NATIONAL COTTON COUNCIL

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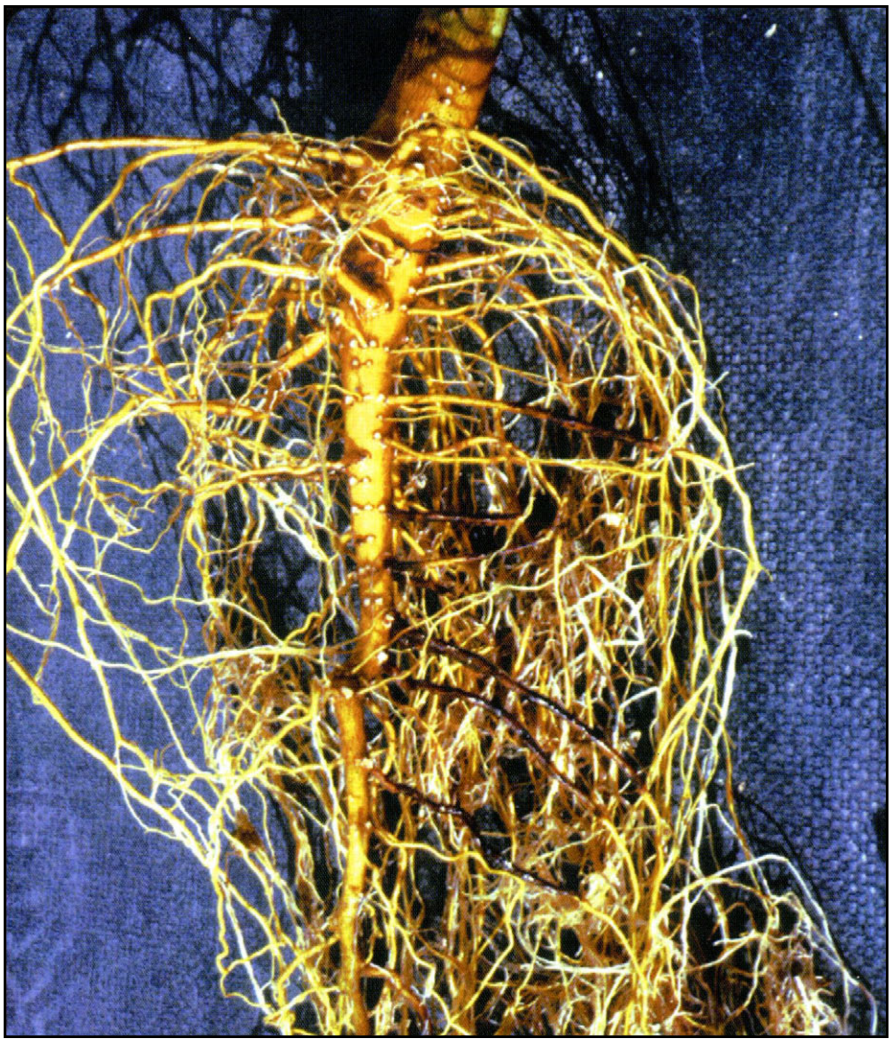
Getting to the Root of Your Crop's Health

Cotton seeds are planted every season. After a few days, or even a week, seedlings seemingly mysteriously break through the crust of the earth and begin to establish themselves. Depending on its location, a crop may eventually grow over a yard high and be full of flowers and bolls of fluffy white lint. It's the lint that puts money back into a grower's pockets, but we may argue that roots, although out of sight, are one of the most important organs to help a plant produce lint. Poor root growth means smaller above ground growth and lower yields.

Although roots account for only 10 to 20% of the total dry weight of a mature cotton plant and up to 40% of an immature plant, they can extend more than 1000 feet when placed end to end (Figure 1).



B. McMichael

Figure 1. Stretched end-to-end, roots of a single cotton plant can extend beyond 1000 feet.

INSIDE:

The Cotton Physiology Education Program (CPEP), now in its 11th year, is funded by a grant to the Cotton Foundation by BASF, makers of Pix®Plus plant regulator. CPEP's mission is to discover and communicate more profitable methods of producing cotton.

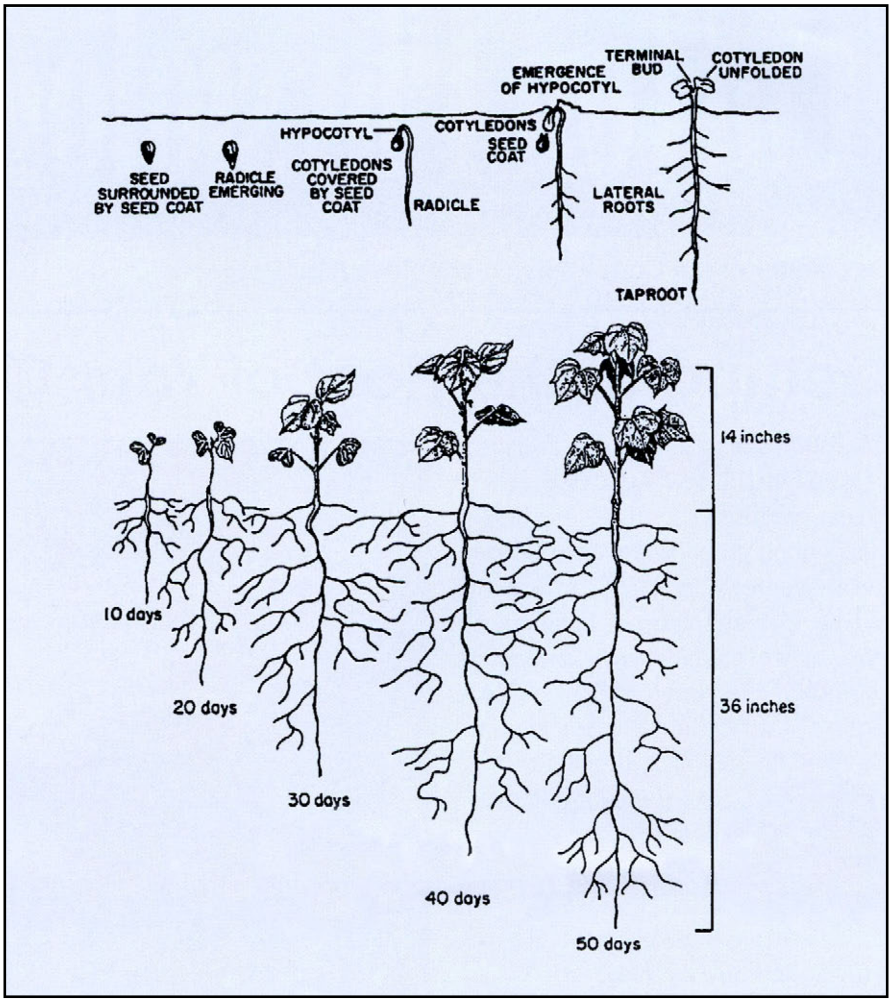
In this newsletter we describe the structure of cotton roots and show how their development and function contribute to the vitality of your crop. We also offer some ideas about how to promote healthy roots for your crop.

AUTHORS:

Anne F. Wrona, National Cotton Council; Derrick Oosterhuis, University of Arkansas; Bobbie McMichael, USDA/ARS

Shape and Structure of Roots (Morphology & Anatomy)

Roots of cotton are distinctive and not at all like the fibrous mats of roots produced by grasses, for example. Cotton has a main (tap) root that extends straight down from the stem into the soil. Branch roots divide, network and subdivide extensively through the soil profile from the taproot (Figure 2). Tap roots of cotton can grow down 1 to 2 inches per day and extend to depths of 3 yards or more in places like California.



D. Oosterhuis

Figure 2. Germination and development of cotton seedlings showing branching of roots from main tap root.

A cross section of a cotton root shows interesting types and patterns of cells making up the tissue (Figure 3). A single row of surface (epidermal) cells forms the outermost layer around the cortex. Root hairs essential for water and nutrient uptake arise from these epidermal cells (arrows). Root hairs enhance the nutrient and water uptake capacity of plants and improve soil contact by increasing root absorptive area. They may increase root surface area four to eight times and root length 20 fold.

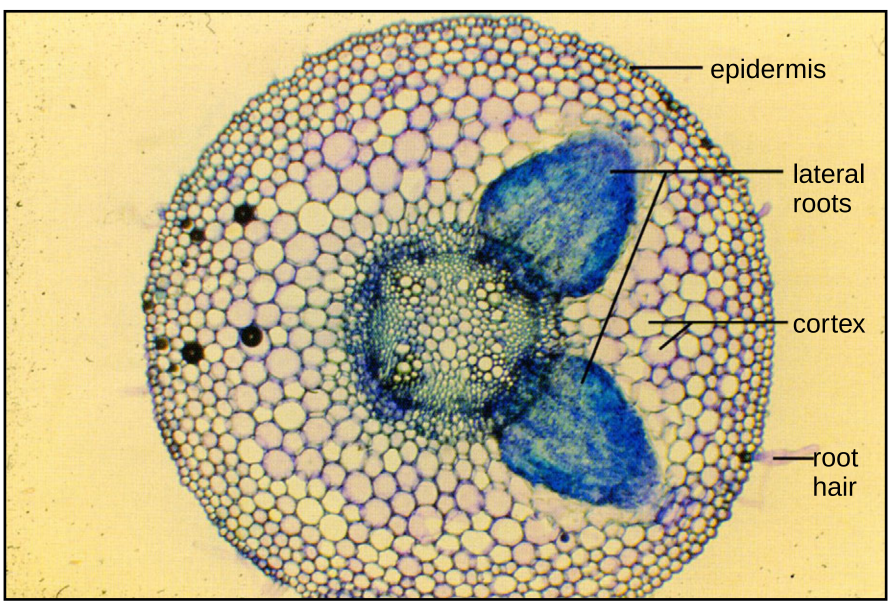


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Figure 3. Cross section of cotton root showing epidermis, cortex, stele (vascular system), and lateral roots originating from pericycle.

Cells making up the cortex are relatively large, loosely arranged cells with a lot of spaces between them. The endodermis, a single layer of cells with thickenings in its walls that are impermeable to water, encircles the innermost portion of the root that is referred to as the stele or vascular system (Figure 4).

Just inside the endodermis is the pericycle, a single layer of cells from which branch (lateral) roots grow (Figures 3, 4). As the root ages, the pericycle eventually becomes a protective layer for the root because both the cortex and endodermis slough off.

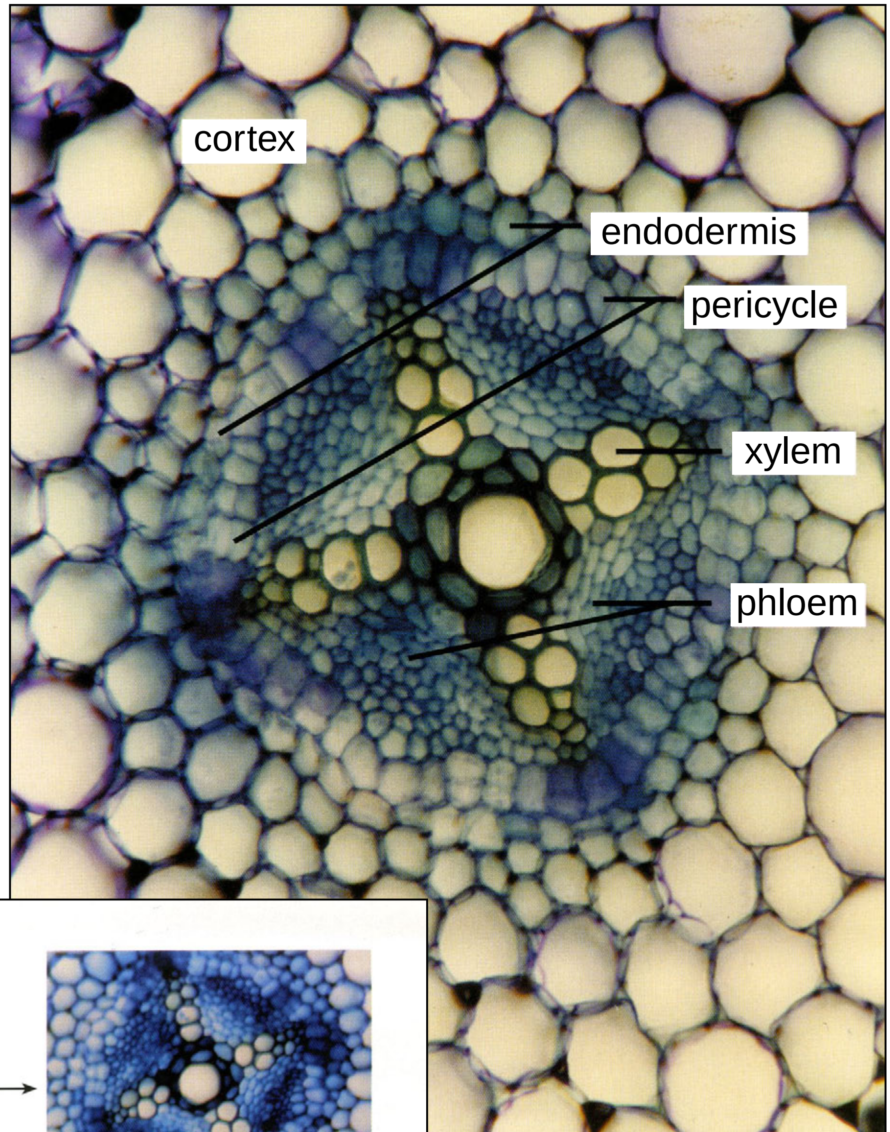

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Figure 4. Inner stele of cotton root in cross section showing star pattern of water conducting cells.

The plant's main plumbing is in the stele (shaded blue in Figure 5). Specialized cells that move water, nutrients, and food (photosynthate and other organic compounds) form an interesting pattern in cross section. Hollow cells conducting water upward through the plant make up the xylem that often looks like a cross or star in cross section (Figures 3, 4). Photosynthate manufactured by the green above-ground tissues is transported down and throughout the plant by the phloem.

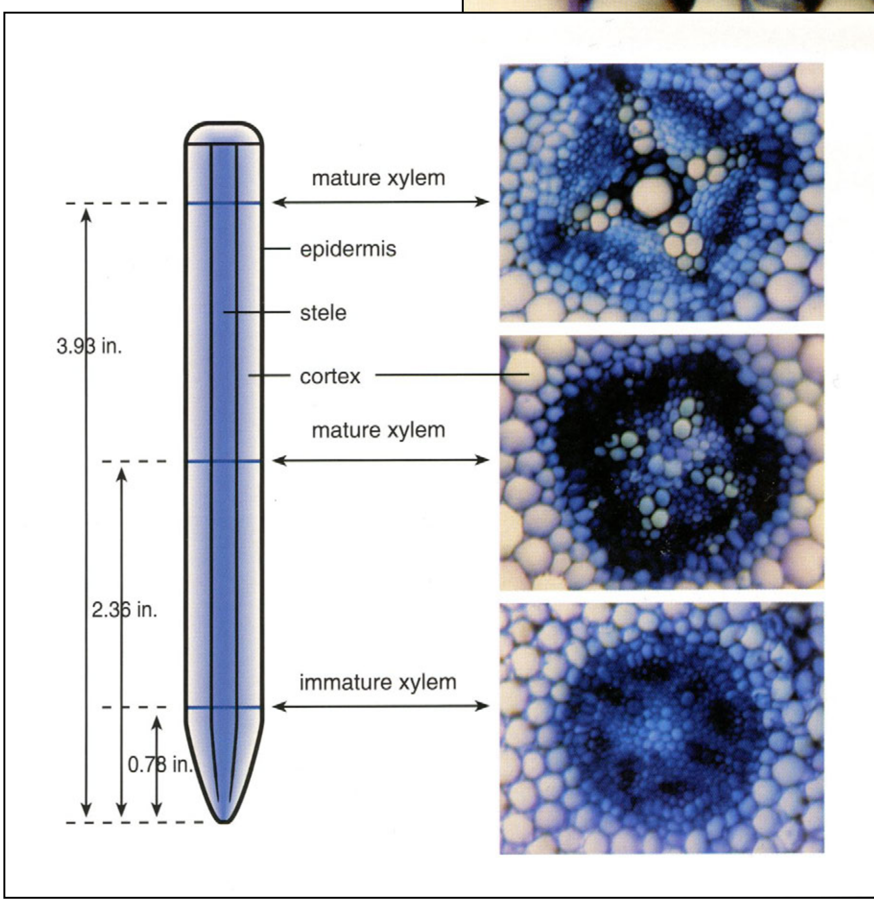

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Figure 5. Cross sections (taken at arrows) of tap root of 10-day-old cotton seedling showing development of water-conducting cells of inner stele. Tissue is youngest at the root tip, older toward the shoot.

In the field, growers can readily distinguish one cotton variety from another by differences in features of the above-ground portion of the crop (e.g. leaf hairiness, branching or columnar habit, height, color, etc.). Not surprisingly, differences in roots can account for differences in overall performance of varieties (Figure 6).

Visual genetic differences in cotton roots result primarily from varied development of branch roots which arise from vascular bundles. Cotton roots of different genetic make-up have different numbers of vascular bundles. Cotton normally has four vascular bundles (Figures 3, 4), but genetic variation can increase the number of bundles to six (Figure 7), or even as many as eight, increasing the potential for formation of branch roots.

B. McMichael

Figure 6. Genetic differences in root branching may account for varietal differences in water and nutrient use.

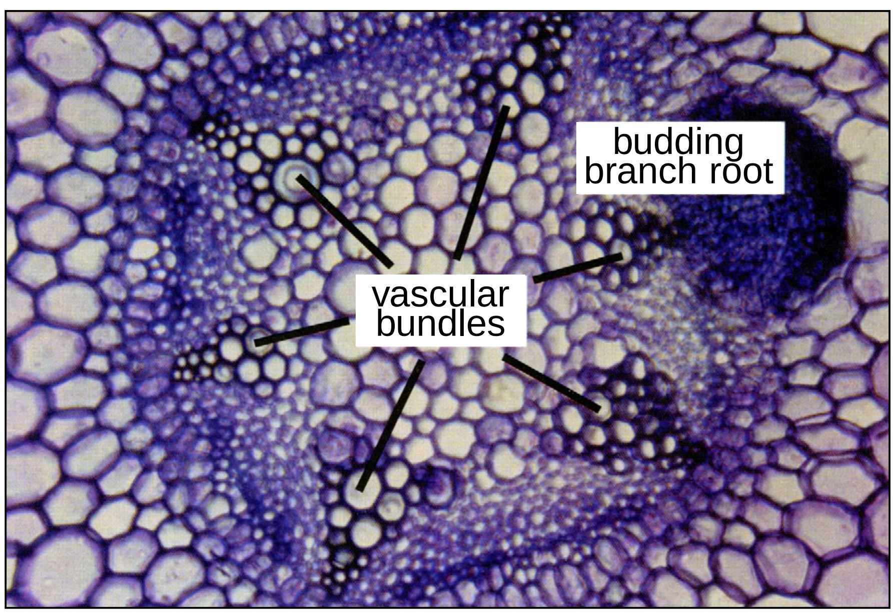

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Figure 7. Increased number of vascular bundles (arrows) improves branching potential. Note budding branch root.

Designed to Work (Structure & Function)

In addition to anchoring plants (Figure 8), roots take up water and essential nutrients from the surrounding soil solution. Root hairs play a major role in this process. Once inside the plant, water moves upward in a continuous stream toward the shoots and ultimately out through small pores in leaves called stomates. As water evaporates into the atmosphere from the stomates (Figure 9a & b), more water moves up from the soil into the root and up through the xylem stream to replace that lost.

B. McMichael

Figure 8. Cotton roots firmly anchor the plants in the soil.

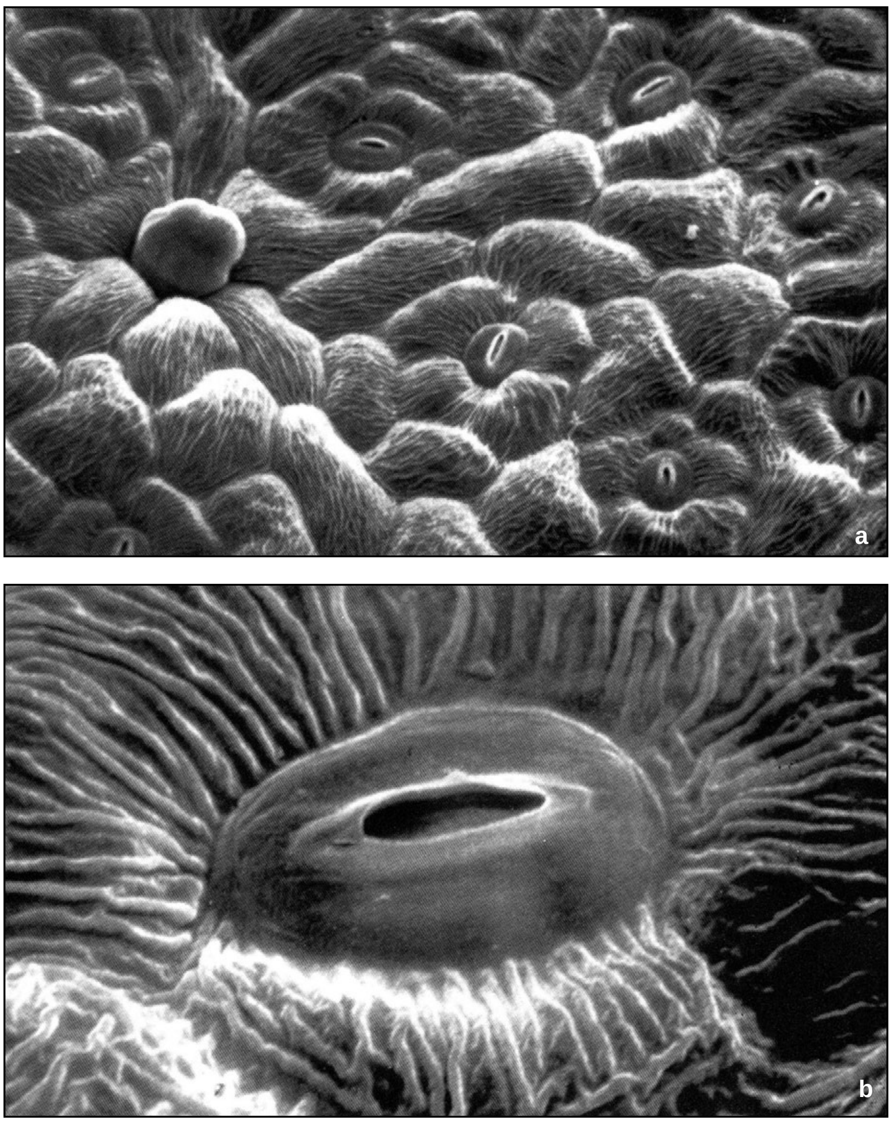

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Figure 9. Highly magnified (x600) view of surface of cotton leaf showing many pores or stomates (a) and (x5000) view of single stomate (b).

Water moves in relation to gradients from the wetter soil into the root, up the root and stem to the leaves, and out of the stomates to the drier atmosphere. This stream of water carries nutrients into the plant. Also, as the water leaves the plant, it cools the leaves through evaporation, a vitally important process in the heat of summer.

Root Environments

How a particular cotton plant's roots develop is often a result of their physical environment. Temperature, bulk density (weight per unit volume), aeration, and moisture of the soil all influence root growth as do fertility of the soil and any pathogens present in the profile. Environmental influences can add to or detract from inherent genetic differences.

Temperature. The successful emergence and initial growth of cotton seedlings is important for the establishment of healthy plants and improved productivity. All growers know that planting into cold soil is not a good way to start a cotton crop. Wanjura and Buxton showed in 1972 that when the minimum soil temperature at planting depth dropped from 68 to 54°F, the hours required for initial seedling emergence increased from 100 to 425 hours.

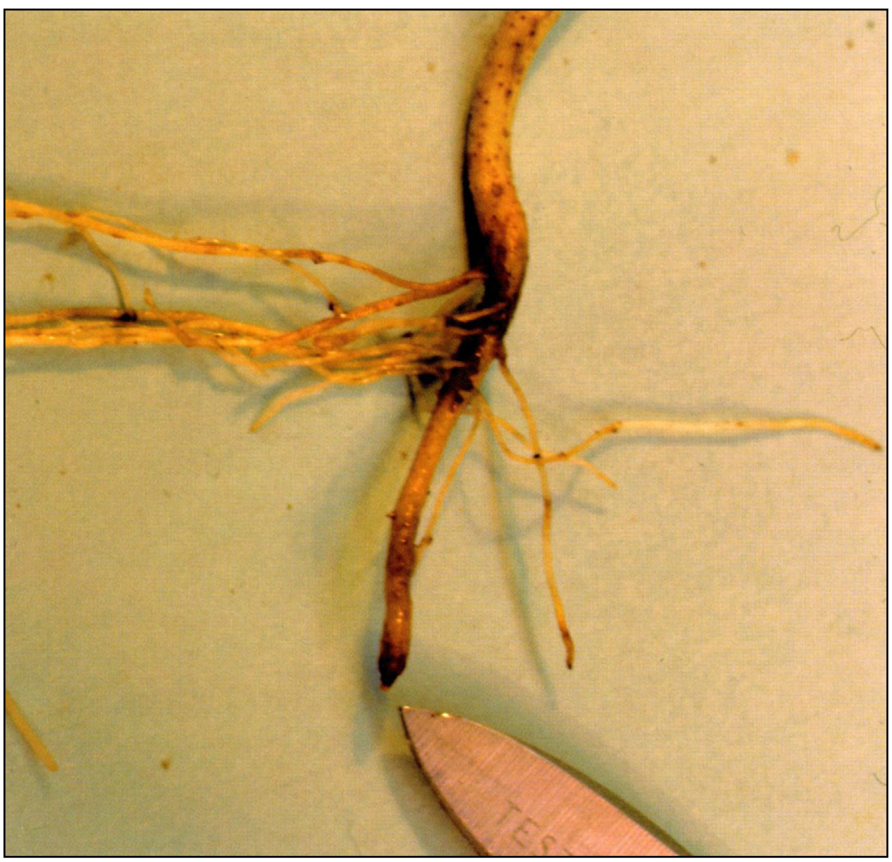
At temperatures below 50°F, the root tip can be damaged permanently, a condition often referred to as "nub root." Weathered or deteriorated seeds also can lead to abnormal seedlings with nub root. Part or all of the tap root fails to develop because of a complete lack of cell division in the root tips (Figure 10). Cotton optimally germinates between temperatures of 80 and 85°F.

Past studies have shown that low soil temperatures (less than 65°F) reduced branching of cotton roots whereas higher temperatures (greater than 90°F) increased branching. The cotton tap root appears to be less sensitive to cold environments than branch roots. Recommendations for the Mississippi Delta are to plant cotton at soil temperatures (measured at a 2" depth) which are above 68°F.

Soil and air temperature both influence cotton root development (Table 1, Figure 11). When the root temperature was low (68°F), root growth was reduced at both shoot temperatures. However, in contrast, the optimum shoot temperature is about 92°F.

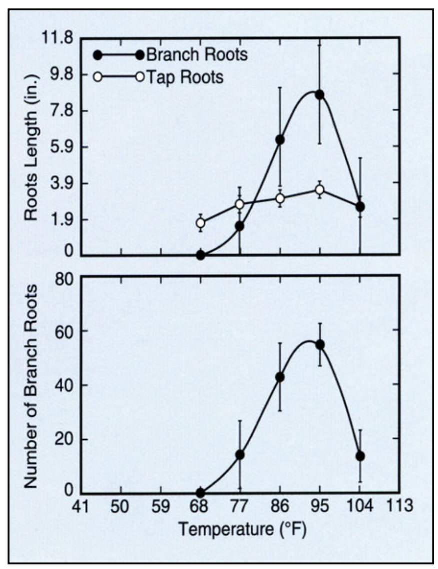
Table 1. Differences in root growth and development of 10-day-old cotton seedlings grown under four controlled temperature treatments. (McMichael & Burke, 1994)

Treatment temperature, °F		Length, inches			Number of branch roots
Shoot	Root	Tap root	Branch root	Total roots	
82	68	1.2	0.0	1.2	0.0
68	82	2.0	0.7	2.7	8.0
82	82	3.0	2.3	5.3	8.4
68	68	1.8	0.0	1.8	0.0



F. Bourland

Figure 10. Cold-damaged root tip results in damaged tap root (nub root) that stops growing.



McMichael & Burke

Figure 11. Influence of temperature on growth of tap and branch roots of 10-day-old cotton seedlings.

Development of varieties that can produce roots at low temperatures would be a way to help growers in areas with short growing seasons produce better stands in soils with temperatures less than the current minimum planting temperature of 65°F.

Bulk density. Compacted soil layers are, unfortunately, all too common an occurrence. Pull up a cotton plant that has been growing over a hard pan, and the stunted, splayed roots are sorry proof of how difficult or limited their progress through the soil has been (Figure 12). As bulk density increases, root growth decreases along with size, water, and nutrient uptake. The denser the soil, the less evenly distributed, thicker, and more branched the roots are in the upper part of the soil profile. The ultimate result of poor root growth is reduced cotton yields.

Aeration and soil water. Cotton roots need to breathe. At soil depths of 6 to 8 inches, air is usually 20% oxygen and 0.5 to 1% carbon dioxide. However, carbon dioxide levels can increase to 20% and oxygen drop to 5% or less depending on the temperature and water content of the soil.

Excess water as a result of temporary saturation (perhaps following a downpour or an irrigation) can deplete the soil almost entirely of dissolved oxygen. Respiration of roots and microorganisms can use all available oxygen. Cotton roots survive only 0.5 to 3 hours under low oxygen. The uppermost roots die first.

What does this mean for a cotton crop? A raised water table under Houston clay prevented cotton roots from growing deeper than 9 inches until quite late in the growing season when the water table lowered again. Reduced root growth means reduced shoot growth and, ultimately, lower yields.

Usually cotton roots more shallowly in soils with a high water holding capacity (clays) than in sandy soils with little water holding capacity. Cotton roots exposed to long cycles of furrow irrigation tend to deteriorate more rapidly during periods of heavy fruiting.

Cotton irrigated with drip lines produces shallow roots with a high percentage of roots less than 1/8 inch in diameter and concentrated around the emitters. Drip-irrigated cotton is dependent upon frequent irrigation for continued growth.

D. Oosterhuis

Figure 12. Cotton roots do not grow well in compacted soil (below white line).

Management for Growth

Management practices that improve soil condition can make all the difference in the world in the development of a cotton crop. Treatment of soil with fungicides also improves growth of seedling roots. Planting when temperatures are adequate will promote good root growth. Factors to manage include soil pH, fertility, drainage and aeration. Making timely weed and insect control applications help, too. More details will follow in a later issue of *Cotton Physiology Today.*

Conclusions

Roots are often overlooked, but they are an integral part of a crop growing system. They often make the difference in either a good or a bad yield. Even though development of root systems is under genetic control, their development can be significantly modified by the environment and your crop management. You can boost your crop yield by caring for your crop's roots.

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