ROOT CONSTRUCTION OF COTTON PLANTS IN THE SAN JOAQUIN VALLEY OF CALIFORNIA

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INTRODUCTION

Cotton plants may be severely stunted, or even killed, when their roots are choked in hard soil. The injury occurs a little below the surface of the ground, where the soil becomes dry and hardens around the small seedling taproot, thus preventing further expansion. As the plant grows the stalk bulges out over the hard soil and forms an enlarged calloused base, contrasting with the threadlike taproot firmly encased in the hard soil. The plant reaches a stage of development where such constriction of the root causes it to wilt rather suddenly and it will die if the condition is not relieved in a short time.

In Texas, instances of root constriction have been reported in which cotton plants growing in heavy clay soils were strangled as a result of root constriction when the soil was compacted by continuous rain or excessive irrigation. A similar effect was observed by the writer at the United States cotton field station, Shafter, Calif., in 1930. In this case the constriction was caused by withholding water early in the season, thus allowing the soil to become dry and hard near the surface.

The disorder as noted in Texas was recorded as a new disease and named “root strangulation”; but since it is neither physiological nor parasitic, it is hardly to be reckoned as a disease unless the word is used in its broadest sense, to include any departure from normal structure or function. Cook, in discussing leaf cut, or tomosis, a common disorder of cotton seedlings, recognizes a class of ecological disorders intermediate between physiological diseases and mechanical injuries or traumatisms. To this intermediate class the strangulation of plants by root constriction may be added, though the causal factors are purely mechanical.

OBSERVATIONS AND STUDIES

At Shafter, Calif., several dead plants were found in plots of cotton that showed no general indications of stress conditions. When examined the roots of these plants were found to be severely constricted just under the surface mulch where they entered the firmer soil. In most cases the root just above the constriction was enlarged beyond the normal size at the base of the stalk, and calloused. The reduction from these large calloused bases to the constricted root below was usually very abrupt. Often a reduction from a stem 1.5 to 2 cm. in diameter to a root about 1 mm. in diameter would occur in the space of 1 cm. or less.
The constrictions of the roots were usually from 3 to 6 inches or more in length, extending through the extremely hard dry soil near the surface. Beneath this hard dry soil layer the roots appeared normal in every respect. In many cases there were no lateral roots near the surface and the plants were merely resting on flat, calloused bases. In such cases the plants were kept erect largely by the tension of the threadlike taproots that held these large calloused bases firmly against the hard soil. When the plots were irrigated many such plants fell prostrate as the soil softened and gave way under the bases.

The first observations of the disorder at Shafter were recorded July 2, 1930, the condition appearing in a series of plots that were planted April 21. These plots had been irrigated on April 15 by flooding and were harrowed lightly before planting. On June 13 the stand was thinned to about 12 inches between plants, and this operation was followed by a shallow cultivation, leaving a surface mulch from 2 to 3 inches deep. The average plants in the plots were about 12 to 15 inches high and had been flowering for several days when the first dead ones were observed. The dead and severely wilted plants were slightly smaller than the average. Further investigations showed that most of the plants were more or less constricted, and many of the smaller ones were observed to show slight symptoms of a deficient water supply. In the following days more of these plants wilted and died rather suddenly, and the condition became so severe that the plots were irrigated on July 8. Several plants that were severely wilted immediately before irrigation were tagged for further study. Some of these recovered very slowly from their wilted condition, while others regained turgidity soon after irrigation but remained a dull bluish color for several days, indicating water stress. Only a few plants failed to recover, and these were practically dead when irrigated.

Several of the tagged plants were removed July 10, two days after irrigation, by digging them carefully and washing the soil from the roots. All of these plants had badly constricted taproots and very few old lateral roots near the surface, but they had many white rootlets springing from the bases of the stalks and taproots. These rootlets ranged in length from very short stubs to more than one-fourth inch, as shown in Figure 1.

Additional specimens of the plants that were severely wilted before irrigation were removed July 22. Most of these recovered completely, and in every case in which the top of the plant had recovered the taproot was filled out to normal size. A few of the tagged plants were left undisturbed throughout the season. These showed no ill effect of the early constriction but developed normally and produced good crops of cotton.

Figure 2 shows a plant severely wilted from root constriction, in comparison with an adjacent normal plant. When the plot was irrigated a few minutes after this photograph was taken the wilted plant fell because the soil softened beneath its base. Other plants in the same plot that were wilted to about the same extent immediately before irrigation made recoveries, some apparently complete, others only partial. The degree of wilt represented by the wilted plant in Figure 2 appeared to be about the limit of stress from which a plant could recover to normal.
FIGURE 1.—Parts of constricted cotton plants two days after irrigation, showing the development of white rootlets and the quick response of the plants to irrigation. (Natural size)
In a further study of this disorder, in another set of plots, two series of natural-size photographs were made of root-constricted plants, showing portions of the taproots before and after irrigation. The first series was begun July 23 in a plot of cotton that was planted May 24, and the second series was begun August 15 in a plot planted June 7. Neither of these plots had been irrigated after planting, previous to the beginning of the studies. A group of three plants in each plot was used for study. The first group will be referred to as series 1 and the second group as series 2. Photographs are shown of only one plant in each group. In series 1 the photographs of plant 1 typify all three plants studied. In series 2 only one of the three plants survived.

**Series 1**

The upper portions of the taproots of the three plants in series 1 were photographed July 23. This was done by digging a trench about 8 to 10 inches deep close to the plants and washing away the soil from one side of the taproots by means of a small pressure tank and hose. Natural-size photographs were taken as soon as the taproots were clearly exposed. The soil was then carefully replaced about the roots and the plot irrigated.

The roots of these plants were again photographed in a similar manner on August 8 for comparison with the photographs taken on July 23. Figure 3 shows the condition of the taproot of plant 1.
of this series at the time of the first and second exposures. These observations merely confirm the result of the more casual determinations already made showing that the plants were able to fill out the constrictions of the roots in a very short time after irrigation. Each of the three plants under observation showed severely constricted roots before irrigation and a complete recovery 16 days after irriga-

FIGURE 3.—Three views of base of stalk and taproot of plant 1, series 1: A, Severely constricted taproot as it appeared before irrigation, July 23; B, taproot showing recovery from constriction, August 8, 16 days after irrigation; C, longitudinal section of the root after recovery. (Natural size)
The plants were removed from the field on August 8, and the taproots were split in longitudinal sections to show the newly developed wood. (Fig. 3, C.) No lines of demarcation were visible between the old wood of the constricted root and the new wood formed after irrigation.

**Series 2**

In series 2, consisting of three plants, the roots were first exposed for photographing on August 15, primarily to determine the rate of recovery of the constricted roots of plants that recovered promptly aboveground. These plants were in a plot that was planted June 7 and received no irrigation after seeding. Many plants in this plot were dead or dying from root constriction when the first exposure was made. Figure 4 shows a section of a row near the location of the three plants of this series, taken just before irrigation, showing plants in several stages of wilt caused by root constriction. This plot was irrigated August 15 immediately after the first set of photographs was taken.

Plant 1 of this series was turgid and green when photographed, but wilted soon afterward and did not make a complete recovery. Plants 2 and 3 were slightly wilted at 9 a.m., before the roots were disturbed. Plant 2 failed to recover and was dropped with plant 1 from this investigation, leaving only plant 3 to be studied for the rate of root expansion. This plant recovered from wilting promptly and assumed a normal appearance aboveground a few days after irrigation. A second exposure was made of this plant on August 21 and a third exposure on August 26. Figure 5 shows the condition of the taproot at the time of the first, second, and third exposures, respectively. Some idea of the rapid development that takes place in constricted roots after irrigation may be had by comparing these views. The rapid development of lateral roots near the surface of the ground appears remarkable.

In Figure 5, A, which shows the plant before irrigation, it may be seen that there were no lateral roots near the surface at the time of the first exposure. In B, which was taken six days after the first exposure and irrigation, many small white lateral roots are shown. These roots were very tender and some were broken; others were exposed entire, but care was taken not to disturb them more than was
FIGURE 5.—Base of stalk and roots of plant 3, series 2, showing rapid development after irrigation, (about seven-eighths natural size): A. View August 15, before irrigation, showing taproot severely constricted with no lateral roots near the surface; B. view August 21, six days after irrigation, showing taproot greatly increased in diameter, and development of many small white lateral roots, some of them more than 6 inches long; C. view August 26, five days after B and 11 days after A, showing taproot practically normal in size and lateral roots of tough woody structure with numerous secondary branches.
necessary, since further study of the plant was desirable. Figure 5,
C, which was taken five days after B and 11 days after A, shows these
laterals to be of tough, woody structure, with many small secondary
branches.

Several neighboring plants were removed from the plot August 21
and cross sections were made of the taproots through the constriction.
A small hard center of old wood was clearly distinguishable in these
sections, with a large ring of clear, semitransparent wood and rather
heavy bark. The proportions of old wood, new wood, and bark on
an average root were, respectively, three thirty-seconds, three
thirty-seconds, and one-sixteenth of an inch. The new wood was
very soft, and the greater part of it could be scraped off easily with
the thumb nail into a clear jellylike mass. Similar cross sections of
roots removed August 26 showed no definite lines of demarcation
between the old and new wood, but the cambium was very active and
a thin outer portion of the wood was rather soft.

DISCUSSION

Constriction of taproots was found to be general at the United
States cotton field station in plots that were not irrigated for a long
time after planting; and in many cases it became necessary to irrigate
before the plants had reached a stage of development where irrigation
appeared desirable, except as a measure to prevent some losses in
seedling stand. Some plots at the station were irrigated early in the
season during the seedling stage of the plants, and the roots of these
plants developed normally, while the roots of plants in adjoining plots
that were not irrigated became constricted. The general practice
among cotton growers in the San Joaquin Valley is to irrigate freely
rather early in the season, in order to develop a large plant, and then
to stop irrigation in an effort to force maturity of the crop. While
this practice is not considered a good cultural method, it prevents
root constriction and is probably the reason why the disorder has not
been reported heretofore. The objection to irrigating early in the
season before the cotton has reached the flowering stage is that the
plants may grow too rank and fail to mature as large a crop of bolls
as they would otherwise. Moreover, the plants that have too much
water at first may develop shallow root systems and are therefore
likely to suffer in dry weather, so that both the quality of the fiber
and the yield may be impaired. It appears that root constriction
may interfere somewhat with the application of improved cultural
methods on the sandy soils that become very hard when dry; but
since the injury is not permanent and does not appear to affect the
later development of the plants in any way, it is probably of minor
importance.

SUMMARY

Cotton plants grown at the United States cotton field station at
Shafter, Calif., in 1930 were observed to wilt and die suddenly as a
result of taproot constriction. The soil in which these plants were
grown is a light sandy loam that becomes very hard when dry, and
the constricted plants were found in each case in plots that had not
been irrigated after planting.
Irrigation corrected the condition that caused constriction, and the plants that were not too severely injured recovered after irrigation and developed into normal, well-fruiting plants.

Photographs of constricted roots taken before and after irrigation show that the plants made a rapid recovery from the disorder as soon as the cause was removed.

In one series of photographs the development of new lateral roots near the surface of the ground is shown. A plant having no surface lateral roots before irrigation is shown on the sixth day after irrigation with numerous small, white lateral roots, some of them more than 6 inches long. Eleven days after irrigation these new laterals had greatly increased in length, were tough and woody, and had many branches.

In cross sections of constricted roots made during the rapid growth after irrigation a large ring of soft semitransparent wood tissue was observed between the old wood and the bark. Six days after irrigation this new wood tissue could be scraped off with little effort into a clear, jellylike mass, but 11 days after irrigation no lines of demarcation were perceptible to the naked eye between the new and the old wood.

The disorder is probably of little importance to the cotton grower under present conditions, but it may interfere with the utilization of the best cultural methods unless some practical method other than irrigation is devised to correct the conditions causing it.