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CYCLES OF GROWTH IN COTTON ROOT ROT AT GREENVILLE, TEX.

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INTRODUCTION

Observations on root rot of cotton at the United States Cotton Breeding Field Station, Greenville, Tex., were begun in 1919. The first maps of the diseased areas were made in the fall of that year, and in 1920 a systematic mapping of all infested field plots was undertaken. These maps, showing the distribution of dead plants in each row for all plots planted to cotton, are now available for the 9-year period from 1920 to 1928, inclusive.

During the first few years little information other than the location of infested areas was gained from these maps, but after the mapping had been done for several years and a series of records for each spot was available for comparison and study, new information regarding the behavior of root-rot spots was obtained. With the continued mapping of the different spots, there has been hardly a year that new and interesting features in regard to the occurrence and spread of cotton root rot have not been revealed.

From available records, the first maps of root-rot infection were made by C. R. Letteer on the United States San Antonio Field Station, San Antonio, Tex., under the direction of C. S. Scofield, in charge of the Division of Western Irrigation Agriculture. These maps were made during the years 1916, 1917, and 1918, and were reported in 1919 by Scofield (*11*).[1] Since his report a series of maps of root-rot infections in Texas and Arizona have been published by King

[1] Italic numbers in parentheses refer to Literature Cited, p. 17.

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(*2*), King and Loomis (*3, 4*), McNamara (*6*), and McNamara and Hooton (*7*).

All the maps show that root-rot infection usually occurs in well-defined areas or spots and that the amount of injury fluctuates from year to year. It has been shown (*6*) that under conditions at Greenville, Tex., the yearly spread of root rot is ringlike and that the growth of a spot usually is uniform and outward in every direction from a common center. This corresponds closely with the observations made in Arizona on alfalfa and cotton (*2, 9*).

On the other hand, some of the seasonal maps show cases where one or more spots failed to make the usual uniform outward spread and the signs of infection appeared at only a few isolated places. At the end of the season the number of dead plants and the extent of infection remained greatly reduced, though in later seasons a renewed growth was shown. During the nine years of observation at Greenville all the root-rot spots have gone through this cycle of growth. Several years of regular growth of the spots have been followed by a very marked reduction of infection to only a few small centers and from these a resumption of the usual outward growth, characteristic of the original spot. In some cases the breaking up of the spots has occurred at 5-year intervals, while in one case the regular growth of the spot continued for at least eight years, and possibly longer, before it broke up. A more gradual breaking up of infection than occurs at Greenville has been described by King and Loomis (*3, 4*) as occurring at Sacaton, Ariz.

At first it was thought that the periodic reduction of the spots might be due to dry weather, which restricts the spread of the fungus; but the spots have broken independently of cultural and climatic conditions. Some spots have broken in wet seasons, and adjacent spots which have grown together on the same land have, in later seasons, broken up separately. Moreover, the maps show that all the spots that have broken up at the Greenville station have been near other spots which continued to grow in a normal manner. In a given season two neighboring spots have often behaved quite differently, although they have been planted continuously to the same variety of cotton, have received the same cultural treatment, and otherwise have been handled in a similar manner.

The breaking up of the spots apparently is independent of surface-soil conditions, although cases have been observed near Greenville where the carry-over appeared to be confined largely to areas in which the subsoil was either exposed or very near the surface. A detailed study of subsoil conditions, as well as of the surface soil, must be made before it can be stated positively that the carry-over points occur independently of soil conditions.

METHOD OF MAPPING ROOT-ROT INFECTION

A method of mapping root-rot infection has been developed at Greenville to provide a rapid and accurate system of recording the location of dead plants in each row. A 300-foot steel tape has been adopted, and the readings are made cumulatively in distances from the end of the row and are called as rapidly as they can be recorded.

Large-size notebook sheets, with designations D and G for readings of dead and green plants, are used for recording these data. A sample page from the notebook is shown as Figure 1. With this system of recording, a crew of three or four men can map the fields rapidly and accurately. The recorder stands at the end of the row with the tape attached to his waist and with zero on the tape coinciding with the end of the plot. The chainmen keep the tape stretched and make the readings. Handling of the tape is minimized, and efficiency in recording is increased by making the readings for two rows from the same row middle.

In drawing the maps, a paper scale graduated in sixteenths of an inch is attached to the undersurface of a transparent celluloid edge of a T square, and the readings from the field notebook are transcribed directly to the map. The green portions of the rows appear in white, and the dead portions are indicated by solid black lines. These maps show the character and true pattern of infection for each plot.

Date Mapped: NOV. 5 1928
Field or plot: D-3
Beginning N.E. corner, rows running N & S

Row												
1	G115	D116	G211	D215	G229	D232	G →	(TO END OF ROW)			G	D
2	G113	D115	G160	D163	G204	D209	G215	D219	G222	D223	G233	D235
3	G156	D161	G204	D205	G208	D212	G215	D217	G218	D219	G230	D236
4	G115	D117	G119	D122	G176	D182	G184	D195	G197	D200	G203	D213
	G215	D221	G226	D240	G →	D	G	D	G	D	G	D
5	G106	D122	G173	D176	G178	D179	G183	D186	G187	D196	G197	D207
	G212	D218	G220	D235	G →	D	G	D	G	D	G	D
6	G122	D123	G146	D147	G158	D160	G169	D172	G173	D174	G176	D180
	G186	D187	G188	D190	G191	D193	G198	D200	G228	D236	G →	D
	G	D	G	D	G	D	G	D	G	D	G	D
	G	D	G	D	G	D	G	D	G	D	G	D
	G	D	G	D	G	D	G	D	G	D	G	D

FIGURE 1.—Sample page from field notebook for recording root-rot infection. G = Green plants; D = dead plants. (See fig. 3, I)

ROOT INFECTION ON LIVING PLANTS

In mapping, the limit of infection is taken as the point midway between a dead and a living plant in the same row. Usually the root-rot fungus has advanced some distance beyond the last dead plant, and if adjoining green plants are pulled up or dug out they are likely to show diseased roots. This condition continues during the late fall, after temperatures have declined and the growth of the fungus is retarded. The extent of infection that may be found on the larger roots of green plants adjoining dead ones is shown in Figure 2.

While taking the field notes on infection for plot C–1 on November 4, 1927, two isolated plants which had died of root rot late in the season were pulled up and their locations recorded. The occurrence of these two isolated dead plants suggested the possibility of determining the seat of infection. Accordingly, during the period from November 22 to 26, the surrounding green plants were dug out, and the location and extent of infection on the larger lateral roots were noted and plotted, as shown in Figure 2. The infection was found to extend as far as 3½ feet beyond the location of the dead plants.

SMALL INFECTIONS EXTIRPATED

All the dead and diseased roots that could be found in the two spots described above were dug out to a depth of 18 to 26 inches,

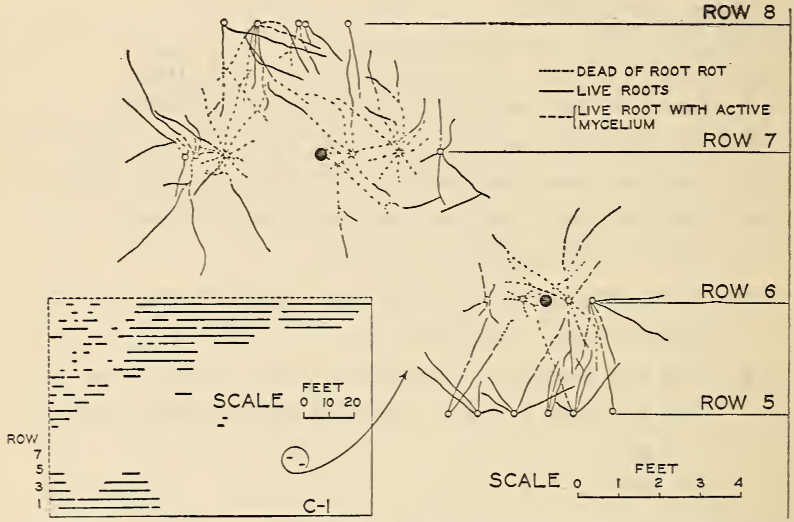

FIGURE 2.—Diagram showing in a general way (in enlarged portion) the extent and relation of root-rot infection that may be found on plants that remain green at the end of the season. The solid-black circles show location of single dead plants that were pulled up before this detailed study was begun. The location of these two small points of infection in plot C–1, and their relation to other spots near by, is shown in the lower left-hand corner

and the soil and root material were scattered over the surface to dry and weather, a procedure suggested by O. F. Cook. Cotton was again planted on the same spot in 1928, but no diseased plants were observed during the year, which indicates that under certain conditions the excavation of small isolated points of infection might be practicable as a control measure. Since the fungus apparently does not withstand such drying in the open, exposure to surface conditions may be sufficient to destroy it.

GROWTH CYCLES OF SPOTS

In this circular primary consideration is given to the individual root-rot spot rather than to the general behavior of the disease. The regular growth of spots under conditions at Greenville has been reported previously (*6*), but further studies have revealed many instances where a spot made a normal growth for several years and then died out to a great extent in a single season, leaving only a few scattered points of infection. When this dying out, or breaking up, of a spot occurs, other spots near by may show vigorous growth with almost complete destruction of plants within their areas of infection. The apparently independent behavior in the breaking up of individual spots at the Greenville station indicates that factors other than summer moisture, soil, or the crop grown are involved.

The influence of moisture on root rot is generally recognized by planters and investigators and has been made the subject of a bulletin by Taubenhaus and Dana (*12*). While the present writers are in accord with the belief that many more plants are killed in summers of excessive rainfall, the infection records for Greenville show that when an individual spot is considered, only slight losses of plants may occur under conditions which ordinarily are very favorable for the growth of the fungus and the spread of the disease.

In presenting infection maps for different spots, information relative to the amount and distribution of rainfall at Greenville will be of interest in connection with the behavior of the disease for different seasons. The monthly rainfall for the United States Cotton Breeding Field Station at Greenville from 1919 to 1928, together with the mean for the city of Greenville from 1900 to 1920, are shown in Table 1.

TABLE 1.—*Monthly precipitation in inches for the United States Cotton Breeding Field Station at Greenville, Tex., 1919–1928, and mean for the city of Greenville, 1900–1920*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1928	1.12	3.38	1.09	5.65	2.21	5.66	2.06	0.10	0.50	9.25	2.17	6.02	39.21
1927	2.04	4.08	3.62	6.20	2.93	6.50	7.13	.21	4.38	5.17	.70	3.56	46.52
1926	5.18	.71	5.00	4.00	4.90	4.36	9.89	5.16	5.28	4.85	1.12	4.47	54.92
1925	2.31	.64	.12	4.30	3.46	2.75	2.30	.63	1.99	4.61	3.85	.07	27.03
1924	1.58	2.02	4.07	1.88	4.77	.86	.02	1.01	9.47	.10	1.79	1.82	29.39
1923	3.77	1.88	2.69	4.11	.83	6.28	.23	2.38	3.38	2.67	1.19	8.16	37.57
1922	2.94	3.11	2.98	6.00	4.33	3.51	.35	1.96	.04	1.20	3.01	.10	29.53
1921	2.91	2.86	3.31	4.17	1.04	7.97	2.18	1.60	2.34	.35	2.61	.40	31.74
1920	4.12	1.03	4.07	1.26	11.81	3.44	.50	3.74	3.15	6.07	2.61	3.33	45.13
1919	1.45	1.63	1.25	2.01	5.64	1.10	5.75	1.90	3.45	13.50	3.71	.98	42.37
1900–1920 [1]	1.89	2.13	2.84	4.92	4.73	2.88	3.53	3.18	2.72	3.37	2.84	2.75	37.78

[1] Mean for city of Greenville.

Maps of infection covering a period of nine years show that all the different spots have passed through periods of sustained growth and then have had a season of relapse or breaking up into a few small points of infection. It happens that all the spots, at the time of breaking, at the Greenville station have been near other spots that continued to grow in a normal manner. The same variety of cotton has been grown continuously on all these spots, and in many cases the spots have received the same cultural treatment, yet their behavior has been different.

The almost complete destruction of plants in a root-rot spot might be offered as a reason for low mortality the following year, but some spots have shown very high mortality of plants for several years and then a mottled or "pepper-and-salt" distribution of the dead plants for a season or two before a more complete breaking up. (Fig. 3, C, D, and E.) Almost invariably the marginal rings have shown a normal advance with a heavy loss of plants on the outer edge of the spot the year before it broke up.

On the other hand, when a spot definitely breaks up, the newly infected areas around the periphery follow the same behavior as the oldest infected areas of the same spot. In other words, although the annual growth is ringlike, and the spot may represent an infection that has extended gradually for several years, all the spot breaks up during the same year, yet a spot only a few feet distant may show a high mortality of plants (figs. 6, 7, and 8) with no sign of breaking up. This difference in behavior apparently can not be attributed to soil, seasonal, or cultural conditions. It remains to be seen whether the advance and retreat of infection of the spots can be associated with features of the life history of the organism, or possibly with an accumulation of its by-products in the soil which might inhibit its vigorous growth, or with some environmental factor not yet understood.

The spots that break up in the same season are as a rule very much in the minority and therefore might easily be overlooked or ascribed to differences in cultural conditions or cropping systems. Fortunately, the Greenville station has had a sufficient number of plots cropped continuously to cotton to verify repeatedly this independent behavior of the spots under varied seasonal conditions.

CONTINUOUS COTTON PLOTS NEEDED IN ROOT-ROT EXPERIMENTS

A way in which the behavior of a spot might be misinterpreted in an experiment with control methods is illustrated by the infection on portions of plots A–9, A–10, A–11, and B–9, B–10, and B–11. This spot made a normal outward growth in 1925. In 1926 a major portion of it was sown to oats and the remainder planted to cotton as a check. Obviously, it was not possible to obtain a record of the infection on that portion of the spot sown to oats in 1926, but a map of the part planted to cotton showed a normal advance of the infection with a high mortality of plants. In 1927 the entire spot was planted to cotton, and the severity of the infection was found to be greatly reduced on the portion that had been in cotton continuously, as well as on the part that had been in oats in 1926. The disintegration on the plot planted to oats can not be attributed to the growing of a nonsusceptible crop, since the spot broke up as a unit even where planted continuously to cotton. This behavior indicates the advisability of using continuous cotton plots as checks in connection with root-rot control experiments. Moreover, it is desirable to have portions of all the different spots that are being used in an experiment treated as check plots and kept continuously in cotton.

HISTORY OF A ROOT-ROT SPOT

Maps showing the location of infection on plots D–3 and D–4 for the 9-year period from 1920 to 1928, inclusive, are shown in Figure 3. The continued extension of this spot and its breaking up in a single year to a few centers of infection, followed by a steady renewed growth from these centers, is typical of the other root-rot spots at the station, although the distribution of the dead plants was less regular than in many other cases. A study of the early infection maps of this spot shows that there was a more or less gradual decrease in the percentage of plants killed within the spot from 1920 to 1924. Whether this interrupted pattern is an indication of the presence of an accumulation in the soil of some inhibiting substance, or simply a decrease in the activity of the fungus, or is due to certain environmental conditions is not known. Whatever the cause of the breaking up in 1925, the disintegration can not be attributed to the lack of live host material, since at the end of the season of 1924 about one-

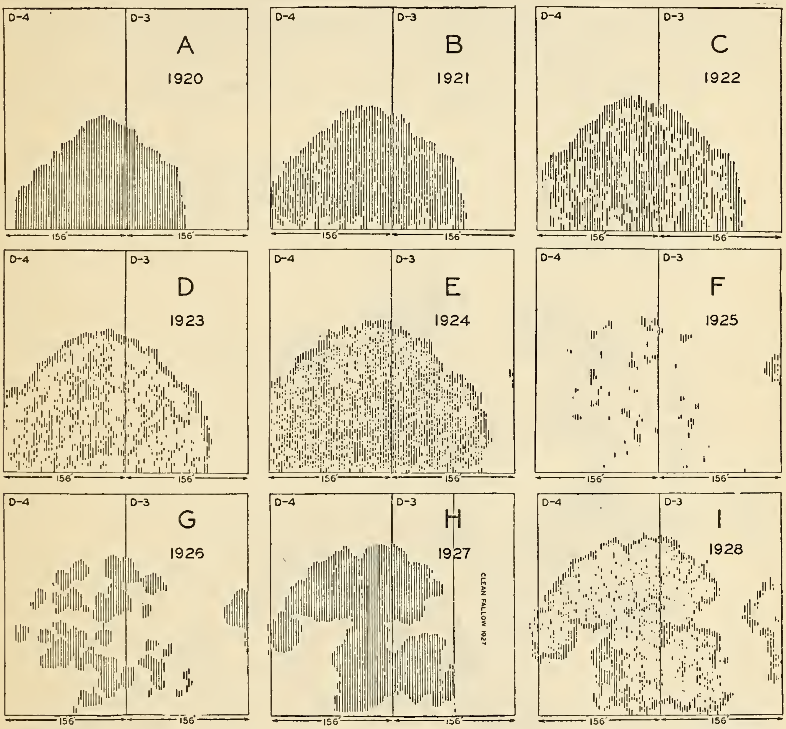

FIGURE 3.—Distribution of infection and cycle of growth on plots D–3 and D–4 for the 9-year period 1920–1928. A small portion of a neighboring spot advancing into plot D–3 is shown on the extreme right of E, F, G, and I. Although only a few feet distant from the spot that broke up in 1925, it continued its normal advance, killing most of the plants within its bounds. The persistence of infection from 1920 to 1924, as shown in the lower left-hand corner of A, B, C, D, and E, stands in sharp contrast to the absence of infection within the same area from 1925 to 1928, inclusive, as shown in F, G, H, and I. The same condition may be noted for a large sector on the lower right-hand side of the spot where the infection persisted until the breaking up of the spot in 1925

third of the plants in the infected area were alive. The small isolated carry-over spots that persisted after the breaking up are shown in Figure 4.

When this spot broke up, there was no appreciable advance along the outer margins, where only a few small points of infection persisted. Figure 5, A, shows the margins of infection from 1920 to 1924, inclusive, and Figure 5, B, shows the margins of infection from 1924 to 1928, with the restricted injuries of 1925 shown as vertical lines. The maps show that with the exception of the break in 1925 the yearly advance of the fungus has been remarkably uniform regardless of the amount of rainfall. (Table 1.) This spot broke up during a rather dry summer, the rainfall for the months of June, July, August, and September totaling 7.67 inches. While the summer of 1922 was considerably drier, with a total precipitation of only 5.86 inches for the same months, the spot showed a normal advance with no signs of breaking up. The June, July, and August rainfall for 1924 was the lightest recorded in the history of the station, and there was no evidence that the spot broke up during that year. However, when the complete breaking up of the spot occurred in 1925, a small portion of another spot invading plot D-3 made a normal advance into new ground, killing most of the plants within its bounds. This in-

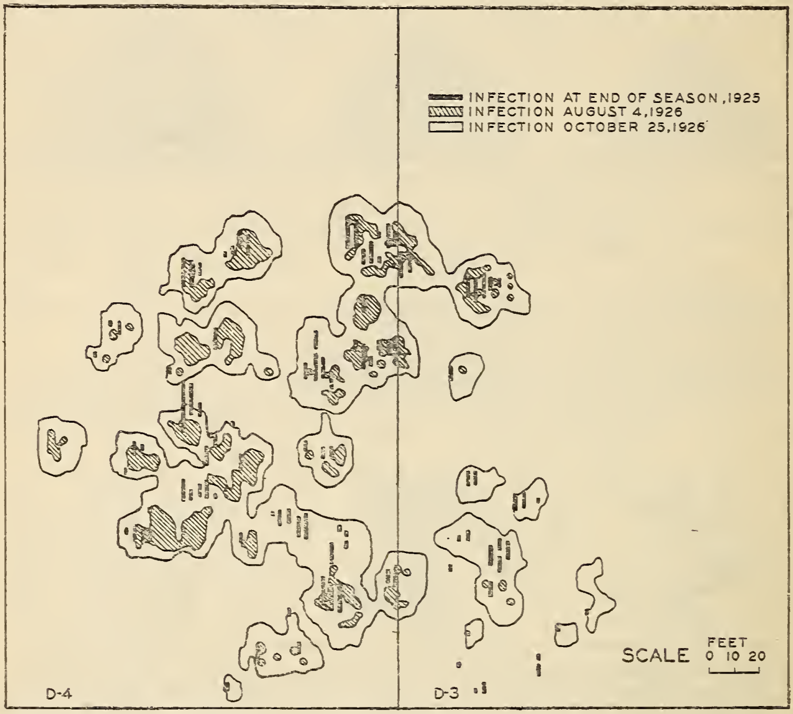

FIGURE 4.—The heavy solid-black vertical lines represent infection on plots D-3 and D-4 as mapped at the end of the season of 1925, when the spot broke up to the small centers shown. The hatched portion shows the extent of infection August 4, 1926, about three weeks after the first plants died. The irregular lines mark the limits of infection at the end of the season of 1926. The subsequent growth of these spots may be seen in Figure 3, H and I, which shows the infection for 1927 and 1928

fection was only a few feet distant from the spot that broke up and is shown in Figure 3, E, F, G, and I, on the extreme right.

A noteworthy feature in the behavior of this spot was the apparent complete disappearance of infection from an area of approximately one-fifth of an acre in a corner of plot D-4, as shown in the lower left-hand corner of Figure 3, F to I. When the spot broke up in 1925, following a heavy infection for five years, not a single carry-over point was evident in this part of the plot, and from 1925 to 1928 there was no recurrence of infection in it other

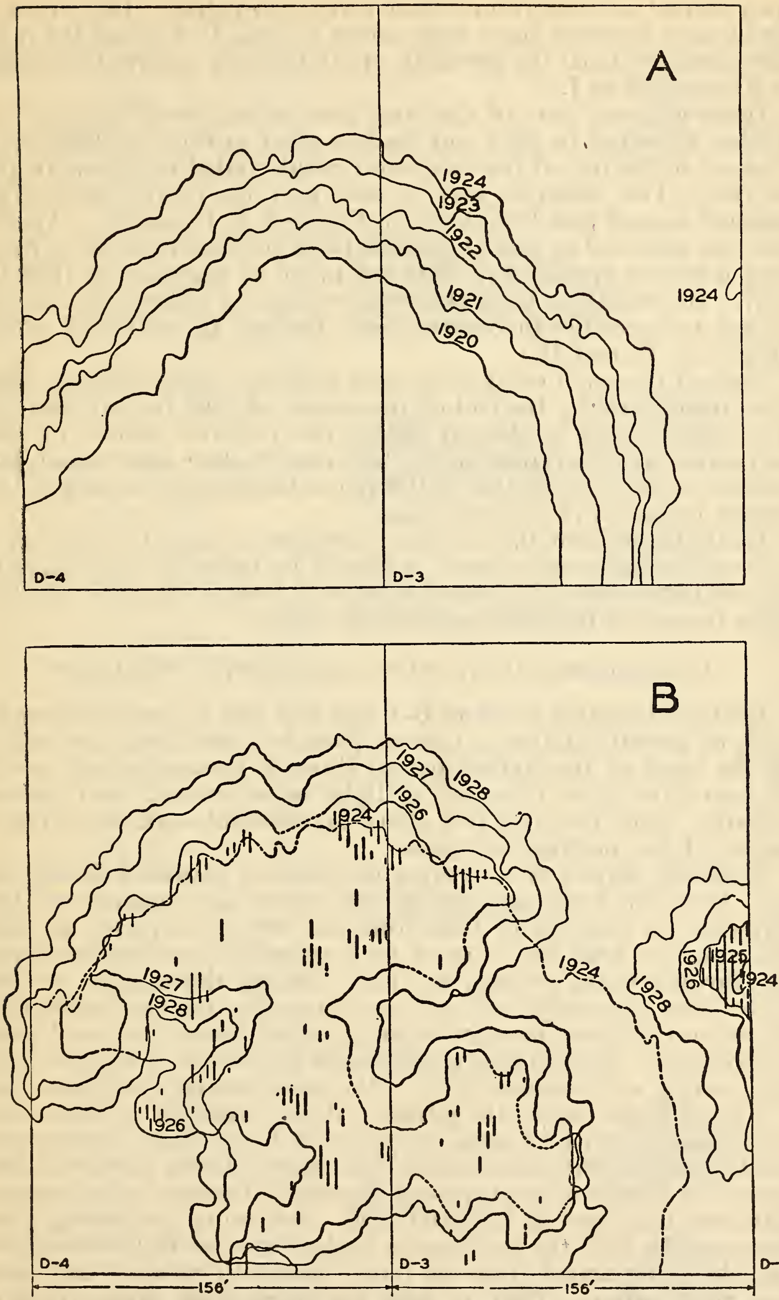

FIGURE 5.—Limits of root-rot infection on plots D–3 and D–4 from 1920 to 1928, inclusive. A, Limits of infection from 1920 to 1924, inclusive; B, limits of infection from 1924 to 1928. The restricted injury of 1925 is represented by the vertical lines in B and also illustrates the importance of the carry-over points of infection to subsequent spread. Regardless of the breaking up of the infection in 1925 and of the character of the season, the infection has made a remarkably uniform advance for the 9-year period. Note also invasion from plot D–2

than normal invasion from outside carry-over points. The same condition may be noted for a large sector on plot D–3 where the infection persisted until the breaking up of the spot occurred, as shown in Figure 3, F to I.

In an adjacent part of the same area several small points of infection appeared in 1925 and made a good growth in 1926, but in contrast to the rest of the carry-over points failed to appear in 1927 or 1928. This behavior may be seen near the central part of the infected area of plot D–4 shown in Figure 3, F, G, and H. Another case was observed on plot D–3 where three very small points of carry-over infection appeared in 1925 but failed to reappear in 1926 and 1927. In 1928 these locations were overrun by other infection, and it was not possible to observe them further as individual points. (Fig. 3, F, G, and H.)

Most of the small carry-over spots, however, made uniform vigorous growth, and by the end of the season of 1928 the infected area was almost equal to that of 1924. The renewed growth of these carry-over spots is typical of the behavior of other spots which have broken up and shows that following a break there is only a temporary reduction of the crop losses.

While throughout this circular reference is made to spots breaking up during certain years, it should be borne in mind that the decline in the activity of the fungus may have occurred at any time after the end of the previous growing season.

NEIGHBORING SPOTS WITH CONTRASTING BEHAVIOR

Root-rot infection on plots B–1 and B–2 (fig. 6) passed through a cycle of growth similar to that on plots D–3 and D–4. In fact, all of the spots at the station passed through these alternate periods of heavy infection followed by light infection and then renewed growth. Plots B–1 and B–2 afford an excellent example of the behavior of two neighboring spots.

Infection limited to one corner of plot B–1 advanced during 1920 and 1921 but broke up during the rather dry summer of 1922. Growth was renewed in 1923 from the carry-over points of infection, and by 1926 the infected area extended considerably beyond the farthest point reached in 1921. During the summer of 1927, which was unusually wet and very favorable for the development of root-rot fungus, this spot broke up again into a few small points of infection. Thus, the same spot broke up twice in five years, in one case during a dry summer and in the other during a wet summer.

Figure 6 also shows the advance of the invading infection from an adjoining series of plots into plots B–1 and B–2. The invasion finally merged with the smaller spot shown in the lower left-hand corner of Figure 6, as previously described, forming what appeared to be one large spot in 1925 and 1926. Following the uniting of the two spots in 1925, the smaller one in the corner of B–1 broke up and completely separated from the larger spot with which it had united two years before. Then, in 1928, the larger spot, from which the smaller one had separated, broke up, while the carry-over points of the smaller spot made a vigorous growth and destroyed most of the plants within the area of its advance.

The growth of these two spots and their uniting in 1925 to form what appeared to be a single spot, which was followed by their alternate breaking up in years that were favorable for root rot, are significant features in the history of infection on plots B–1 and B–2. The loss of many plants in one spot, while the other showed but very few dead plants, indicates that factors other than soil and climate are responsible for such behavior.

BEHAVIOR OF INFECTION INDEPENDENT OF TILLAGE OPERATIONS

Further evidence of the independent behavior of root-rot spots on the same kind of soil that has received identical cultural treatments for several years is found in a spot on plots C–6 and C–7 and one on C–8 and C–9. The character of infection in 1928 together with the limits of infection for 1927 for these two spots is shown in Figure 7. The high mortality of plants in the spot on C–6 and C–7 in 1928 appears in sharp contrast to the spot on plots C–8 and C–9, where the infection was relatively light. The mortality of plants in both spots was high in 1926 and 1927. During these three years both spots had been bedded, planted, and cultivated in identically the same manner.

These two spots are close together, and the distance from the limit of infection of the spot on C–8 and C–9 to the nearest point of infection of the spot on C–6 and C–7 in 1927 was 96 feet. As far as surface indications and plant behavior are concerned, the two spots may be said to occupy the same type of soil.[2]

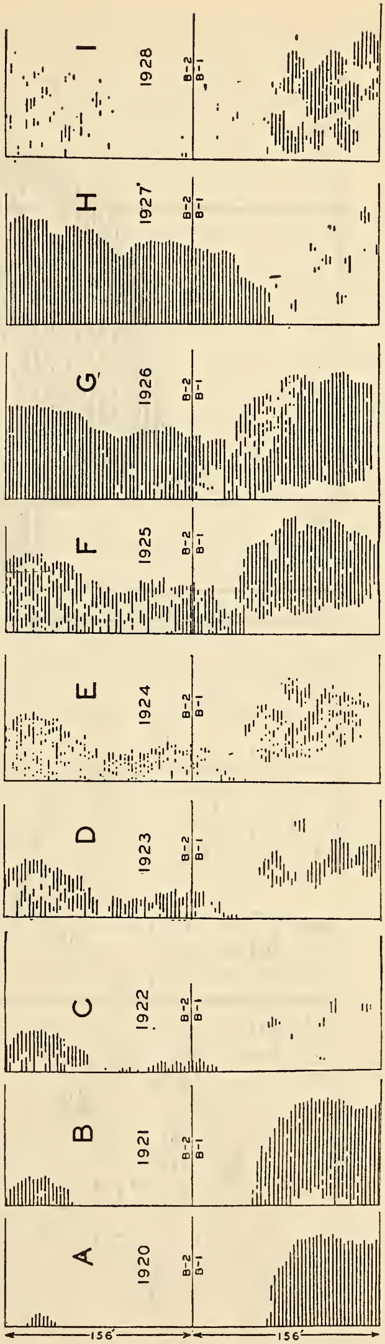

FIGURE 6.—Distribution of root-rot infection of two different spots on plots B–1 and B–2 from 1920 to 1928. The spot in the lower left-hand corner of B–1 has broken up twice within five years, once in the summer of 1922, which was rather dry, and again in 1927, during a very wet summer. The uniting of the two spots in 1925, followed by the breaking up of the smaller spot in 1927 and the larger one in 1928, illustrates how a root-rot spot may behave independently of soil or climate

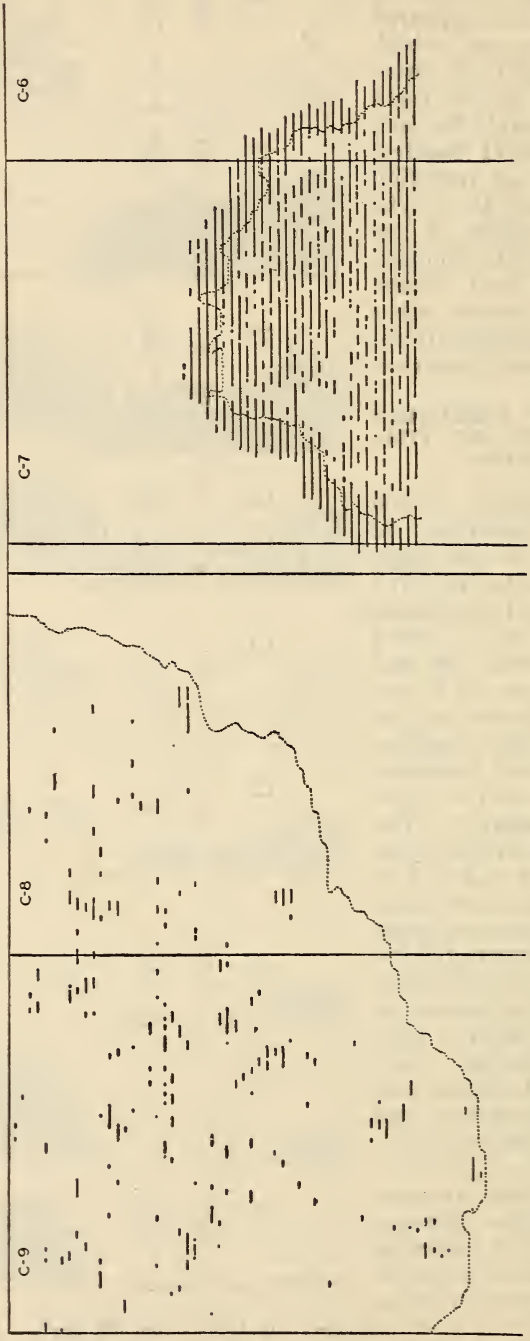

FIGURE 7.—Portions of two different root-rot spots on plots C–6, C–7, C–8, and C–9, showing the limits of infection in 1927 (represented by dotted lines) and the distribution of infection in 1928. The smaller spot, which is in close proximity to the larger one, shows a heavy mortality of plants, while relatively few plants on the larger spot are dead. The surface soil on this series of plots appears to be identical, and the two spots have been bedded, planted, and cultivated in the same manner. The difference in behavior probably can not be attributed to soil, seasonal, or cultural conditions.

A GROWTH-CYCLE CHANGE WITHIN A SPOT

The history of infection on plot C–3 indicates that a change in the growth cycle has occurred and that this change may have been induced by one and one-half seasons of clean culture.

The infection on this plot from 1925 to 1928 is shown in Figure 8. When the first record was made in 1920 the diseased area was limited to eight rows on one side of the plot. In the following five years the fungus spread to the proportions shown in Figure 8, A.

In order to obtain more definite information on the manner in which the disease is carried over from one crop to the next, an experiment was begun in 1925 to test the behavior of the fungus. On July 30, 1925, the infection was carefully mapped, and all the plants in the diseased area, and all the green plants within a radius of 10 feet of the outer margin of the infected area, were pulled up and taken away. The surface was kept in clean fallow the remainder of the season. In 1926 about one-half of the area from which the plants had been pulled up was returned to cotton, while 100 feet on one end of the plot was kept in clean fallow throughout the year.

The portion of the plot returned to cotton in 1926 showed a high mortality of plants, and during October a number of large conidial mats formed on the surface of the soil. In 1927 a heavy loss of plants occurred which was followed by a complete breaking up of infection in 1928.

In contrast with the behavior just described, a very different condition was observed on the part of the plot that had been in fallow for one and one-half seasons, or from July 30, 1925, until planting time in 1927. This 100-foot section was returned to cotton in 1927, and the invasion from two sides where cotton was grown in 1926 is shown in Figure 8, C.

In addition to this invasion of the plot there appeared two independent small isolated spots which are of special interest. These spots evidently were not due to invading infection but were of a hold-over character. Their independent nature was not revealed until the following season when all the surrounding infection broke up and left them as virile carry-over centers.

Figure 8, D, shows the distribution of the infection for 1928. The two points of carry-over infection made a vigorous outward growth with almost complete destruction of plants in the infected area, while the infection on the major portion of the plot, including the invasion into the fallowed area, broke up into only a few scattered points. Such behavior evidently can not be attributed to soil, cultural, or seasonal conditions. There was obviously a difference between the older infection which failed to appear and the younger points which grew so vigorously in 1928. A definite change in the growth cycle within the spot is indicated which apparently was induced by the one and one-half seasons of clean fallow.

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[2] Excavations near these spots have shown that a yellowish subsoil with small calcareous concretions may often be within a few inches of the surface, while from 3 to 4 feet distant the black clay topsoil may extend to a depth of more than 3 feet. After a preliminary examination by W. T. Carter, of the Bureau of Chemistry and Soils, the soil of the Greenville station has been classed as Wilson clay.

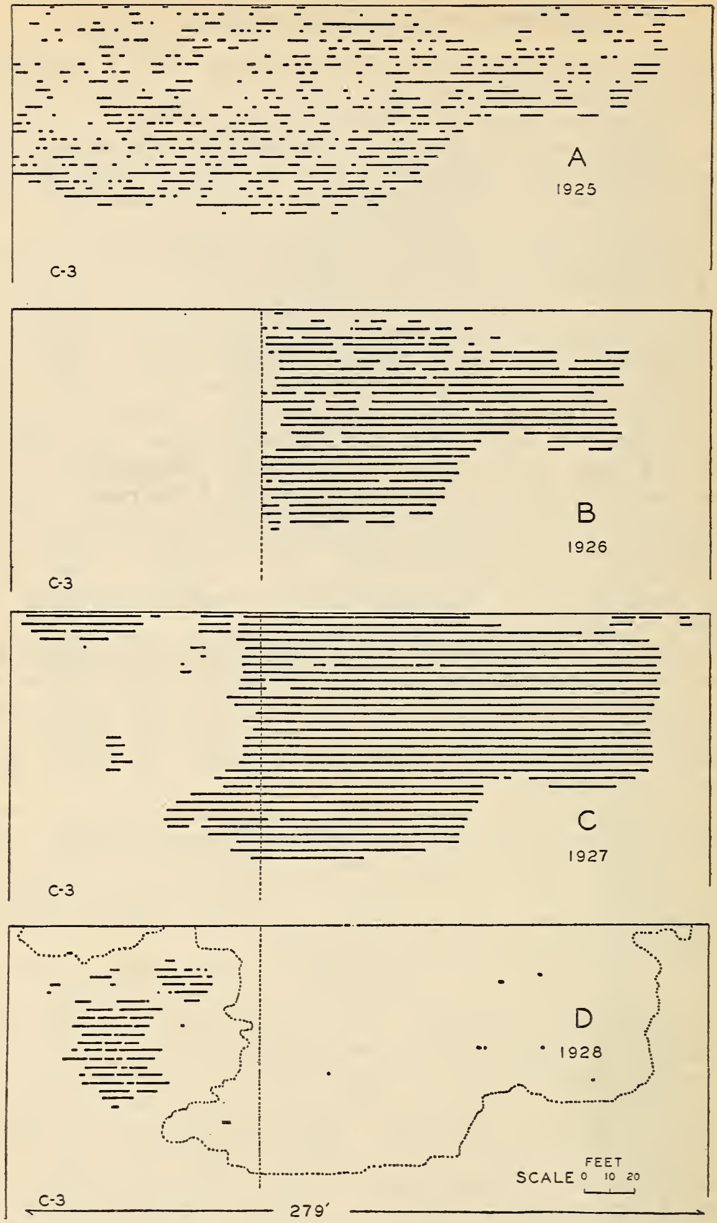

FIGURE 8.—A, Distribution of infection on plot C–3 as mapped July 30, 1925. Immediately after mapping, all of the dead plants were pulled up, along with all of the green plants within 10 feet of a dead plant, and the plot was kept in clean culture the remainder of the season. B (right), Infection present in 1926 where the plants had been pulled up in 1925; (left) clean fallow maintained on 100-foot section of rows in 1926. C, Distribution of infection in 1927, when entire plot was returned to cotton. Note the marginal invasion into the portion of the plot that had been in clean culture for one and one-half seasons. D, Infection map for 1928. The two small carry-over points which appeared in 1927 following the one and one-half seasons' clean culture made a vigorous growth in 1928, while the major portion of the infection on the plot failed to reappear. Dotted line indicates limit of infection in 1927

CARRY-OVER POINTS RESPONSIBLE FOR REINFECTION

When a heavily infected spot breaks up it appears that some factor acting on the whole spot as a unit brings about a complete eradication of the fungus except for the small carry-over points. Although a spot may be several hundred feet in diameter when it breaks up, the same reaction occurs from one extremity to the other, indicating the individuality of each infection. The maps show that in a majority of cases reinfection the following year takes place outward from these carry-over points. Occasionally, however, some infection may appear in the year following the breaking up of the spot, which is due, probably, to delayed infection not observed the previous year. The general tendency for the carry-over points to act as the principal sources of reinfection is well illustrated in Figure 4.

King and Loomis (*5*) have recently discovered sclerotia in culture in *Phymatotrichum omnivorum* (Shear) Duggar, at Sacaton, Ariz., and later Neal (*8*) found them in nature at Greenville and San Antonio, Tex. Ratliffe (*10*) describes a prolonged saprophytic stage of the fungus at San Antonio, Tex., and Dana (*1*) has recently reported the discovery of viable strands of the root-rot fungus existing in the soil independently of plant roots at Texas substation No. 5, at Temple, Tex.

Further investigation of the sclerotial and saprophytic stages may throw important light on the field behavior of root rot and the occurrence of the small carry-over points which are responsible for reinfection. These discoveries explain why experiments with clean fallows and rotations with nonsusceptible crops have not in all cases served to eradicate the fungus (*6*, *13*).

Since these carry-over points appear to be the principal sources of reinfection following the breaking up of a spot, a weak point in the life of the fungus is indicated. Cotton growers might possibly further reduce the infection by planting nonsusceptible crops for several seasons rather than returning the area to cotton. When satisfactory soil disinfectants are available their use may be found profitable in treating the small isolated carry-over spots.

SUMMARY

Maps of root-rot infection have been made each year for all plots on the United States Cotton Breeding Field Station at Greenville, Tex., since 1920, and a comparison of maps of one season with maps of other seasons shows that the spots pass through a period of sustained growth and then in a single season undergo a disintegration, or breaking up, of the original area of infection to a few small isolated points.

Infection maps are made rapidly and accurately by using a 300-foot steel tape and making readings cumulatively, later transcribing the readings directly to a map with the aid of a scale graduated in sixteenths of an inch, or other suitable fractions adapted to the size of the plots.

The limit of root-rot infection is not marked by the last dead plant but may extend at least 3½ feet beyond it.

A small isolated point of infection was apparently eradicated by digging out the diseased plant roots and the surrounding soil to a

depth of 26 inches and exposing the infected material to weather on the surface of a disease-free area.

The breaking up of an infection in a given area apparently is not due to the soil, the season, or the crop grown, but to the more or less independent behavior of the fungus itself, and may be associated with its life history, or it may be due to some peculiar environmental condition not yet understood.

A large spot on plots D–3 and D–4 made a steady growth for five years and then in 1925 broke up to a few small points of infection. These small carry-over points made an active renewed growth, and in 1928 the infected area had reached practically its former size, having advanced beyond the limits reached in 1925 at some points but failed to reach it in others. During the season that this spot broke up, another spot, only a few feet distant, made a normal growth and killed most of the plants within its bounds.

The behavior of the fungus on plots B–1 and B–2 is an excellent example of the independent action of root-rot spots. A small spot on B–1 broke up in 1922 during a rather dry summer, and the renewed growth from the carry-over points began in 1923 and continued until 1927, when it broke up again during an excessively wet summer. Following the breaking up in 1922 the carry-over made a rapid spread, uniting with a large near-by spot in 1925, forming what appeared to be a single large spot. In 1927 the smaller spot broke up the second time, separating completely from the larger spot. While the infection was greatly reduced for the smaller spot in 1927, a high mortality of plants occurred in the larger spot. Then in 1928 when the carry-over infection from the smaller spot showed active renewed growth the larger spot broke up. The alternate independent breaking up of these two spots apparently was not correlated with soil, cultural, or seasonal conditions.

Infection records on plots C–6, C–7, C–8, and C–9 show how two spots on the same type of soil and given the same cultural treatment for several seasons may behave quite differently. One of the spots showed a heavy mortality of plants in 1928, while in the other the loss was very light.

On the infested portion of plot C–3 all dead and live plants were pulled up on July 30, 1925, and the area was kept in clean culture until the following spring, when about one-half of it was planted to cotton and 100 feet on one end of the plot was kept in clean culture throughout the following year. That portion of the plot returned to cotton in 1926 showed a high mortality of plants in 1926 and 1927 and a breaking up of the infection in 1928. Also a number of conidial mats were formed on this area during October, 1926.

The 100-foot section kept in clean culture until 1927 and then planted to cotton showed infection in two independent isolated spots and also some invasion from two adjoining sides where cotton was grown in 1926. In 1928 all of the infection on plot C–3, except the two carry-over spots which made a normal advance, broke up into a few scattered points. Such behavior indicates a definite change in the growth cycle within the spot which was apparently induced by one and one-half seasons of clean culture.

The small carry-over points of infection following a break usually begin their renewed growth with greater vigor and are largely responsible for reinfection. The breaking up of spots indicates a weak point in the life of the fungus and presents a favorable opportunity for the use of soil disinfectants or the planting of nonsusceptible crops for several seasons with the possibility of further reducing the infection.

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