The color of the leaf blades, succulence of the plant and the root development appeared to be affected. Dark green to blue-green leaf blades resulted from the ammonium source. Differences were more pronounced at later stages of growth.

In summary, the amount and frequency of water applied and the nature of the soil can influence the relative effectiveness of nitrogen sources. The more water or the more frequently water passes through the soil the greater the advantage for the ammonium sources. The soil texture can be an important factor here.

Time of application is an important factor in determining the behavior of different nitrogen forms. Ammonium forms are favored by early application, particularly when large amounts of water are added subsequently to the soil. However, a nitrate form may be advantageous when a severe nitrogen deficiency occurs and should be corrected in a minimum period of time.

Under most normal field conditions the detrimental effects of ammonium observed in nutrient solution probably would not result. Three factors are involved: Nitrification, presence of some nitrate, and the proportion of the plant root system in contact with ammonium ions in the soil.

Additional experiments are in progress and are planned for cotton and other crop plants to study the effects of nitrate and ammonium.

Root Development in Upland Cotton

(Howard E. Ray & T. Curtis Tucker)

Growth and development of cotton roots are influenced by soil texture, structure and depth, moisture supply, cultivation, fertilizer placement and numerous other factors. Such influences must be considered in making decisions concerning tillage, fertilizer placement, irrigation, etc.

Numerous studies have been conducted to determine the size and extent of cotton root systems. At Shafter, California, taproots of cotton planted on May 9 had reached a depth of 40 inches by June 16 and 77 inches by July 16. In contrast, maximum rooting depths in two West Tennessee soils were only 30 and 32 inches. Variability in lateral root development is illustrated by the same Tennessee investigations in which maximum lateral root development was found in the zone 0 to 6 inches beneath the surface in a well-drained medium textured soil as contrasted to maximum development in the 6- to 18-inch zone of a poorly drained soil with similar texture. Also, total weight of roots produced was more than twice as great for the well-drained soil.

The present study was undertaken to determine rate and extent of both vertical and lateral root development by Acala 44-10 and Deltapine Smooth Leaf cotton in a typical fine-textured soil of Southern Arizona.

METHODS

The excavation site was at the Cotton Research Center near Phoenix on soil classified as Adelanto clay loam. In land leveling operations performed three years earlier, approximately two feet of fill had been placed over the original

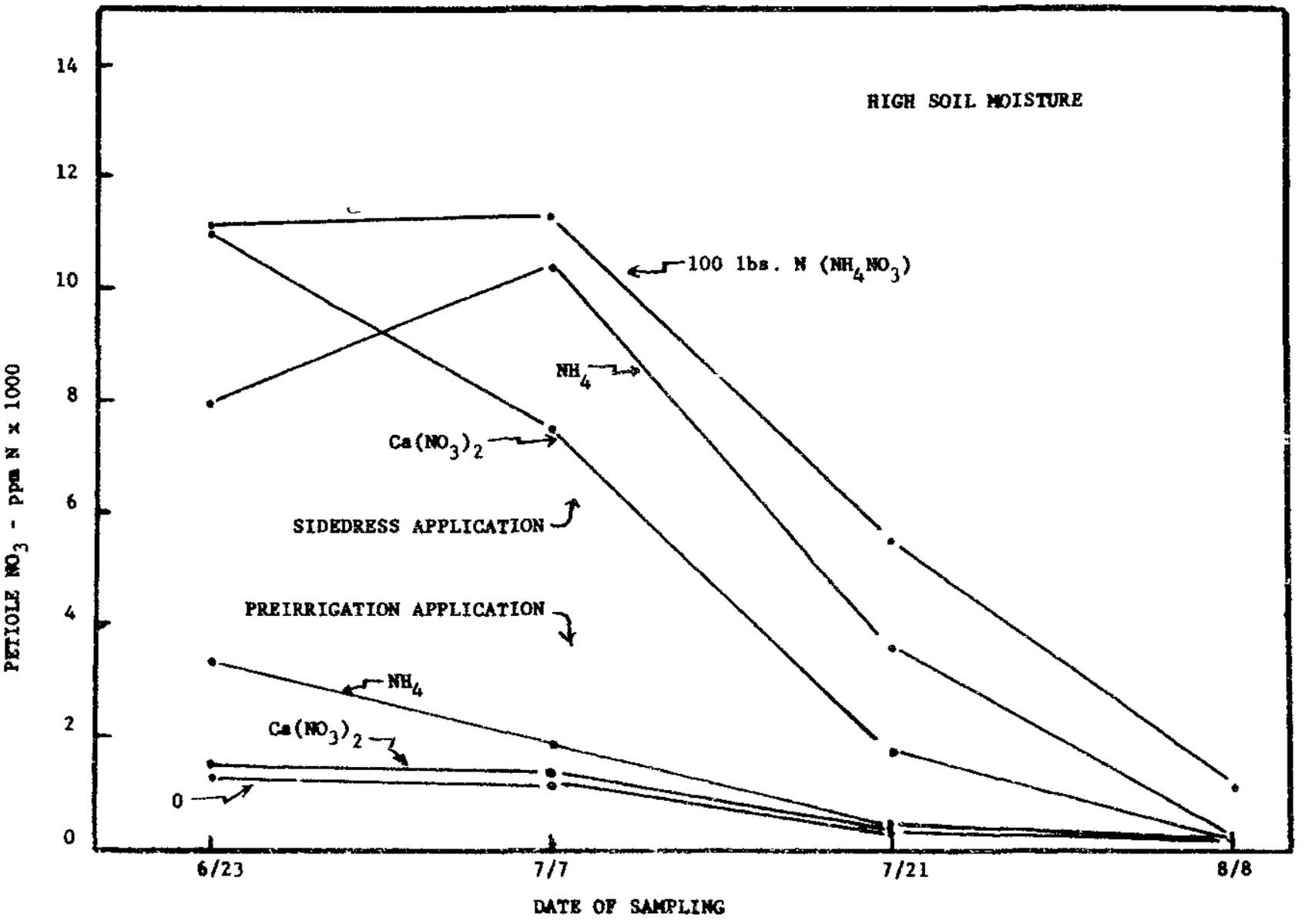


FIGURE 2. PETIOLE NITRATE AS INFLUENCED BY SOURCE, TIME OF APPLICATION AND TIME OF SAMPLING UNDER HIGH MOISTURE.

soil surface. In a zone about 6 inches thick extending just above and below this interface, the soil was seriously compacted. Caliche concretions beginning at a depth of 48 inches became semi-consolidated at about 54 inches.

Cotton was planted on April 9 on a moist seedbed. It received the first postplanting irrigation on May 25, and subsequent irrigations on June 25, July 12, July 27, August 14, and August 29. The land received 100 pounds nitrogen per acre in 1961, but no fertilizer was applied in 1962. Early season top growth was slow due to an unusually cool spring, but the remainder of the growing season was favorable and yields averaged -- pounds lint per acre for Acala 44-10 and -- for Deltapine Smooth Leaf.

Roots of one to three plants each of Acala 44-10 and Deltapine Smooth Leaf growing in adjacent rows were carefully excavated at each of six dates -- 16, 25, 35, 53, 74, and 177 days after planting. (Measurements of root development six days after planting were made in a nearby plot planted April 20 on the same soil type.)

Results:

SIX DAYS AFTER PLANTING (Figure 1)

Seedlings were still in the crook stage, just ready to emerge. Acala seedlings were slightly more advanced with roots and hypocotyls as long as 6 and 2 inches respectively. In Dp. S.L., 4-inch roots with 1-3/4 inch hypocotyls could be found. There was no evidence of branching of the young roots at this stage of development.

APRIL 25 -- 16 DAYS AFTER PLANTING (Figure 1)

The first true leaf was just beginning to emerge on the young plants. Taproots of both varieties had grown downward at an average rate of about one inch per day to a depth of 20 inches for Acala and 15 inches for Dp. S.L. Numerous lateral roots ranging in length up to a maximum of 4 inches were noted in both varieties. Undecayed residues from the previous cotton crop were easily found at this time.

MAY 4 -- 25 DAYS AFTER PLANTING (Figure 1)

Plants at this time exhibited 2 to 3 true leaves. Taproots had continued downward at about the same rate (one inch per day), reaching a depth of 23 to 24 inches below the original seed position. Taproots and laterals of both varieties showed evidence of disease injury.

Extensive lateral root development began slightly below the original seed position and extended to within 4 inches of the taproot tip. Small feeder roots were numerous on the larger laterals. Maximum lateral penetrations (at depths of 3 to 6 inches) were 7-1/2 inches for Acala and 12-3/8 inches for Dp. S.L. Laterals became progressively shorter with increasing depth, and averaged only about 1/2 inch in length at depths of 18 to 20 inches.

Thus, some root pruning would occur if fertilizer were sidedressed 6 to 10 inches from the plant in early May. On the other hand, fertilizer placed 8 inches to one side and somewhat below the seed would already have been reached by cotton roots in early May.

MAY 14 -- 35 DAYS AFTER PLANTING (Figure 2)

Plants of both varieties exhibited 4 or 5 true leaves, and were 6 to 7 inches in height. The cotton had not yet received a postplanting irrigation, and plants were somewhat smaller than those in adjacent plots which had been irrigated.

Disease injury, evident on both Acala plants examined, resulted in rotting of the taproot at a depth of about 22 inches (at the top of the compacted zone). A healthy Dp. S.L. taproot had penetrated to a depth of 35 inches.

Development of new branch roots in the surface 6 inches of the beds had ceased, and laterals developed earlier in this zone appeared to be drying up and disintegrating. This was apparently due to lack of available moisture near the soil surface. Vigorous branch root growth continued at lower depths. Lateral roots of the Dp. S.L. plant extended out beyond the row middle, and Acala laterals extended almost to the middle. On the Acala plant, a lateral root had assumed the function of the defunct taproot, and had already extended downward for several inches.

By mid-May, therefore, cotton was able to feed readily from row middle to row middle and to a depth of 10 or 12 inches. However, very little feeding was possible in the dry soil of the bed proper. The use of any type of chisel for injecting fertilizer or deep cultivation would result in some root pruning -- the amount of pruning would be governed by depth and distance from the plant.

JUNE 1 -- 53 DAYS AFTER PLANTING (Figure 3)

The cotton had been irrigated on May 25, and was now growing vigorously. Plants were 8 to 10 inches high with about 10 nodes. Effects of the compaction zone on root development were becoming noticeable.

The rate of downward growth of taproots had apparently decreased slightly. The Acala taproot tip was found at a depth of 44 inches, and the Dp. S.L. tip at 48 inches. At a depth of 37 inches the Acala taproot encountered a large stone which it grew around before again proceeding downward. Small differences between varieties in root penetration at this and other stages were not considered significant. When a taproot was injured, a lateral tended to assume its function and continue downward growth. When taproot penetration was impaired for some reason, lateral development was stimulated.

Lateral root development reflected the influence of several factors. The increased moisture supply in the top few inches of bed following irrigation had resulted in development of numerous new branch roots from the taproot at about the original seed position. Some such laterals were already as long as 3-1/2 inches. This well illustrates the rapid regenerative capacity of plant roots under favorable conditions.

Major laterals with numerous feeder roots commonly extended out past the row middle in the top 18 to 20 inches of soil. The tip of one lateral from an Acala plant was found just one inch from the taproot of a plant in the adjacent row. No evidence of branch root development was found on the bottom 3-1/2 to 4 inches of either taproot.

Two effects of soil compaction were noted. First, no lateral roots could be found in the zone of compaction (22 to 28 inches), although taproots penetrated this zone without apparent difficulty. (The same situation existed with respect to a small zone of compaction found in the Dp. S.L. row at a depth of 11 to 15 inches.) Second, a major lateral of Dp. S.L. grew horizontally along the top of the deeper compaction zone for a distance 38-3/8 inches, considerably longer than was usual for laterals at that depth.

It is evident that, by June 1, the feeding area of the cotton plant is very extensive under favorable conditions, and that any tillage operation other than shallow cultivation must result in some root pruning.

JUNE 22 -- 74 DAYS AFTER PLANTING (Figure 4)

Acala plants had reached a height of 11 to 12 inches, and Dp. S.L. plants were slightly smaller. The branch root system nearly filled the soil to a depth of 22 inches, the beginning of the compaction zone. Residues from the 1961 crop were still in evidence, although in advanced stages of decomposition.

Taproots of three Acala plants were found to extend to depths of 58, 61 and 66-1/2 inches, respectively, and two Dp. S.L. taproot tips were located at depths of 45 and 60 inches. One Acala taproot descended vertically to the zone of compaction, followed a tortuous path through that zone, and resumed downward growth. At a depth of 51 inches, the taproot split and both branches continued downward.

Although, as noted above, a network of main lateral and feeder roots nearly filled the soil from row to row down to the zone of compaction, no laterals were found within this zone. Branch root development was again evident below the compaction zone, although to a much lesser degree. Several small masses of partially decomposed crop residues encountered at various depths near the taproot of the Acala plant were filled with a proliferation of active feeder roots.

OCTOBER 3 -- 177 DAYS AFTER PLANTING (Figure 5)

The last excavation was made on October 3 as plants neared maturity. The final irrigation had been applied on August 29. Some interesting differences and similarities between plants of the two varieties were noted at this time.

On Acala, branch roots developed to within 4 inches of a taproot tip found at a depth of 65 inches. In contrast, a Dp. S.L. taproot penetrated 94 inches beneath the soil surface, but had few laterals (none more than 3 inches long) below 19 inches. On another Acala plant, the taproot terminated at the zone of compaction, but a strong lateral root grew along the top of this zone for 10-1/2 inches, then turned downward again to a total depth of 55 inches. This again illustrated the manner in which roots can compensate.

Shallowest branch roots on Acala plants were found 6-1/2 inches below the bed peak. Major laterals arising at and somewhat below this point extended in a nearly horizontal plane, and were no more than 2-1/2 inches beneath the soil surface under the furrow. Branch roots developing from such laterals were found within an inch of the soil surface directly beneath the furrow.

In contrast to the Acala, major lateral roots of Dp. S.L. were initiated from the taproot in the bed beginning only 3-1/2 inches below the bed peak. Such laterals grew downward in conical fashion, approximately following the contours of the bed, and passed under the furrow in about the same position as Acala roots. A proliferation of active feeder roots in the furrow area was evident for both varieties.

The major system of branch roots developed from the Acala taproot in a zone 6-1/2 to 14-1/2 inches below the surface, although smaller laterals developed to a much greater depth. On Dp. S.L., the major branch root system developed from the portion of the taproot between 2-1/2 and 19 inches in depth with only a few laterals below that depth. The total number and size of laterals in the major zone of development were comparable for the two varieties insofar as could be determined -- 10 to 12 major lateral and about 20 smaller branch roots per plant.

As a matter of interest, one lateral initiating from an Acala taproot reached a total length of 91 inches. Beginning at a depth of 14 inches below the bed surface, it extended 55 inches in a nearly horizontal plane at which time it was 15 inches beneath the surface of the second furrow. This lateral then progressed downward for 17 inches (passing through the zone of compaction) before turning back toward the original row and proceeding another 19 inches.

DISCUSSION

It is of course impossible to draw final conclusions from a single study of this nature conducted for one season on one soil type. The cool temperatures in early season may have altered early relationships between top and root growth somewhat. Nevertheless, some implications are evident which may be of practical importance.

1. Under conditions of favorable moisture and a deep soil, taproots of Acala 44-10 and Deltapine Smooth Leaf cotton extend downward at a rate of approximately one inch per day for the first 50 to 75 days after planting. This is in agreement with results of similar investigations at Shafter, California.

2. The oft-quoted difference between rooting depth of Acala and Deltapine Smooth Leaf cotton was not evident, although differences in lateral development were found late in the season. Through at least the first 74 days after planting, maximum rooting depth and location of major lateral roots were nearly comparable. This supports the work of Erie in the Salt River Valley which indicates that profile distribution of water use for the season is similar for the two types. In October, however, a distinct difference in lateral development was evident. Although depth of taproot penetration was somewhat greater for the Deltapine plant, very little lateral root development was found below 19 inches. In contrast, lateral roots developed on the Acala plant to a much greater depth.

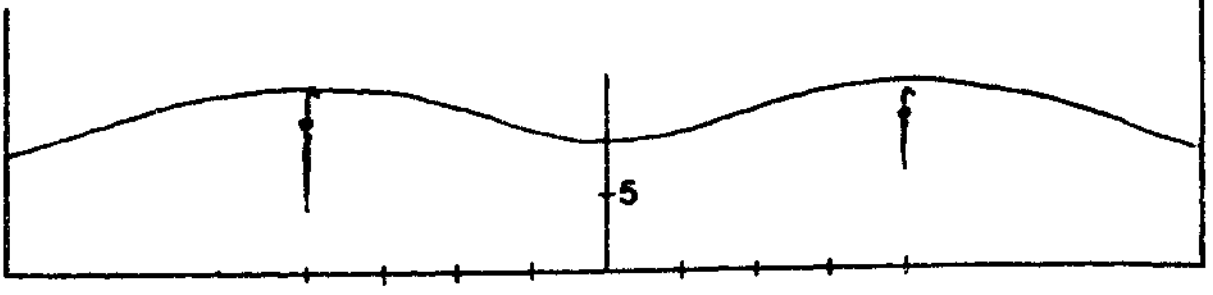
3. Although no quantitative measurements were made, observations of total root development would indicate that water uptake from each fourth of the root zone as determined by Erie is closely related to the proportion of the total root system in each portion. Erie reported that Upland cotton in the Salt River Valley absorbs 45 percent of its total water from the top fourth of the root zone, 29 percent from the second fourth, 17 percent from the third fourth and 9 percent from the botton fourth.

4. Root development is very rapid in early season, and the feeding area of the plant extends out to the middle approximately one month after planting. Therefore, placement of fertilizer in close proximity to the row should be neither necessary nor desirable.

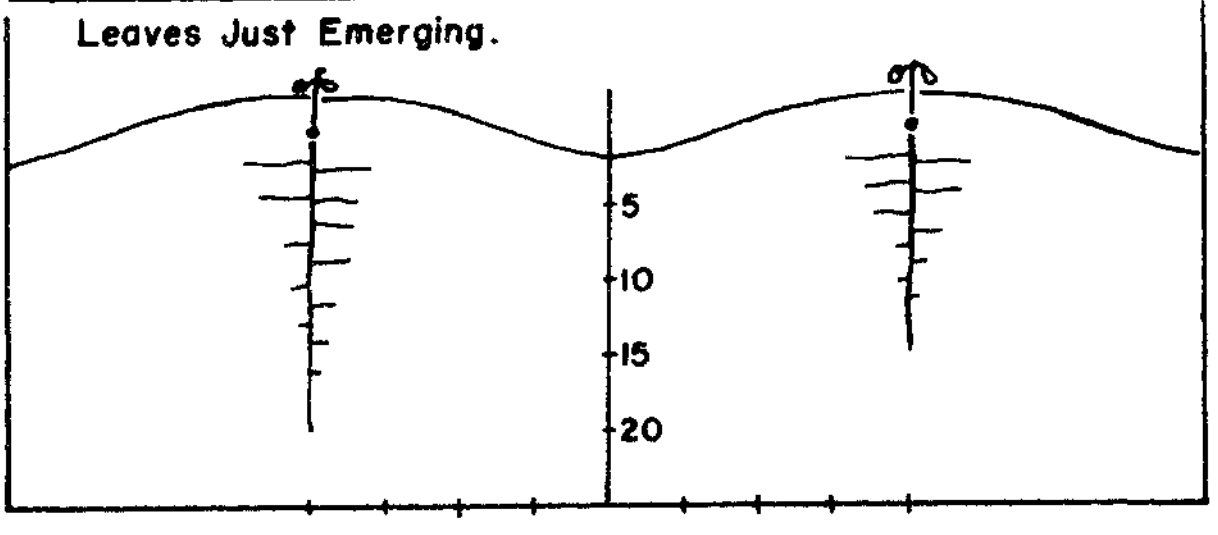
5. Any deep cultivation, injection, or chiseling operation performed later than one month after planting is almost certain to result in some root pruning.

6. Following injury to a specific portion of the root system from drought, disease, etc., roots regenerate very rapidly when a favorable environment for growth is restored. Thus, moderate root pruning caused by shallow injections or chiseling in the row middle during June may not be of practical significance.

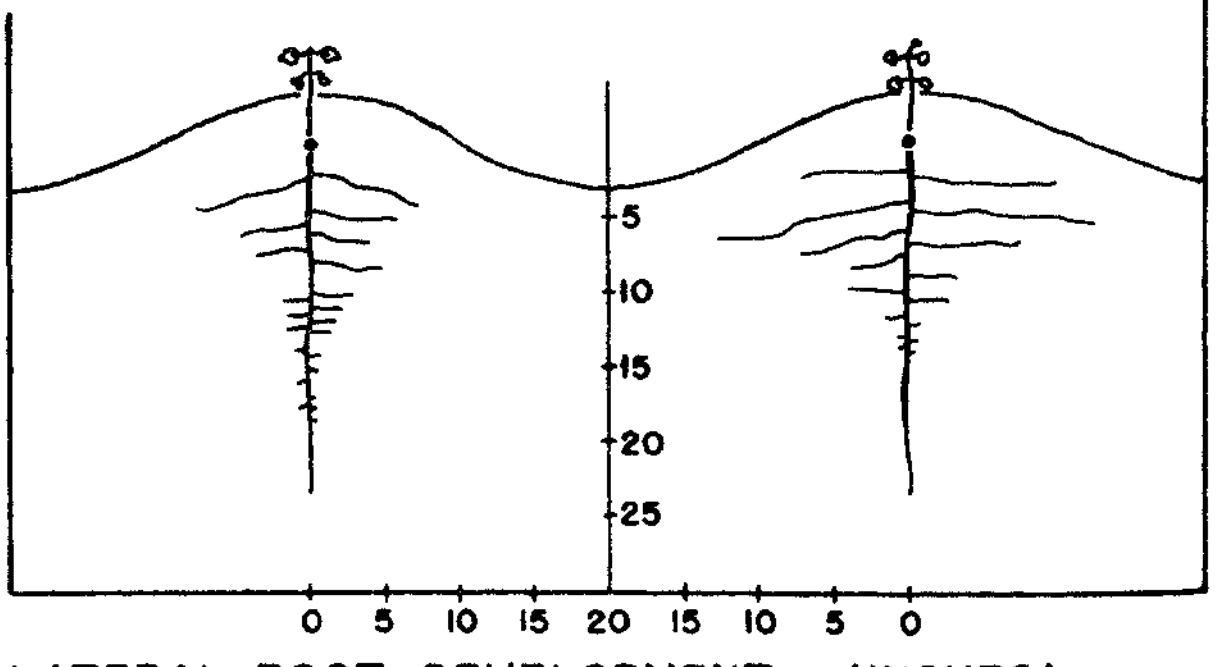
5 DAYS AFTER PLANTING



16 DAYS AFTER PLANTING – 2 Cotyledons Showing, First True Leaves Just Emerging.



25 DAYS AFTER PLANTING – 2 to 3 True Leaves, 4-6 in. Tall.



ROOT PENETRATION (INCHES)

LATERAL ROOT DEVELOPMENT (INCHES)

Figure 1

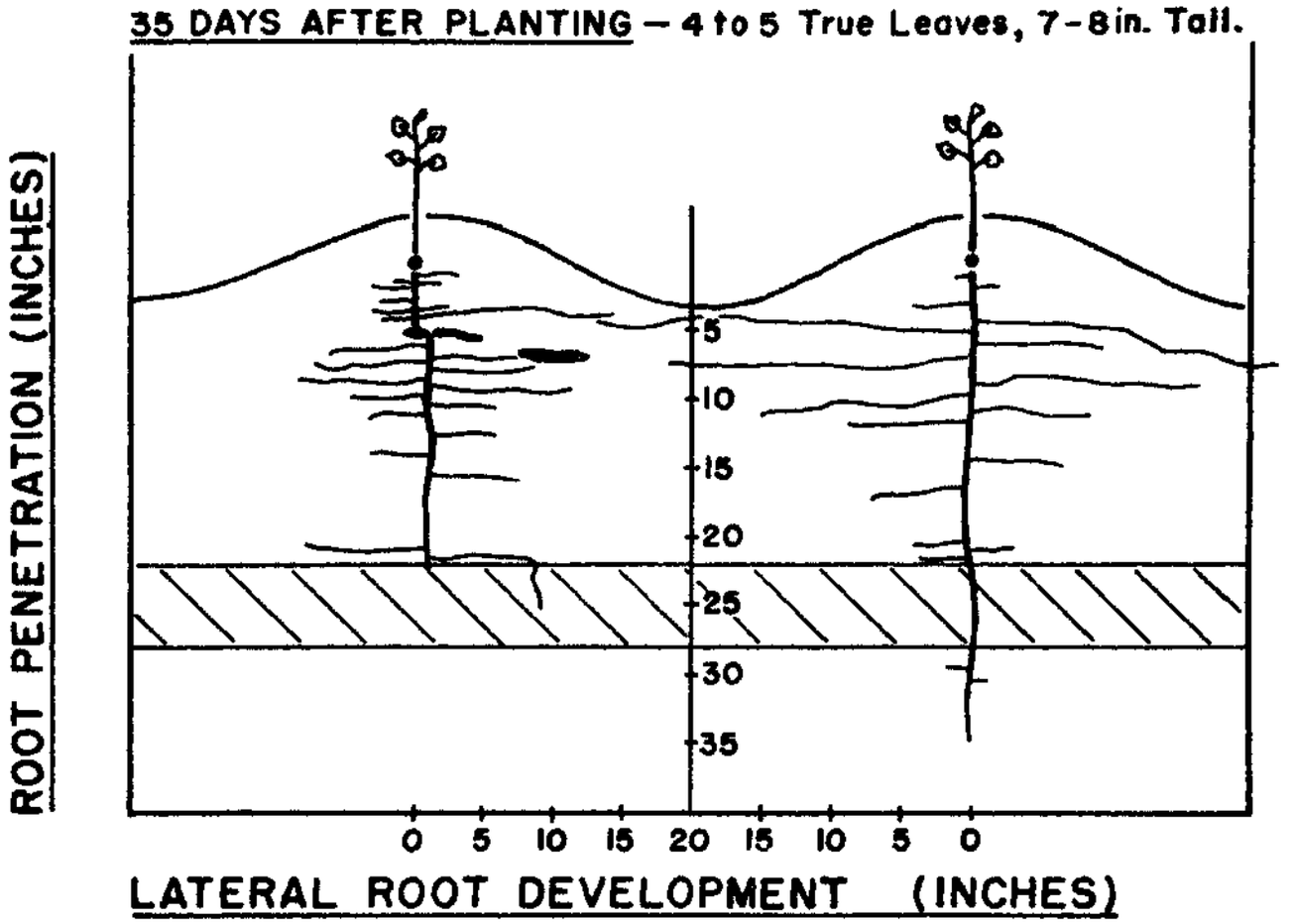

35 DAYS AFTER PLANTING — 4 to 5 True Leaves, 7-8 in. Tall.
ROOT PENETRATION (INCHES)
5
10
15
20
25
30
35
0 5 10 15 20 15 10 5 0
LATERAL ROOT DEVELOPMENT (INCHES)

Figure 2

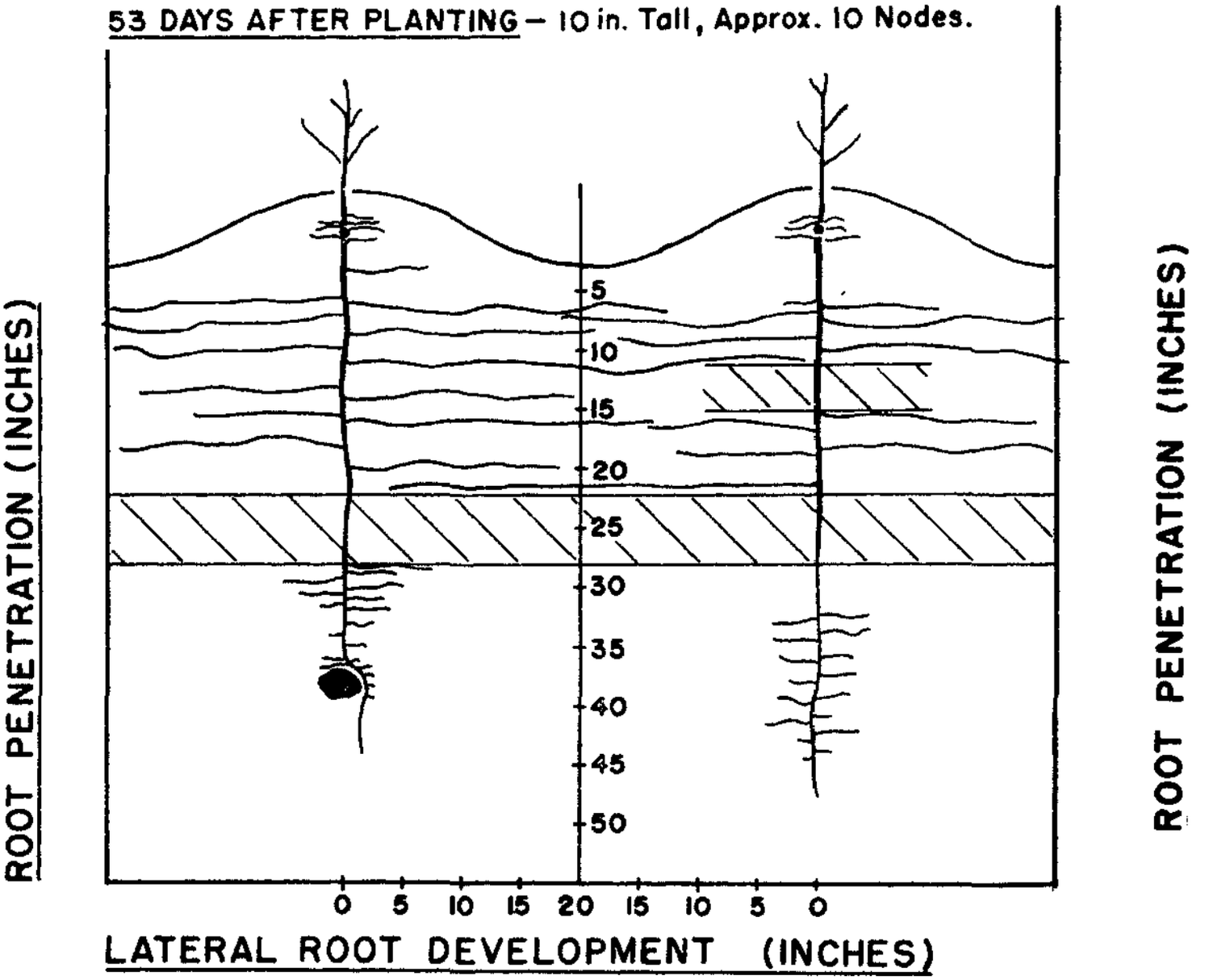

53 DAYS AFTER PLANTING – 10 in. Tall, Approx. 10 Nodes.
ROOT PENETRATION (INCHES)
ROOT PENETRATION (INCHES)
5
10
15
20
25
30
35
40
45
50
0 5 10 15 20 15 10 5 0
LATERAL ROOT DEVELOPMENT (INCHES)

Figure 3

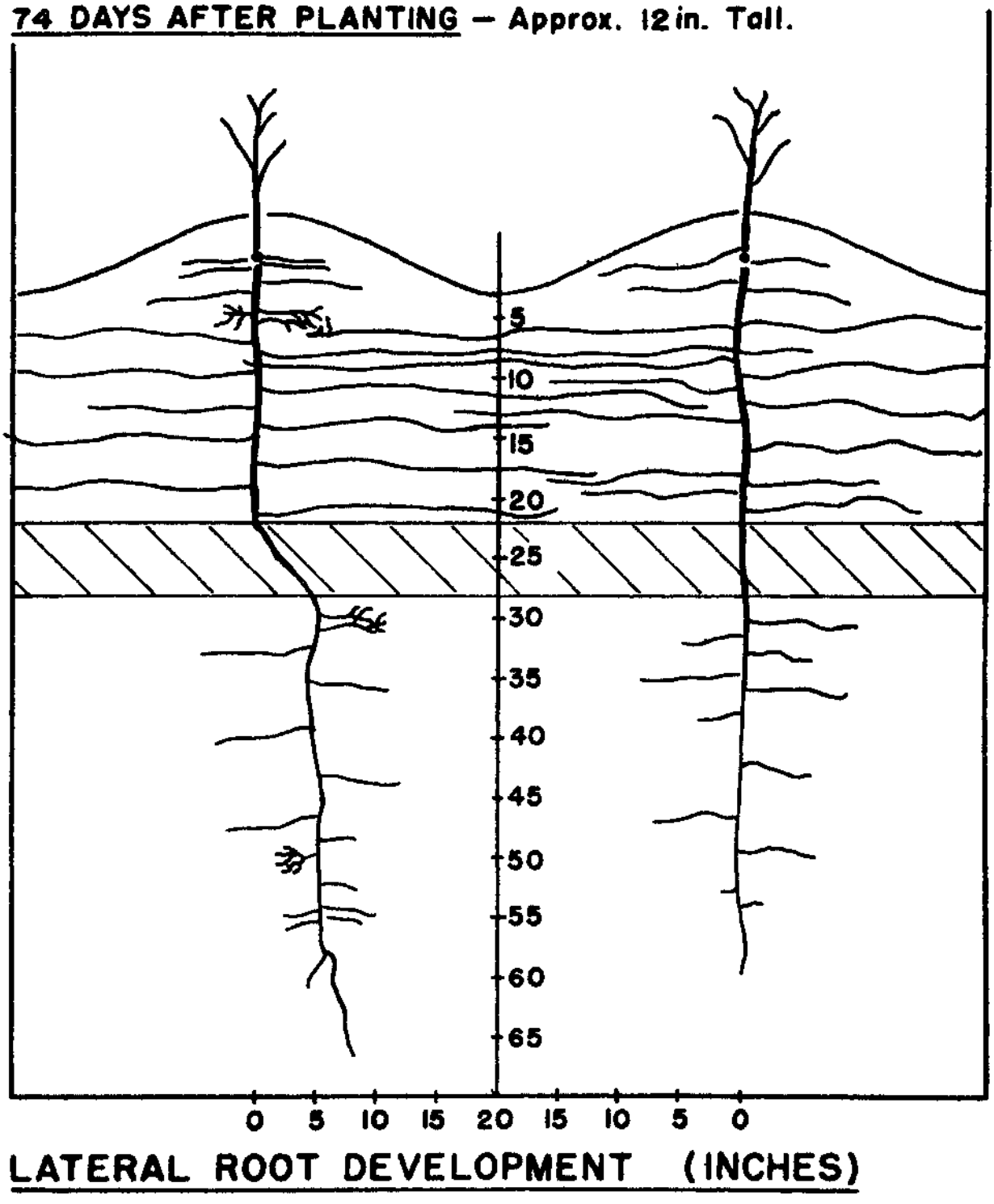

74 DAYS AFTER PLANTING — Approx. 12 in. Tall.
5
10
15
20
25
30
35
40
45
50
55
60
65
0 5 10 15 20 15 10 5 0
LATERAL ROOT DEVELOPMENT (INCHES)

Figure 4

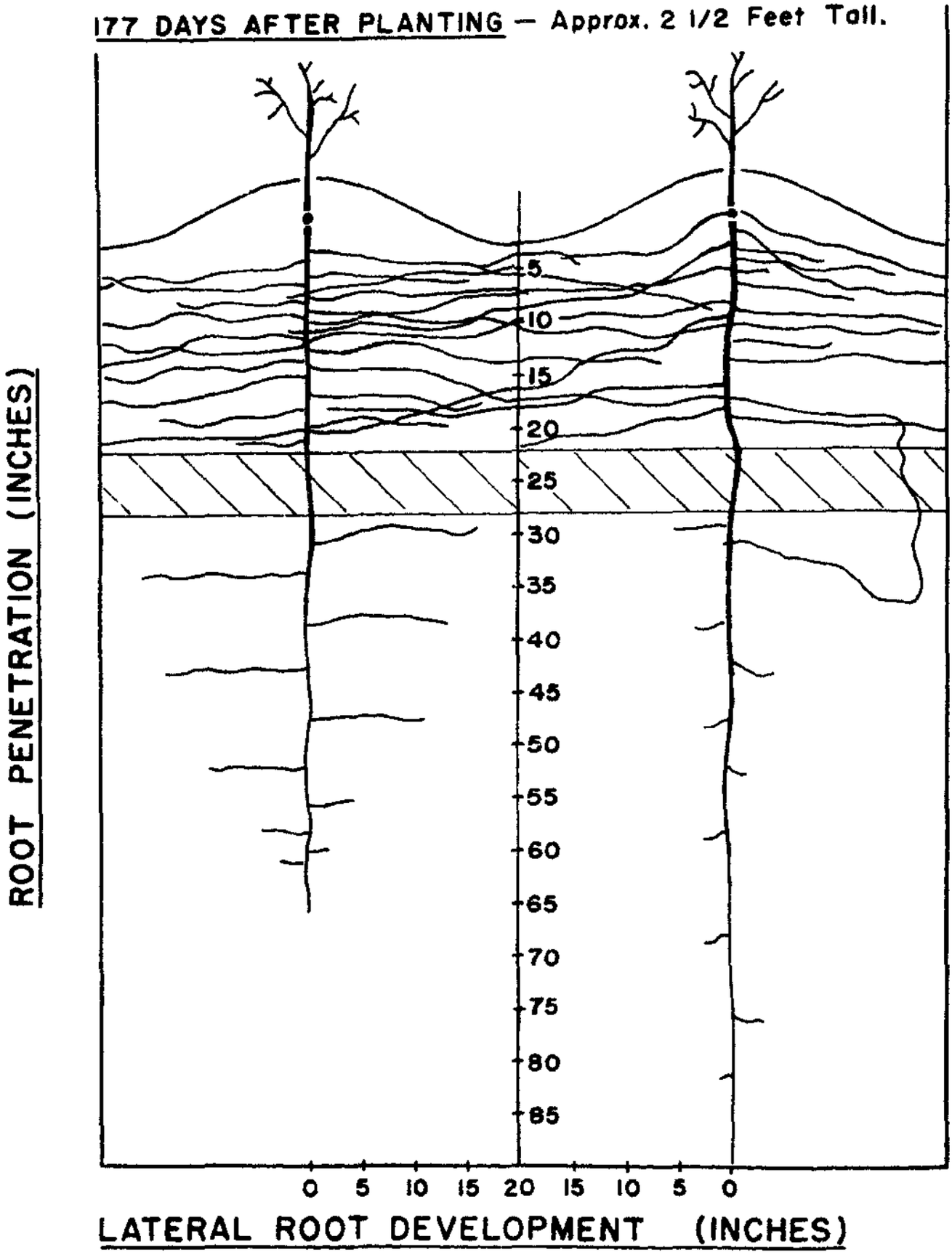

177 DAYS AFTER PLANTING — Approx. 2 1/2 Feet Tall.
ROOT PENETRATION (INCHES)
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
0 5 10 15 20 15 10 5 0
LATERAL ROOT DEVELOPMENT (INCHES)

Figure 5