to fertilizer
				Pounds
K-21	15-0-0	54.5	0.1	211
K-check		43.4	3.1	
K-5	3-9-3	41.9	1.2	124
K-12	3-3-9	49.8	1.5	145
K-14	9-3-3	56.4	.0	102
K-check		50.4	2.5	

NONSUBSOILED

Plot no.[1]	Fertilizer analyses ($N-P_2O_5-K_2O$)	Oct. 4, 1928	Oct. 31, 1930	Increased or decreased yield
Check		83.5	38.9	
21	15-0-0	73.0	22.2	386
5	3-9-3	59.1	29.7	82
12	3-3-9	68.4	22.0	−5
Check		88.4	30.1	
14	9-3-3	90.9	18.6	140

[1] Plots are given in same order as they occurred in the field.

Whereas the distribution of dead cotton was relatively uniform in 1928, with if anything a lower proportion on plots later made check plots, the situation was very different in 1930. In the latter year there was a marked suppression of root-rot loss on the plots treated with high-nitrogen fertilizers. This is true in both subsoiled and nonsubsoiled areas, although the level of infestation was appreciably higher on the latter. Correspondingly it was the high-nitrogen ratios which were most effective in increasing yields.

Data of another experiment on the same farm are presented in table 22. This area was in cotton in 1929 and root rot was severe and uniformly distributed. It was planted to sorghum in 1930, was subsoiled in the summer of that year, and was returned to cotton in 1931 with fertilizer treatments as noted. The percentage of dead cotton on each plot on September 25 is shown in the table, together with the effect of fertilizers on yields.

TABLE 22.—*Effect of fertilizers on root rot and yields, W. H. A. Nelson experiment no. 2, Sept. 25, 1931*

Plot no.	Fertilizer used and quantity per acre	Dead cotton	Increased yield of seed cotton per acre due to fertilizer
		Percent	*Pounds*
K-N-100	Sulphate of ammonia, 100 pounds	4.2	69
K-check	Check	5.4	
K-50-300	6-10-0,[1] 300 pounds	1.7	185
K-50-450	6-10-0, 450 pounds	0.0	110
K-N-200	Sulphate of ammonia, 200 pounds	0.3	74
K-check	Check	4.4	

[1] 90 percent of the nitrogen from sulphate of ammonia, 10 percent from cottonseed meal.

All treatments were effective in increasing yields. While the differences in degree of infestation are not large, there is a consistently lower proportion of dead plants on the fertilizer plots.

A parallel example was noted in an experiment in 1931 on Denton clay on the Carl Stried farm.[13] This area, which had produced oats in

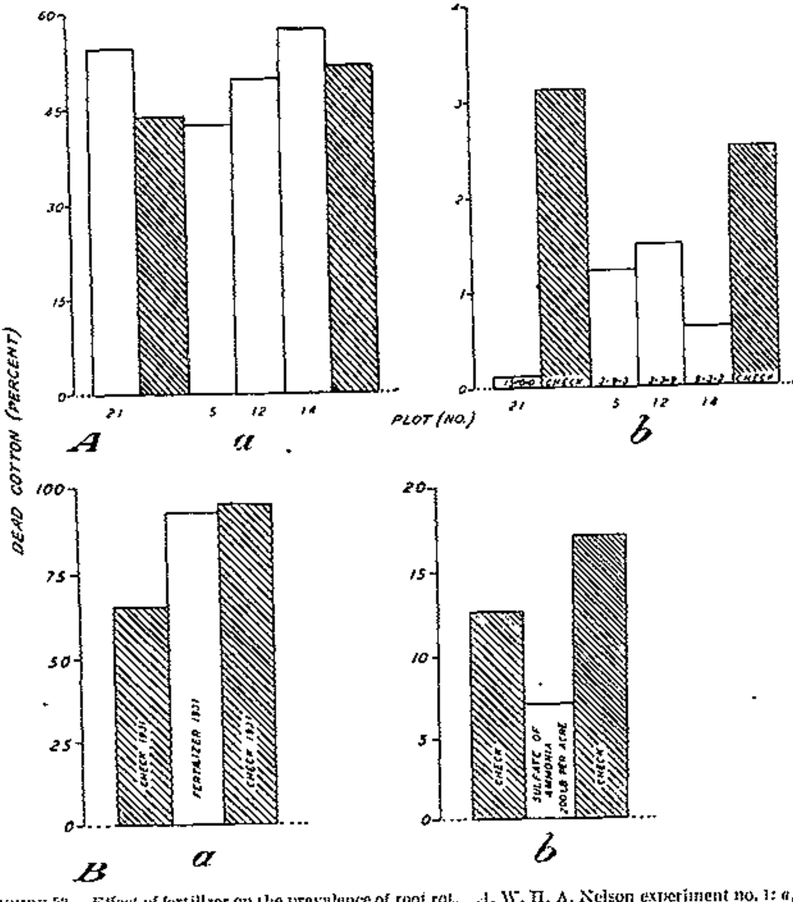


FIGURE 33.—Effect of fertilizer on the prevalence of root rot. A, W. H. A. Nelson experiment no. 1: a, Percentage of dead cotton October 4, 1928, before treatment; b, percentage of dead cotton October 31, 1930, following sorghum and subsoiling in 1929 and fertilizers in 1930. B, Carl Stried field: a, Percentage of dead cotton in the fall of 1927 before treatment; b, percentage of dead cotton October 23, 1931, following oats in 1928–29, sorghum in 1930, and fertilizers in 1931.

1928 and 1929 and sorghum in 1930, had relatively little root rot when returned to cotton in 1931. It was divided into 3 plots; 2 served as checks, and 1 was treated with sulphate of ammonia. The data of the experiment are shown in table 23 and depicted graphically in figure 33, *B*.

[13] This test was conducted as part of an experiment comparing the effects of noncotton crop and clean fallowing carried out by H. C. McNamara of the Office of Cotton, Rubber, and Other Tropical Plants. Through his cooperation the plot was made available for supplementary fertilizer experiments.

TABLE 23.—*Effect of fertilizer on root rot and yield of cotton, Carl Stried field, 1931*

Fertilizer treatment	Dead cotton		Increased yield of seed cotton per acre due to fertilizer
	Fall, 1927	Oct. 23, 1931	
	Percent	*Percent*	*Pounds*
Check	65.0	12.6	
Sulphate of ammonia, 200 pounds per acre	92.8	7.0	117
Check	95.4	17.2	

The fertilizer was effective in increasing the seed cotton yield by 117 pounds an acre and it resulted further in a significantly lower proportion of dead plants in the area of the treatment.

A similar effect was demonstrated in an experiment (no. 1) at the Blanks plantation on Houston clay, flat phase. The experiment

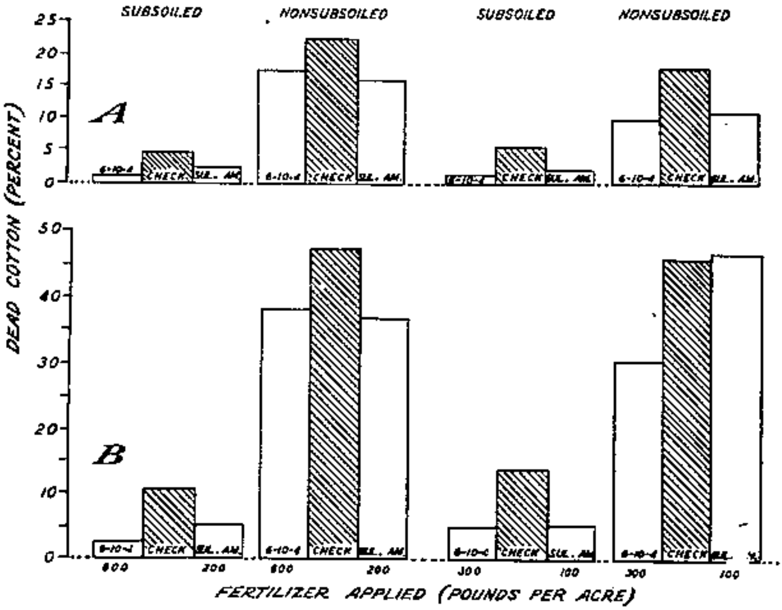


FIGURE 34.—Effect of fertilizers on the prevalence of root rot, Blanks experiment no. 1; percentage of dead cotton (*A*) July 21, 1931, (*B*) August 5, 1931.

field, heavily infested with root rot, was in cotton in 1928; it was cropped to hegari in 1929 and 1930, and half of the area was subsoiled in the summer of the latter year. This treatment greatly lowered the degree of infestation over the field, especially in the subsoiled area, when returned to cotton in 1931. An experiment with a number of fertilizers was conducted that year, the treatments being duplicated on the subsoiled and nonsubsoiled areas.

The fertilizer treatments and their effect on yields and on the distribution of dead cotton are shown in table 24. These data for July 21 are represented graphically in figure 34, *A*. The lower proportion of dead cotton on fertilized plots, as compared with adjoining check plots, is outstanding. All fertilizer treatments were very effective in increasing yields. In general, the effect of fertilizers on the proportion of dead plants was inversely proportional to their effect on yields.

TABLE 24.—*Effect of fertilizers on root rot and yield of cotton, Blanks experiment no. 1, 1931*

Plot no. and treatment	Fertilizer used and quantity per acre	Dead cotton, 1931		Increased yield of seed cotton per acre due to fertilizer
		July 21	Aug. 5	
		Percent	*Percent*	*Pounds*
Subsoiled:				
K-50-600	6-10-4 [1], 600 pounds	1.0	2.3	345
K-check	Check	4.6	10.1	
K-N-200	Sulphate of ammonia, 200 pounds	2.5	4.8	324
Nonsubsoiled:				
50-600	6-10-4 [1], 600 pounds	17.7	38.2	209
Check	Check	22.2	47.8	
N-200	Sulphate of ammonia, 200 pounds	16.0	36.8	330
Subsoiled:				
K-50-300	6-10-4 [1], 300 pounds	1.2	5.0	316
K-check	Check	5.3	13.5	
K-N-100	Sulphate of ammonia, 100 pounds	1.8	5.0	210
Nonsubsoiled:				
K-50-300	6-10-4 [1], 300 pounds	9.7	30.7	292
K-check	Check	18.0	40.3	
K-N-100	Sulphate of ammonia, 100 pounds	11.4	46.5	106

[1] 90 percent of the nitrogen from sulphate of ammonia; 10 percent from cottonseed meal.

This direct effect of fertilizers seems to be largely one of retarding the rate of spread of the disease and delaying the killing of plants. By August 5, on nonsubsoiled ground, the effect was less marked. The difference persisted on subsoiled ground, however, where the severity of the disease had been reduced to a greater extent. This is shown in figure 34, *B* which represents graphically the records of August 5.

The examples described above represent instances in which, the severity of root rot having first been reduced by growing nonsusceptible sorghum crops or by a combination of this practice and subsoiling, the disease was still further suppressed by suitable fertilizer treatment. The fertilizer most effective under these conditions was in all cases one relatively high in nitrogen content. In fertilizer-ratio trials a similar suppression of the disease has become evident in some fields where applications have been cumulative over a number of years. In general it is most marked on those fields which have been most responsive, and the most effective fertilizer has been that which increased production to the greatest extent. The Craig field presents the best example, and here the greatest reduction in root rot resulted from ratios combining phosphoric acid and nitrogen.

In 1927 before work was begun on this field, root rot was uniformly distributed over the area used for the ratio-experiment plots. It caused the death of 94 percent of the cotton in the west section of these plots that year. Figure 35 shows the distribution of dead cotton on the field, the areas included in the plots, and the area used in making the following calculations.

Identical fertilizers were applied to the same plots in each of the following years. Only a very slight indication of direct effect was noted in 1928, after 1 year's treatment. Evidence of an actual reduction in the proportion of plants killed by the disease became more pronounced with each succeeding year. In table 25 are given the percentages of cotton killed by root rot by the end of the 1931 season on the fertilized and check plots. The last column presents the ratios

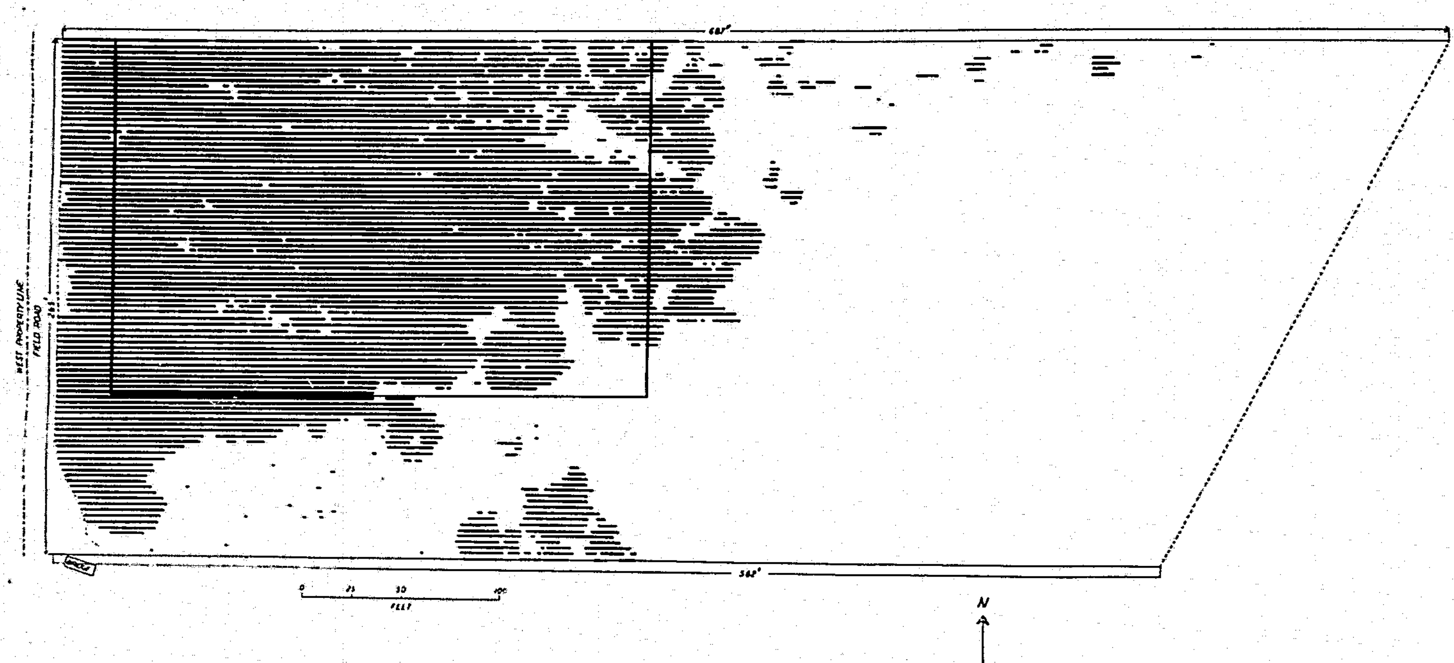


FIGURE 35.—Diagram of Craig field at the end of the 1927 season, black lines showing distribution of dead cotton before experimental treatments began, and the area included in the calculations for 1931.

between the proportion of dead cotton on the fertilized plots and that on the check plots, expressed as percentages. A value less than 100 indicates that less cotton was killed on the fertilized plot than on the comparable check, while a value greater than 100 indicates a reverse relationship. The comparisons appear more strikingly when plotted on the triangle graph (fig. 36).

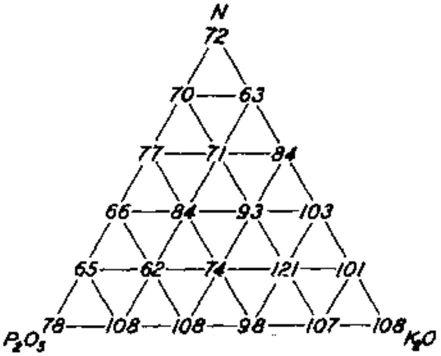


FIGURE 36.—Effect of fertilizers on root rot in the R. W. Craig experiment, showing ratio of percentage of dead cotton on fertilized plots to that on comparable check plots (X 100), October 26, 1931.

Both nitrogen alone (plot 21) and phosphate alone (plot 1) reduced the percentage of dead cotton. The greatest reductions, however, occurred from ratios combining these two constituents. Maximum reduction occurred on plot 5, which was treated with a 3–9–3 fertilizer. This same ratio gave the greatest increase in yield in 1931, and is very nearly of the same composition as the optimum ratio for 1929 and 1930, which was the 6–9–0. High potash ratios have apparently increased somewhat the proportion of plants killed, although the differences are probably so small that they lack significance. These figures in all cases were computed from map records made at the end of the season on October 26.

TABLE 25.—*Percentage of cotton killed by root rot on fertilized and unfertilized plots of Craig experiment, 1931*

Plot no.	Fertilizer analyses ($N-P_2O_5-K_2O$)	Dead cotton Oct. 26, 1931	Ratio, $\frac{\text{Percent dead on fertilizer plot}}{\text{Percent dead on comparable check plot}} \times 100$ [1]
		Percent	
Check		25.5	
1	0–15– 0	19.8	78
2	0–12– 3	20.5	108
3	3–12– 0	19.0	65
Check		20.1	
4	0– 9– 6	31.3	108
5	3– 9– 3	23.6	62
6	6– 9– 0	30.8	66
Check		46.9	
7	0– 6– 9	45.8	98
8	3– 6– 6	41.0	74
9	6– 6– 3	54.0	84
Check		64.1	
10	9– 6– 0	40.3	77
11	0– 3–12	68.7	107
12	3– 3– 9	78.0	121
Check		64.3	
13	6– 3– 6	59.7	93
14	9– 3– 3	53.5	71
15	12– 3– 0	60.8	70
Check		87.4	
16	0– 0–15	94.7	108
17	3– 0–12	83.2	101
18	6– 0– 9	81.1	105
Check		77.1	
19	9– 0– 6	64.5	84
20	12– 0– 3	40.8	63
21	15– 0– 0	36.3	72
Check		53.3	

[1] Fertilizer plots adjoining check plots were compared with those plots; other fertilized plots compared with average of 2 nearest check plots.

Evidence of a similar reduction in dead cotton from fertilizer treatments is found in others of these fertilizer-ratio experiments, although it is in no case so conclusive as on the Craig field. In general, the greatest reduction in root rot has resulted from fertilizer ratios near the optimum for cotton production, and the effect is most pronounced where fertilizers have been most effective in stimulating plant growth and increasing yields.

It is clearly evident that the increase in yield secured in these experiments is not the result of a lowered infestation on fertilized plots when the magnitude of the two effects is considered. For example, on the subsoiled area of the Nelson experiment no. 1, a difference of 3 percent in dead cotton between plots K-check and K-21 could not have resulted in an increased yield of 211 pounds of seed cotton an acre for the treatment (table 21). Similarly in the Blanks experiment no. 1 the greatest contrast in percentage of dead cotton between check and fertilized plots is found when plot 50-300 of the nonsubsoiled area is compared with the check plot adjoining (table 24). Here the difference is 15.6 percent. An increase in yield of 292 pounds of seed cotton per acre could not be attributed to such a small reduction in root rot. In the Craig experiment 23.6 percent of the cotton died on plot 5. On the check plots with which this plot is compared mortality amounted to 38 percent. The difference of 14.4 percent could not account for an increased yield of 363 pounds of seed cotton per acre. Rather the two effects must be interpreted as being more or less independent, except as to cause, although the lowered infestation has necessarily contributed in small degree to the increased yields from fertilizer.

This effect of fertilizers on cotton root-rot disease is not of sufficient magnitude to indicate economic importance at present. It is highly significant, however, as reflecting the influence of soil fertility factors in general and of the relation of fertilizers to the root-rot disease. It also implies that the continued use of effective fertilizers in successive years, together with the application of other measures designed to restore or maintain fertility, may eventually lead to material control.

CONSIDERATIONS INVOLVED IN FERTILIZER USAGE

In the experiments reported herein response to fertilizers of suitable ratio has, with minor exceptions, been obtained on the more important soils of the Texas black-land prairie section. The magnitude of such responses varies materially with the soil type and the location and past history of fields on the same soil type. The extent to which fertilizer usage may find application to increasing efficiency of production and to reducing, directly or indirectly, losses from cotton root rot will be determined by the magnitude of the response that can be attained and by a number of factors of economic nature.

The prevailing soil and climatic conditions of the section present certain problems with regard to fertilizer usage which are widely different from those common to the older fertilizer-using territory. The more restricted rainfall places a limit on the maximum crop expectation, considerably below that prevailing in the more humid areas of the South. The soils, having developed under conditions of more limited rainfall, are in general more productive and less responsive to added plant food. The latter characteristic is further accentuated by the heavy clay texture of the prevailing soils. These factors have combined to present certain problems more or less peculiar to the section, and optimum fertilizer practice will probably differ in some respects from that common elsewhere.

FACTORS AFFECTING FERTILIZER RESPONSE

The distribution of rainfall throughout the growing season undoubtedly affects the degree of fertilizer response in the black-land prairie section. Normally, rainfall is adequate to insure maximum fertilizer effect in the early part of the growing season. From about the middle of June until the middle of September, however, rains are infrequent and occur mostly as light showers. The surface 3 to 5 inches of soil gradually lose moisture until practically air-dry. Fertilizers placed in this zone accordingly become increasingly less effective. This has been reflected in the development of the cotton in these experiments. The fertilized plots showed marked superiority over check plots in May and early June and gradually lost some of their advantage as the season advanced.

The method of placement in the several experiments, particularly in the earlier years, was determined to a considerable extent by expediency, the depth depending upon whether placement was made in water furrows or opened beds, and upon the physical condition of the soil at the time of fertilizer distribution. Opportunity was therefore afforded for observation on the influence of fertilizer placement upon the degree of response. These observations have shown that nitrogen with relatively shallow placement may be fully effective in any season so far encountered in this section. This has been reflected in increased vegetative growth and deeper green color of plants with deep placement and shallow placement alike.

Phosphoric acid with shallow placement may be effective in a wet season, but is likely to fail of producing maximum returns in a dry season. On the other hand deep placement has been fully as effective as shallow placement in wet years. Accordingly, a depth of placement approximately 4 or 5 inches beneath the soil surface seems best suited under all conditions. A positive correlation between degree of response and depth of fertilizer placement can be shown in these experiments. Deep placement, therefore, offers opportunity for extending the period of maximum fertilizer effect well beyond the period of spring rains.

As pointed out in a previous section (p. 47), a number of fertilizer materials, in particular the ammonium phosphates, possess properties which should make them especially suitable for use under Texas black-land prairie conditions. The experiments have demonstrated their advantage in many instances over ordinary commercial materials in respect to enhanced early plant growth and accelerated maturity, and it is noteworthy that such advantage was most pronounced in the driest season encountered, 1930. This is highly significant, and suggests that a better understanding of these materials may lead to enhanced returns. Work along these lines is being continued.

The effectiveness of certain concentrated fertilizers in these experiments suggested that part of their value might be due to their granular structure or large particle size. The larger particles might be expected to dissolve and become available more slowly. Accordingly experiments were conducted to compare coarse (3.5- to 5.5-mm diameter), medium (2.5- to 3.5-mm diameter), and fine (less than 1-mm diameter), superphosphate particles combined in 6–10–4 fertilizers and applied to a number of soil types. The results are not conclusive, but indicate some advantage for the larger particle sizes. Coarse superphosphate (18-percent P_2O_5) particles which had been applied in the field before cotton was planted were dug up and analyzed on August 22. It is significant that these particles contained at that time 9.14 percent of total phosphoric acid, of which 1.03 was water soluble and 8.92 percent citrate soluble.[14] Because of relatively deep placement they were in moist soil at the time and accordingly had been a potential source of readily available phosphoric acid for the growing cotton throughout the season.

The distribution of rainfall in this section makes the use of side dressings or split fertilizer applications uncertain. Fertilizers higher in nitrogen with respect to phosphoric acid than those in common use were found most effective on Houston black clay, Houston clay, and Wilson clay. In regions of better distributed rainfall these proportions of nitrogen and phosphoric acid would probably be supplied by applying mixed or complete fertilizer before planting and following this with a side application of nitrogen. Here, with rainfall uncertain after time of chopping cotton, this practice cannot be followed with any reasonable assurance of success. Accordingly, if a continuation of these experiments substantiates present findings, the need for such ratios will be indicated.

METHOD OF FERTILIZER APPLICATION

Common practice in this section is to bed or list the land for cotton in fall and winter. At planting time these beds are levelled off with a sweep on the planter which deposits the seed below the surface of the resultant, almost level field. Bedding is practiced as a means of insuring moist soil in which to plant, and for the additional object of securing drainage while the cotton is in the seedling stage.

Fertilizers for the experiments already described have been distributed from a week to 10 days in advance of planting. One of two methods has been followed. Either the fertilizer was deposited in the water furrows between the beds and the land subsequently rebedded; or beds were opened with a middle breaker or sweep, fertilizer distributed, and the beds then thrown back in their original position. A type of distributor was used which deposited the fertilizer in a rather concentrated stream and about an inch beneath the bottom of the furrow. Figure 5 shows fertilizer being distributed in this manner.

Such a method of application involves considerable risk. Drying winds are the rule at the time when placement must be made; and the soil may lose enough moisture to necessitate a delay in planting until rains supply the deficit, which may be beyond the optimum date. It further entails considerable labor.

Accordingly some experiments were initiated in which fertilizers were distributed at planting time with attachments on the cotton planter. Standard equipment was used with some simple modifications. Figure 37 shows cotton being planted on an experiment

[14] Analysis by E. R. Collins, assistant soil technologist.

with a standard two-row planter, while fertilizer is being distributed simultaneously with specially modified attachments. These experiments have demonstrated the entire feasibility of such practice, although, with the experience gained, some further modifications in the design of the fertilizer-distributing machinery suggest themselves. Such equipment will, when perfected, reduce to a minimum the overhead cost of fertilizer use.

ECONOMIC CONSIDERATIONS

Fertilizer usage is not an established practice in this section, and much of the work has necessarily been of an experimental nature. The rates of application have in most cases been arbitrary and rather liberal in magnitude. The sources of plant food have not

FIGURE 37.—Method of applying fertilizer simultaneously with planting by the use of attachments on a two-row cotton planter.

necessarily been the most economical, and fertilizers have not been applied on areas larger than the plots ordinarily used in such experiments. In their inception the plans of the experiments did not necessarily contemplate their study from an economic point of view; nevertheless data have accumulated on which such a study might be based.

The price of cotton will determine to a large extent the profits to be anticipated from the use of fertilizer, and this will of course vary from year to year. The cost of fertilizer will vary, but within more narrow limits. Current valuations for a number of the more common fertilizer analyses are given in table 27, computed on the assumption that the sources of nitrogen, phosphoric acid, and potash are, respectively, sulphate of ammonia alone, 20 percent superphosphate, and muriate of potash. From the experimental results and these data the reader may make his own calculations, and these can be adjusted to meet local and seasonal conditions.

TABLE 27.—*Approximate average retail cost*[1] *of experimental fertilizers used in 1930–31*

Fertilizer analyses		Cost per ton	Cost per 600-pound application	Fertilizer analyses		Cost per ton	Cost per 600-pound application
No.	$N-P_2O_5-K_2O$			No.	$N-P_2O_5-K_2O$		
1	0–15–0	$16.18	$5.45	13	6–3–6	$25.86	$7.76
5	3–9–3	22.03	6.61	14	9–3–3	30.67	9.20
8	3–6–6	21.54	6.46	16	0–0–15	15.78	4.73
9	6–6–3	26.34	7.90	21	15–0–0	39.78	11.93
12	3–3–9	21.07	6.32				

[1] Costs calculated from data reported by Fraps and Asbury (*17, p. 11*): Cost of nitrogen as in sulphate of ammonia, 13.26 cents per pound; phosphoric acid as in 20 percent superphosphate, 6.06 cents per pound; potash as in muriate of potash, 5.26 cents per pound.

If the average price received by producers on December 15, over the period from 1920 to 1930, inclusive, is taken as the value of the cotton, and the cost of fertilizers is computed as above outlined, the increased yields produced by the more effective fertilizer in the trials on the most prevalent soils will pay the cost at least. By such calculations most of the experiments show a narrow to very satisfactory margin of profit. As regards soil type, fertilizer application is shown to be highly profitable on Wilson clay loam and Denton clay. The margin of profit is quite satisfactory on Houston clay, Bell clay, and Irving clay. Fertilizers on Houston black clay and Wilson clay paid their cost in increased cotton yields and yielded small profits when the returns for all years of the experiments are considered. Soils in the first group seem to offer possibilities for the practical introduction of commercial fertilizers on a field scale. On soils of the last group specific trials on a small scale should precede and serve as a guide for more extensive utilization. The soils of the second group occupy an intermediate position in this respect.

Furthermore, as demonstrated by the results reported, fertilizers, through their effect in accelerating maturity, furnish insurance against excessive losses from the root-rot disease, insect damage, and deteriorating influences to which the cotton crop is subject as the season progresses. They have also been shown in many instances to effect a direct, though gradual, control of root rot itself. In the degree to which these effects are manifested the margin of profit will be increased. This will contribute to maximum efficiency of production.

A number of other factors have been brought out in this study which have bearing on the economics of fertilizer use. Among these are the following:

Evidence has been presented to show that on some of the more productive soils lower acre rates of application than 600 pounds might be used with almost equal effect. Such applications would, of course, permit wider margins of profit.

Marked residual effect of fertilizers has been demonstrated on practically all of these soils. Accordingly, the current year's increase in yield cannot be taken as the full measure of benefit of a single application.

Fertilizer-distributing machinery attached to the cotton planter has proved practicable. This will reduce the overhead cost of application to a low level.

Work with concentrated fertilizers has shown that some have special value under these conditions. These materials may reasonably be expected to cost less per pound of plant food than ordinary commercial goods.

It has been possible to increase the effectiveness of fertilizers by better adapted placement. Further knowledge of the placement factor may permit even greater economies.

The use of larger particle size than is common in ordinary fertilizers offers promise of increasing their effectiveness.

These factors must be given consideration in any attempt to forecast the value of fertilizers for the soils of this section.

RELATION OF FERTILIZER USAGE TO OTHER MEANS OF CONTROL OF COTTON ROOT ROT

As pointed out in the introduction, extensive investigations on the control of cotton root rot thus far reported have not developed means of actual eradication of the disease on a field scale. While attainment of such an end is much to be desired, it would appear that, for the present, the most hopeful prospect is so to plan cultural operations in the production of cotton that losses may be evaded or offset to as great a degree as possible. Practices developed by the work of other investigators and in the experiments described herein may be made to contribute to such control of root rot as to insure production of a crop, with minimum loss, even though infestation by the disease is still prevalent.

Crop rotation has been advocated as a control measure and experiments have demonstrated that, under many conditions, introduction of appropriate noncotton crops in the crop sequence is effective in reducing losses (*11, 12, 13, 14, 66, 70*). For this purpose sorghum has proved among the most effective crops on root-rot-infested ground. Clean fallowing, in certain instances, has likewise been effective (*14, 31, 32, 70*). Deep tillage in late summer, as exemplified in subsoiling experiments by this division and others (*13, 14*) has greatly reduced the loss of crop in the succeeding season.

Without question, the above-described effects of fertilizers in evading, counterbalancing, or directly reducing losses from root rot will be enhanced and will attain their maximum when such fertilizers are judiciously employed in conjunction with these other treatments. It is entirely conceivable that a rational practice combining fertilizer usage with one or more of these cultural treatments, as conditions dictate, through material control of cotton root rot from year to year, may eventually, as a cumulative effect lead to actual eradication of the disease in many fields so handled.

SUMMARY

A progress report is presented of the results of field experiments on the relation of fertilizer usage to the control of cotton root rot, conducted in the black-land prairie section of Texas during the period 1928 to 1931, inclusive. These experiments were designed to test the effects of fertilizer treatments upon the growth and yield of the cotton crop under conditions of root-rot infestation, and upon the resistance of plants to the disease. The tests were conducted in cooperation with cotton growers and on field stations of the Bureau of Plant Industry and the Texas Agricultural Experiment Station; and they were so distributed as to cover the most prevalent soil types and the variations in climatic conditions characteristic of the section.

Fertilizer-analysis experiments, based on the triangle system, with applications of mixtures containing a total of 15 percent of plant food

at a rate of 600 pounds an acre, in some instances 300 pounds an acre, were carried out on representative areas of the several soil types. The data presented include results from five such trials on Houston black clay, each extending through 2 or 3 seasons, and from 1 experiment on Houston clay; 2 years' results on Bell clay; 4 years' results each on Wilson clay and Wilson clay loam; 2 seasons' results on Irving clay; and 3 years' results on Denton clay.

For the section as a whole the greatest fertilizer response, in acceleration of maturity and in increased yields of cotton, has been secured from the combined application of nitrogen and phosphoric acid. Nitrogen alone has usually shown a marked effect on early plant growth and color of foliage; but in only a few cases has such fertilizer given the greatest increase in total yield. A few fields have responded to phosphoric acid alone. For maximum effect on the majority of the soils, however, the two constituents must be present in combination. There has been relatively little response to potash, insofar as plant growth and yields are concerned; and in these respects the element is apparently of minor importance on the black-land soils.

The results on Houston black clay indicate a response to fertilizers relatively high in nitrogen, with increases in yield ranging from 13 to 53 percent, after application of fertilizers containing nitrogen and phosphoric acid in ratios of 1:1, to 3:1. Most pronounced acceleration of maturity resulted from ratios of higher phosphoric acid content, although higher nitrogen ratios were also effective in this regard. Fertilizers applied at a rate of 300 pounds per acre were nearly as effective as the 600-pound rates. The trend of response on Houston clay was similar; but in the instance reported, the magnitude of yield increases was greater than on most of the Houston black-clay fields. In the experiments on Bell clay there was a trend toward pronounced response to phosphoric acid, with marked hastening of maturity and increases in yield of 28 to 34 percent from fertilizers containing a 1:3, to 1:1 ratio of nitrogen and phosphoric acid. On Wilson clay appreciable acceleration of maturity and increases in yield ranging from 19 to 28 percent were obtained from fertilizers containing 6 to 9 percent of nitrogen, 3 to 6 percent of available phosphoric acid, and about 3 percent of potash. Wilson clay loam proved to be the most responsive soil encountered in the experiments, with marked acceleration of maturity and increases in yield ranging from 68 to 117 percent, from ratios high in phosphoric acid. The principal response was to phosphoric acid; but the presence of some nitrogen and perhaps a small proportion of potash in the ratio appeared necessary, particularly after repeated fertilizer treatments. Irving clay also responded to ratios relatively high in phosphoric acid, with marked acceleration of maturity and increases in yield of 23 to 47 percent from 1:3:1 to 2:3:0 or 2:3:1 ratios. On Denton clay marked response was obtained from applications of nitrogen and phosphoric acid in combination, with increases in yield amounting to 48 to 82 percent. Little or no consistent response to any fertilizer ratio was obtained in the experiments on Miller silty clay loam or on the Houston clay loam at the United States San Antonio Field Station.

The data show evidence of an appreciable residual effect of fertilizers as successive applications to the same areas become cumulative. The effectiveness of a given treatment must be judged by the average results over a term of years rather than by a single year's returns.

Results of supplementary experiments with concentrated fertilizer materials, particularly the ammonium phosphates, have shown their marked effectiveness in accelerating early plant growth and maturity in certain seasons. The increases in yield compared favorably with those from ordinary commercial materials; but the results were not entirely consistent, and have not demonstrated the advantages of such concentrated materials over those of lower analysis that might be anticipated on theoretical grounds.

In tests of various sources of nitrogen no decided advantage for any of the common nitrogen carriers was demonstrated.

Marked response to phosphoric acid was obtained in cotton following clean fallow on Wilson clay. The increases in yield were of such magnitude as to contribute materially toward compensating for the loss of crop during the period of fallow.

Application of nitrogenous fertilizers to cotton following crops of sorghum resulted in increased yields of such magnitude as to offset the unfavorable after effects of the sorghum and to provide a further increase in yield.

Evidence is presented to show the importance of the appreciable acceleration of maturity effected by favorable fertilizers in most of the experiments as a means of evading losses of crops due to progressive killing of plants by root rot. Likewise the increases in total yield are in most cases of such magnitude as to more than compensate for losses that would otherwise occur. These two well-defined effects of fertilizers combine to provide means of indirect control of the disease. Instances are cited in which such indirect control has been operative.

Data are also submitted which demonstrate conclusively and relatively consistently a significant reduction in the proportion of cotton killed by root rot where fertilizer treatments have been effective in enhancing plant growth and vigor and in increasing yields of crops. This direct effect of fertilizers, while of insufficient magnitude to be of economic importance per se, is highly significant as reflecting the influence of soil fertility in general and of the use of fertilizers on the effective virulence of the root-rot disease. It also implies that the continued use of appropriate fertilizers in successive years, together with the application of other measures designed to restore or maintain fertility may eventually lead to material control.

When such effects of fertilizers are taken into consideration, their use may prove economically practicable and profitable even on soils where the increased yields alone are relatively low. To such degree as the magnitude of all effects can be enhanced by most effective placement, selection of most suitable materials and ratios, and most efficient utilization of minimum rates of application, to the same degree will the practicability of fertilizer usage on these soils be enhanced, and the greater will be the profitableness on more responsive soils that already justify fertilizer usage.

The maximum effectiveness of fertilizers in respect to control of cotton root rot will, under many conditions, be attained when they are applied in conjunction with crop rotation, fallowing, modified tillage, and other cultural treatments. Cumulatively, continued control by such measures combined may eventually lead to eradication of the disease in fields so handled.

LITERATURE CITED

(1) Bach, W. J., and Taubenhaus, J. J.
1931. THE RESISTANCE OF MALVAVISCUS CONZATTII (ABOREUS) TO PHYMATOTRICHUM ROOT ROT. (Abstract) Phytopathology 21: 120.

(2) Bancroft, W. D.
1902. SYNTHETIC ANALYSIS OF SOLID PHASES. Jour. Phys. Chem. 6: [178]-184, illus.

(3) Bear, F. E.
1929. THE FERTILIZER TRIANGLE. Indus. and Engin. Chem. 21: 382-385, illus.

(4) Breazale, J. F.
1924. THE INJURIOUS AFTER EFFECTS OF SORGHUM. Jour. Amer. Soc. Agron. 16: 689-700.

(5) Carter, W. T.
1931. THE SOILS OF TEXAS. Tex. Agr. Expt. Sta. Bull. 431, 192 pp., illus.

(6) Conner, A. B.
1928-31. [COTTON ROOT ROT DISEASE, STUDIES AND INVESTIGATIONS.] Tex. Agr. Expt. Sta. Ann. Rept. 41: 68-69, 104-106, 1928; 42: 64-70, 114-118, 1929; 43: 56-62, 112-115, 1930; 44: 59-68, 129-132, 1931.

(7) Conrad, J. P.
1927. SOME CAUSES OF THE INJURIOUS AFTER EFFECTS OF SORGHUMS AND SUGGESTED REMEDIES. Jour. Amer. Soc. Agron. 19: 1091-1111.

(8) Dana, B. F., and Rea, H. E.
1931. DEVELOPMENT OF ROOT ROT IN COTTON PLANTED AT DIFFERENT DATES. (Abstract) Phytopathology 21: 120.

(9) ——— Rea, H. E., and Dunlavy, H.
1932. THE INFLUENCE OF DATE OF PLANTING COTTON ON THE DEVELOPMENT OF ROOT ROT. Jour. Amer. Soc. Agron. 24: 367-377.

(10) Duggar, B. M.
1916. THE TEXAS ROOT-ROT FUNGUS AND ITS CONIDIAL STAGE. Ann. Mo. Bot. Gard. 3: 11-23, illus.

(11) Ezekiel, W. N.
1929. REPORT OF THE COTTON ROOT-ROT CONFERENCE AT COLLEGE STATION, TEX. (Phytopath. Note) Phytopathology 19: 687-689.

(12) ——— and Neal, D. C.
1930. REPORT OF THE COTTON ROOT-ROT CONFERENCE AT TEMPLE, TEX. Phytopathology 20: 889-894.

(13) ——— Neal, D. C., Dawson, P. R., and Reynolds, E. B.
1931. REPORT OF THE FOURTH ANNUAL COTTON ROOT-ROT CONFERENCE. Phytopathology 21: 957-964.

(14) ——— Neal, D. C., Dawson, P. R., and Reynolds, E. B., editors.
1932. REPORT OF THE FIFTH ANNUAL COTTON ROOT-ROT CONFERENCE. Phytopathology 22: 983-993.

(15) ——— Taubenhaus, J. J., and Carlyle, E. C.
1930. SOIL-REACTION EFFECTS ON PHYMATOTRICHUM ROOT ROT. Phytopathology 20: 803-815, illus.

(16) ——— Taubenhaus, J. J., and Fudge, J. F.
1931. NUTRITIONAL STUDIES ON PHYMATOTRICHUM OMNIVORUM. (Abstract) Phytopathology 21: 120.

(17) Fraps, G. S., and Asbury, S. E.
1931. COMMERCIAL FERTILIZERS IN 1930-31 AND THEIR USES. Tex. Agr. Expt. Sta. Bull. 434, 47 pp.

(18) Haenseler, C. M.
1930. RESULTS OF PEA ROOT ROT AND EGGPLANT WILT INVESTIGATIONS. N.J. State Hort. Soc. Proc. 1929: 159-168.

(19) ———
1930. REDUCING PEA ROOT ROT. N.J. Agr. 12(4): 12.

(20) Kellerman, K. F.
1932. OZONIUM ROOT ROT, A PROBLEM OF THE ERADICATION OF A SOIL-INFECTING FUNGUS. Jour. Econ. Ent. 25: 433-434.

(21) King, C. J.
1923. COTTON ROOTROT IN ARIZONA. Jour. Agr. Research 23: 525-527.

(22) KING, C. J.
1924. HABITS OF THE COTTON ROOT ROT FUNGUS. Jour. Agr. Research (1923) 26: 405–418, illus.
(23) ——— and HOPE, C.
1932. DISTRIBUTION OF THE COTTON ROOT ROT FUNGUS IN SOIL AND IN PLANT TISSUES IN RELATION TO CONTROL BY DISINFECTANTS. Jour. Agr. Research 45: 725–740, illus.
(24) ——— HOPE, C., and EATON, E. D.
1932. THE COTTON ROOT-ROT FUNGUS INDIGENOUS IN ARIZONA DESERTS. Science (n.s.) 75: 48–49.
(25) ——— and LEDING, A. R.
1926. AGRICULTURAL INVESTIGATIONS AT THE UNITED STATES FIELD STATION, SACATON, ARIZ., 1922, 1923, AND 1924. U.S. Dept. Agr. Circ. 372, 46 pp., illus.
(26) ——— and LOOMIS, H. F.
1926. EXPERIMENTS ON THE CONTROL OF COTTON ROOT ROT IN ARIZONA. Jour. Agr. Research 32: 297–310, illus.
(27) ——— and LOOMIS, H. F.
1929. COTTON ROOT-ROT INVESTIGATIONS IN ARIZONA. Jour. Agr. Research 39: 199–221, illus.
(28) ——— and LOOMIS, H. F.
1929. FURTHER STUDIES OF COTTON ROOT ROT IN ARIZONA, WITH A DESCRIPTION OF A SCLEROTIUM STAGE OF THE FUNGUS. Jour Agr. Research 39: 641–676, illus.
(29) ——— and LOOMIS, H. F.
1932. AGRICULTURAL INVESTIGATIONS AT THE UNITED STATES FIELD STATION, SACATON, ARIZ., 1925–30. U.S. Dept. Agr. Circ. 206, 64 pp., illus.
(30) ——— LOOMIS, H. F., and HOPE, C.
1931. STUDIES ON SCLEROTIA AND MYCELIAL STRANDS OF THE COTTON ROOT-ROT FUNGUS. Jour. Agr. Research 42: 827–840, illus.
(31) McNAMARA, H. C.
1926. BEHAVIOR OF COTTON ROOT ROT AT GREENVILLE, TEX., INCLUDING AN EXPERIMENT WITH CLEAN FALLOWS. Jour. Agr. Research 32: 17–24, illus.
(32) ——— and HOOTON, D. R.
1929. STUDIES OF COTTON ROOT ROT AT GREENVILLE, TEX. U.S. Dept. Agr. Circ. 85, 16 pp., illus.
(33) ——— HOOTON, D. R., and PORTER, D. D.
1931. CYCLES OF GROWTH IN COTTON ROOT ROT AT GREENVILLE, TEX. U.S. Dept. Agr. Circ. 173, 18 pp., illus.
(34) MILES, L. E.
1929. COTTON DISEASES. Miss. Agr. Expt. Sta. Ann. Rept. 42: 22–23.
(35) ———
1930. ADAMS FUND PROJECT. Miss. Agr. Expt. Sta. Ann. Rept. 43: 31.
(36) NEAL, D. C.
1928. COTTON WILT: A PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATION. Miss. Agr. Expt. Sta. Tech. Bull. 16, 87 pp., illus.
(37) ———
1929. THE OCCURRENCE OF VIABLE COTTON ROOT-ROT SCLEROTIA IN NATURE. Science (n.s.) 70: 409–410.
(38) ——— and McLEAN, L. G.
1931. VIABILITY OF STRAND HYPHAE OF THE COTTON ROOT-ROT FUNGUS. Jour. Agr. Research 43: 499–502, illus.
(39) ——— and RATLIFFE, G. T.
1931. INFECTION EXPERIMENTS WITH THE COTTON ROOT-ROT FUNGUS, PHYMATOTRICHUM OMNIVORUM. Jour. Agr. Research 43: 681–691, illus.
(40) ——— WESTER, R. E., and GUNN, K. C.
1932. TREATMENT OF COTTON ROOT ROT WITH AMMONIA. Science (n.s.) 75: 139–140.
(41) NOLL, C. F., SCHREINER, O., and SKINNER, J. J.
1915. FERTILIZER RATIO EXPERIMENTS WITH GRASS ON HAGERSTOWN LOAM. Pa. Agr. Expt. Sta. Ann. Rept. 1913–14 (pt. 2): 22–36, illus.
(42) PAMMEL, L. H.
1888. ROOT ROT OF COTTON, OR "COTTON BLIGHT." Tex. Agr. Expt. Sta. Bull. 4, 18 pp.

(43) PAMMEL, L. H.
1890. COTTON ROOT ROT. Tex. Agr. Expt. Sta. Bull. 7, 30 pp., illus.

(44) PELTIER, G. L., KING, C. J., and SAMSON, R. W.
1926. OZONIUM ROOT ROT. U.S. Dept. Agr. Bull. 1417, 28 pp., illus.

(45) RATLIFFE, G. T.
1929. A PROLONGED SAPROPHYTIC STAGE OF THE COTTON ROOT-ROT FUNGUS. U.S. Dept. Agr. Circ. 67, 8 pp., illus.

(46) ——— and ATKINS, I. M.
1931. CROP ROTATION AND TILLAGE EXPERIMENTS AT THE SAN ANTONIO (TEXAS) FIELD STATION. U.S. Dept. Agr. Circ. 193, 40 pp., illus.

(47) REYNOLDS, E. B.
1930. THE EFFECT OF SULPHUR ON YIELD OF CERTAIN CROPS. Tex. Agr. Expt. Sta. Bull. 408, 23 pp.

(48) ——— and KILLOUGH, D. T.
1927. CROP ROTATION IN THE BLACKLAND REGION OF CENTRAL TEXAS. Tex. Agr. Expt. Sta. Bull. 365, 21 pp.

(49) ——— and LEIDIGH, A. H.
1922. SULFUR AS A FERTILIZER FOR COTTON. Soil Sci. 14: 435–440.

(50) SCHREINEMAKERS, F. A. H.
1893. GRAPHISCHE ABLEITUNGEN AUS DEN LÖSUNGS-ISOTHERMEN EINES DOPPELSALZES UND SEINER KOMPONENTEN UND MÖGLICHE FORMEN DER UMWANDLUNGSKURVE. Ztschr. Phys. Chem. 11: [75]–109, illus.

(51) SCHREINER, O., and SKINNER, J. J.
1910. SOME EFFECTS OF A HARMFUL ORGANIC SOIL CONSTITUENT. U.S. Dept. Agr., Bur. Soils Bull. 70, 98 pp., illus.

(52) ——— and SKINNER, J. J.
1918. THE TRIANGLE SYSTEM FOR FERTILIZER EXPERIMENTS. Jour. Amer. Soc. Agron. 10: 225–246, illus.

(53) SCOFIELD, C. S.
1919. COTTON ROOTROT SPOTS. Jour. Agr. Research 18: 305–310, illus.

(54) ———
1921. COTTON ROOTROT IN THE SAN ANTONIO ROTATIONS. Jour. Agr. Research 21: 117–125.

(55) SEWELL, M. C., and MELCHERS, L. E.
1924. THE EFFECT OF ROTATION AND TILLAGE ON FOOT-ROT OF WHEAT IN KANSAS, 1920–1924. Jour. Amer. Soc. Agron. 16: 768–771, illus.

(56) SHEAR, C. L.
1907. NEW SPECIES OF FUNGI. Bull. Torrey Bot. Club 34: 305–317.

(57) ———
1925. LIFE HISTORY OF THE TEXAS ROOT ROT FUNGUS, OZONIUM OMNIVORUM SHEAR. Jour. Agr. Research 30: 475–477, illus.

(58) ——— and MILES, G. F.
1907. THE CONTROL OF TEXAS ROOT-ROT OF COTTON. U.S. Dept. Agr., Bur. Plant Indus. Bull. 102: 39–42, illus.

(59) ——— and MILES, G. F.
1908. TEXAS ROOT-ROT OF COTTON: FIELD EXPERIMENTS IN 1907. U.S. Dept. Agr., Bur. Plant Indus. Circ. 9, 7 pp., illus.

(60) SHIVE, J. W.
1915. A STUDY OF PHYSIOLOGICAL BALANCE IN NUTRIENT MEDIA. Physiol. Researches 1: 327–397, illus.

(61) STREETS, R. B.
1928. STUDIES OF TEXAS ROOT ROT IN ARIZONA. (Abstract) Phytopathology 18: 952–953.

(62) TAUBENHAUS, J. J., and DANA, B. F.
1928. THE INFLUENCE OF MOISTURE AND TEMPERATURE ON COTTON ROOT ROT. Tex. Agr. Expt. Sta. Bull. 386, 23 pp., illus.

(63) ——— DANA, B. F., and WOLFF, S. E.
1929. PLANTS SUSCEPTIBLE OR RESISTANT TO COTTON ROOT ROT AND THEIR RELATION TO CONTROL. Tex. Agr. Expt. Sta. Bull. 393, 30 pp., illus.

(64) ——— and EZEKIEL, W. N.
1930. RECENT STUDIES ON PHYMATOTRICHUM ROOT-ROT. Amer. Jour. Bot. 17: 554–571, illus.

(65) ——— and EZEKIEL, W. N.
1930. STUDIES ON THE OVERWINTERING OF PHYMATOTRICHUM ROOT ROT. Phytopathology 20: 761–785, illus.

(66) TAUBENHAUS, J J., and EZEKIEL, W. N.
1931. COTTON ROOT-ROT AND ITS CONTROL. Tex. Agr. Expt. Sta. Bull. 423, 39 pp., illus.

(67) ——— and EZEKIEL, W. N.
1931. RESISTANCE OF MONOCOTYLEDENOUS PLANTS TO PHYMATOTRICHUM ROOT ROT. (Abstract) Phytopathology 21: 119.

(68) ——— EZEKIEL, W. N., and KILLOUGH, D. T.
1928. RELATION OF COTTON ROOT ROT AND FUSARIUM WILT TO THE ACIDITY AND ALKALINITY OF THE SOIL. Tex. Agr. Expt. Sta. Bull. 389, 19 pp., illus.

(69) ——— EZEKIEL, W. N., and LUSK, J. P.
1931. PRELIMINARY STUDIES ON THE EFFECT OF FLOODING ON PHYMATOTRICHUM ROOT-ROT. Amer. Jour. Bot. 18: 95–101.

(70) ——— and KILLOUGH, D. T.
1923. TEXAS ROOT ROT OF COTTON AND METHODS OF ITS CONTROL. Tex. Agr. Expt. Sta. Bull. 307, 98 pp., illus.

(71) TOTTINGHAM, W. E.
1914. A QUANTITATIVE CHEMICAL AND PHYSIOLOGICAL STUDY OF NUTRIENT SOLUTIONS FOR PLANT CULTURES. Physiol. Researches 1: 133–245, illus.

(72) UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.
1931. CLIMATOLOGICAL DATA: TEXAS SECTION. GENERAL SUMMARY. v. 36, no. 13, pp. [97]–104.

(73) WILSON, B. D., and WILSON, J. K.
1928. RELATION OF SORGHUM ROOTS TO CERTAIN BIOLOGICAL PROCESSES. Jour. Amer. Soc. Agron. 20: 747–754.

(74) YOUNG, V. H., JANSSEN, G., and WARE, J. O.
1932. COTTON WILT STUDIES IV. EFFECT OF FERTILIZERS ON COTTON WILT. Ark. Agr. Expt. Sta. Bull. 272, 26 pp., illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	HENRY A. WALLACE.
Under Secretary	REXFORD G. TUGWELL.
Assistant Secretary	M. L. WILSON.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Director of Finance	W. A. JUMP.
Solicitor	SETH THOMAS.
Agricultural Adjustment Administration	CHESTER C. DAVIS, *Administrator.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Biological Survey	J. N. DARLING, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology and Plant Quarantine	LEE A. STRONG, *Chief.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Chief.*
Forest Service	FERDINAND A. SILCOX, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Bureau of Plant Industry	KNOWLES A. RYERSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Weather Bureau	WILLIS R. GREGG, *Chief.*

This bulletin is a contribution from

Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Soil investigations	A. G. MCCALL, *Chief.*
Division of Soil Fertility	OSWALD SCHREINER, *Principal Biochemist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE 1934

END