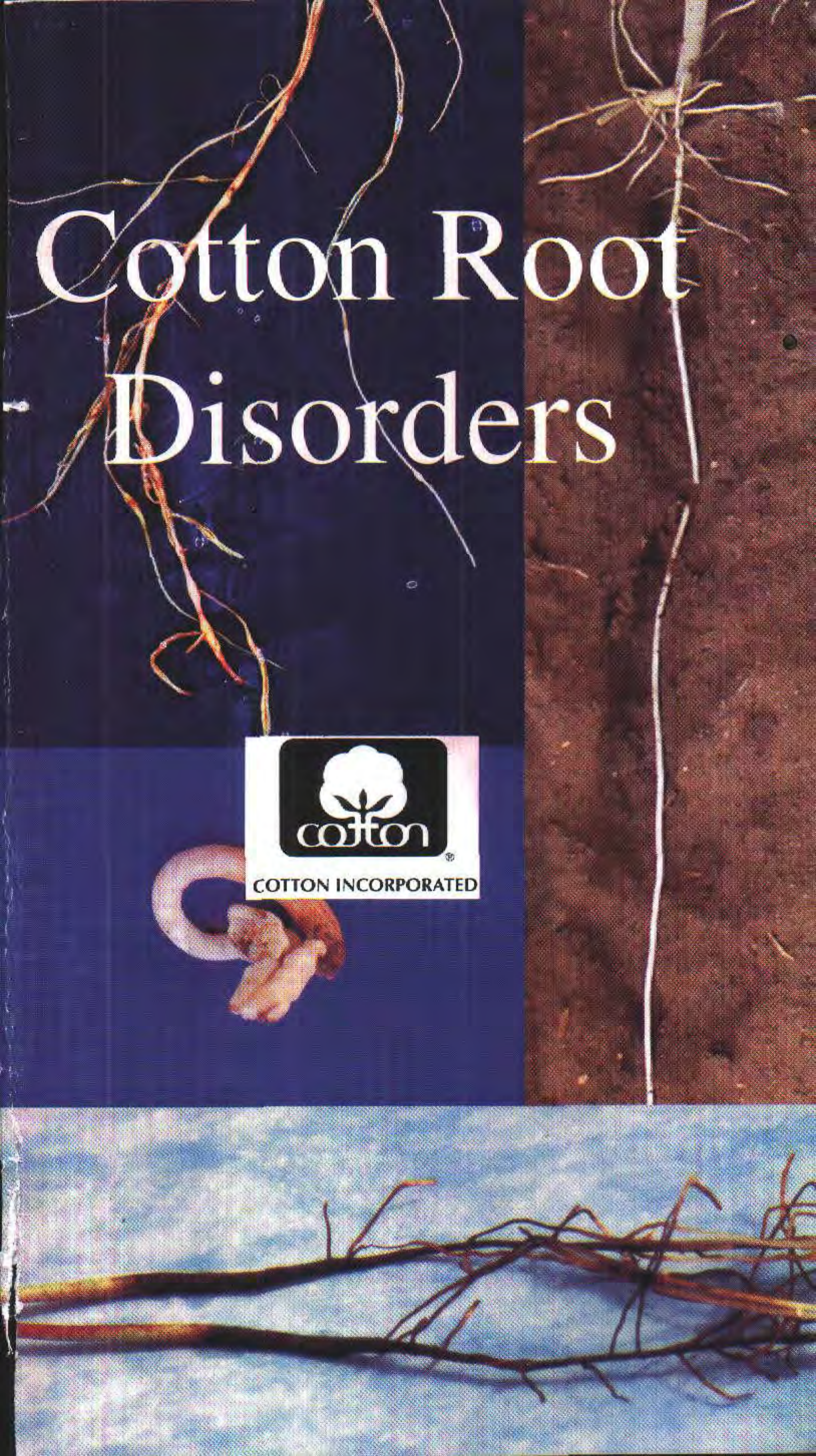
Cotton Root Disorders



COTTON INCORPORATED

Cotton Root Disorders

COTTON INCORPORATED

The authors gratefully acknowledge both the Texas and Arkansas State Support Committees of Cotton Incorporated for their support in funding this project.

Project Designer: Brad Calame
USDA-ARS
Lubbock, Texas

Contributors

Dr. B.L. McMichael

USDA-ARS
Plant Stress and Germplasm Development
Lubbock, TX 79415

Dr. John Burke

USDA-ARS
Plant Stress and Germplasm Development
Lubbock, TX 79415

Dr. Randy Boman

Texas Cooperative Extension
Lubbock, TX 79403

Dr. Peter Dotray

Texas Tech University
Texas Cooperative Extension
Lubbock, TX 79403

Contributors

Dr. Norman Hopper

Texas Tech University
Texas Agricultural Experiment Station
Lubbock, TX 79409

Dr. Harold Kaufman

Texas Cooperative Extension
Lubbock, TX 79403

Dr. Derrick Oosterhuis

University of Arkansas
Fayetteville, AR 72701

Dr. Terry Wheeler

Texas Agricultural Experiment Station
Lubbock, TX 79403

Dr. John Zak

Texas Tech University
Lubbock, TX 79409

Table of Contents

Contributors 4

Table of Contents 6

Introduction 8

Herbicide Injury 16

- Seedling Growth Inhibitors 18
- Growth Regulators 20
- Amino Acid Synthesis Inhibitors 22
- Photosynthetic Inhibitors 22

Pathogens 24

- *Rhizoctonia solani* 26
- Black Root Rot 28
- Cotton Root Rot 30
- Root-knot Nematode 32

Table of Contents

Fertilizer Injury 34

50 Pounds per Acre 36
100 Pounds per Acre 38
200 Pounds per Acre 40

Chilling Injury 42

Soil Compaction 48

The information given herein is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement is implied.

Introduction

Growth and Development of the Cotton Plant with Emphasis on the Root System

Cotton (*Gossypium hirsutum L.*) is a major row crop grown primarily for fiber and seed. The cotton plant is perennial with an indeterminate growth habit and has perhaps the most complex structure of any major field crop. The growth and development of the cotton plant has been described by a number of authors. However, these descriptions all lack comprehensive details about how these root systems respond to biotic and abiotic stresses.

The development and function of the root system of the cotton plant is critical to the growth of the whole plant and in the determination of yield. The primary functions of the root system are to facilitate both water and nutrient uptake as well as anchor the plant. Other functions include the production of plant hormones that can impact the regulation of growth and fruit production in the plant.

There are many factors that can influence the development and function of the root system. These factors can be broadly categorized into either environmental or biological. Environmental factors include soil temperature, soil compaction, water and nutrient availability and chemical factors such as pH, herbicides and fertilizers. Biological factors include diseases and nematodes.

Since many of these factors interact to impact root development in cotton, it can be very difficult to determine which may be the dominant influence when plants are observed under field conditions during early seedling development. It is important to be able to detect the cause of root disorders early when corrective measures may be taken to help alleviate the problem and maintain productivity.

This handbook is designed to provide the producer and crop consultant with a field guide to common disorders and, where applicable, suggest possible management decisions to deal with them. It should be pointed out that this handbook is by no means a comprehensive guide since the possible combinations of factors affecting root systems are great. Rather, the book addresses the basic disorders that may be encountered in field situations and provides the basis for further investigation.

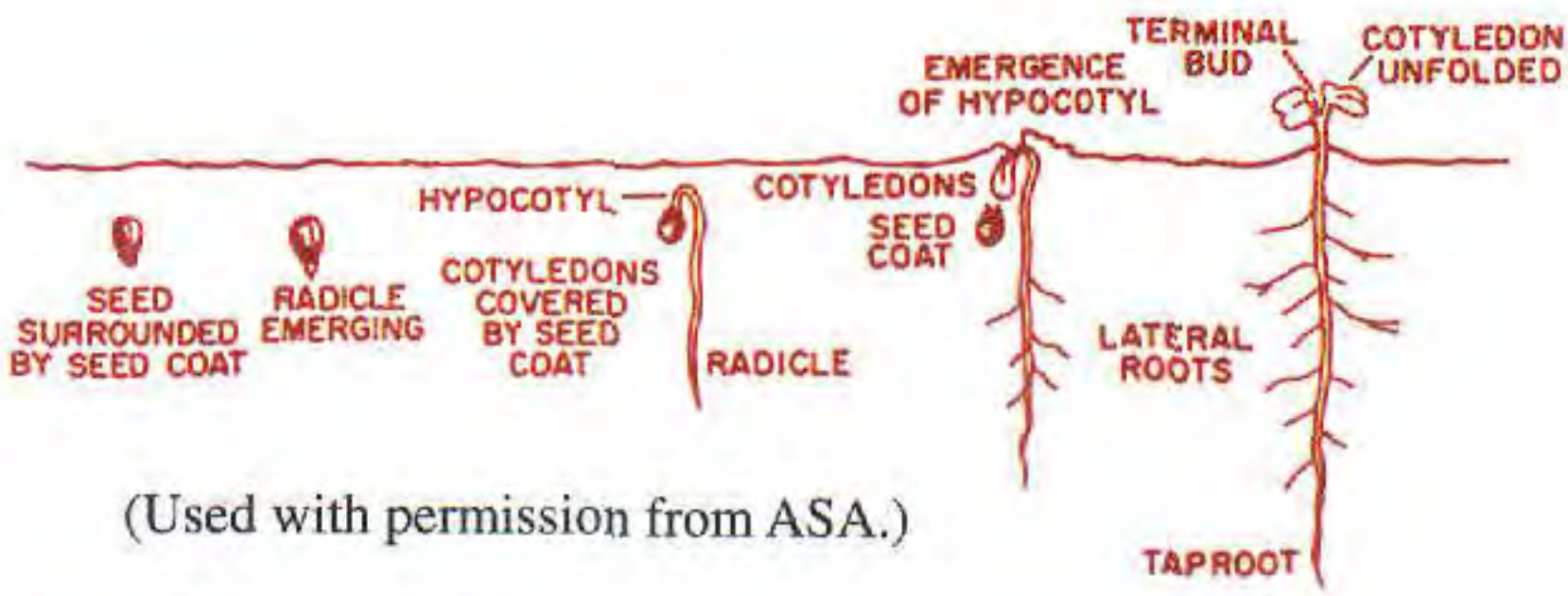
Main Stages of Growth and Development of the Cotton Plant

For practical reasons in relation to production management, plant development in cotton proceeds through five main growth stages: (1) germination and emergence, (2) seedling establishment, (3) leaf area-canopy development, (4) flowering and boll development and (5) maturation. However, the transitions between these successive

stages are subtle and not always clearly distinguishable. Furthermore, each stage may have different physiological processes operating with specific requirements. A better understanding of cotton growth and development in commercial production is important in the continuing efforts of growers to produce lint and seed yield more efficiently and profitably. Root growth occurs in all of these stages, particularly in the early stages when the emphasis of the plant is in the establishment of an adequate root system to support the subsequent fruit development.

Germination begins with the entry of moisture within the first few hours. Under favorable conditions for germination, the radicle emerges through the pointed micropylar end of the seed in two to three days (Fig. 1). The radicle becomes the primary root that grows downward into the soil. The tissues between the radicle and cotyledons (the hypocotyl) grow rapidly, arching near the cotyledons (Fig. 1). With continued expansion of the hypocotyl, the cotyledons and epicotyl are pulled up through the soil surface. Typically, the seed coat is shed and remains in the soil. Germination is favored by high soil oxygen, adequate soil moisture and soil temperatures above 65° Fahrenheit. Germination of cotton seed can begin when the average daily soil temperature is 60° Fahrenheit or slightly below at seeding depths,

but growth will be slow at these temperatures. Under favorable conditions, seedlings emerge in 5 to 10 days and require 50 to 60 heat units. Possible problems that hinder germination include poor seed quality, flooding, soil crusting, salinity, herbicide residue, cool temperatures and disease.

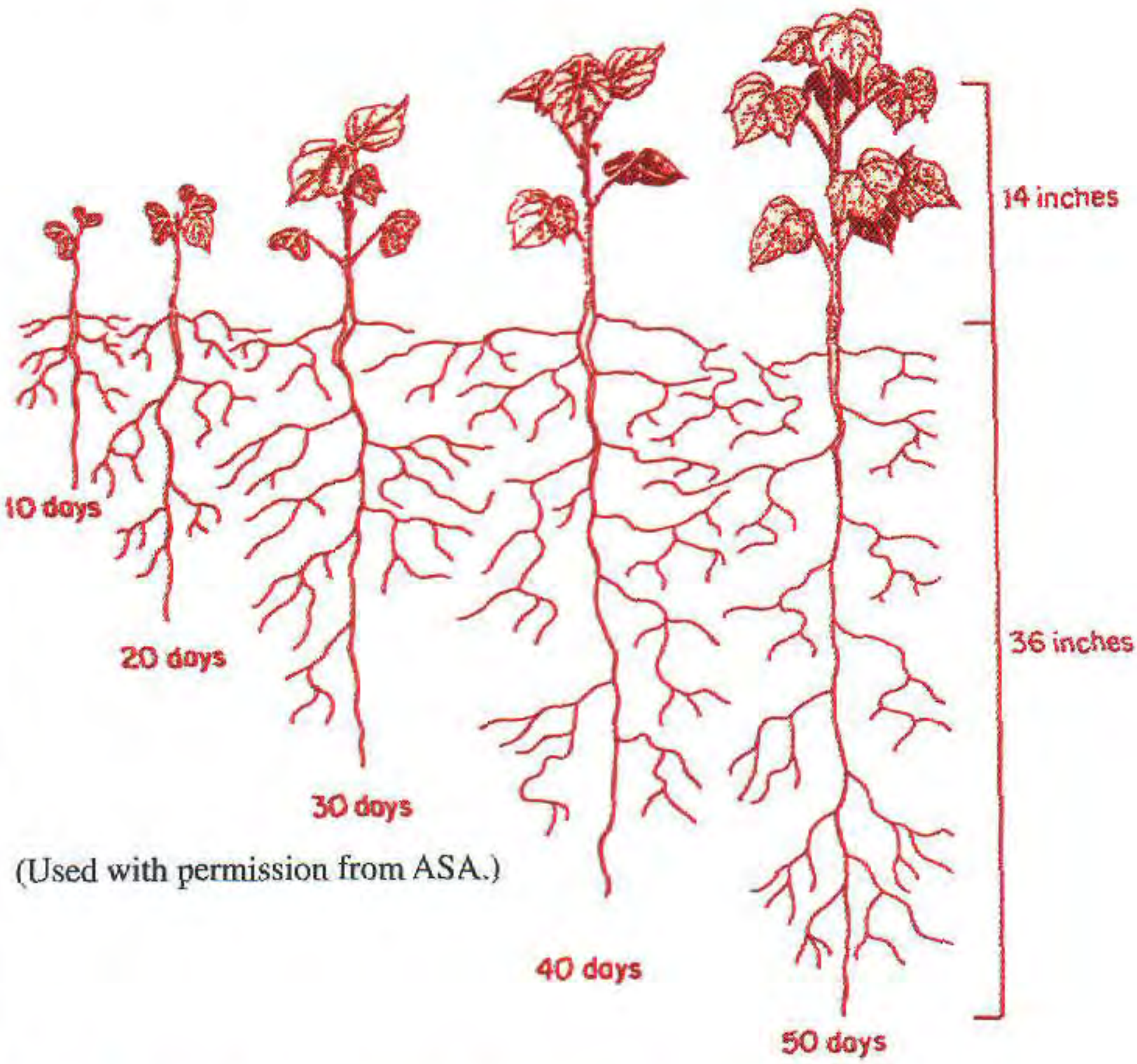


(Used with permission from ASA.)

Fig. 1 Germination and seedling emergence.

Much of the early development of the cotton plant is focused on the development of a substantial root system. Growth of the above ground portion (first true leaves) is relatively slow prior to canopy development. The radicle, or primary root, develops rapidly and is the first organ to emerge from the seed coat during germination. The primary root, or taproot, penetrates the soil rapidly and may reach a depth of up to 10 inches or more by the time the cotyledons unfold. Root development during the early vegetative stage may proceed at the rate of 0.5 to 2 inches per day, depending on conditions. Thus, the roots may be 3 feet deep when the above ground portion of the

plant is only about one foot tall (Fig. 2). High water tables, compacted soils and cool temperatures may result in much shallower root systems.



(Used with permission from ASA.)

Fig. 2 Root development of the cotton plant.

Numerous lateral roots proliferate outward from the taproot forming a mat of roots which can extend outward several feet (Fig. 3). The greater portion of the root system is located in the upper 3 feet, but this is dependent upon soil moisture,

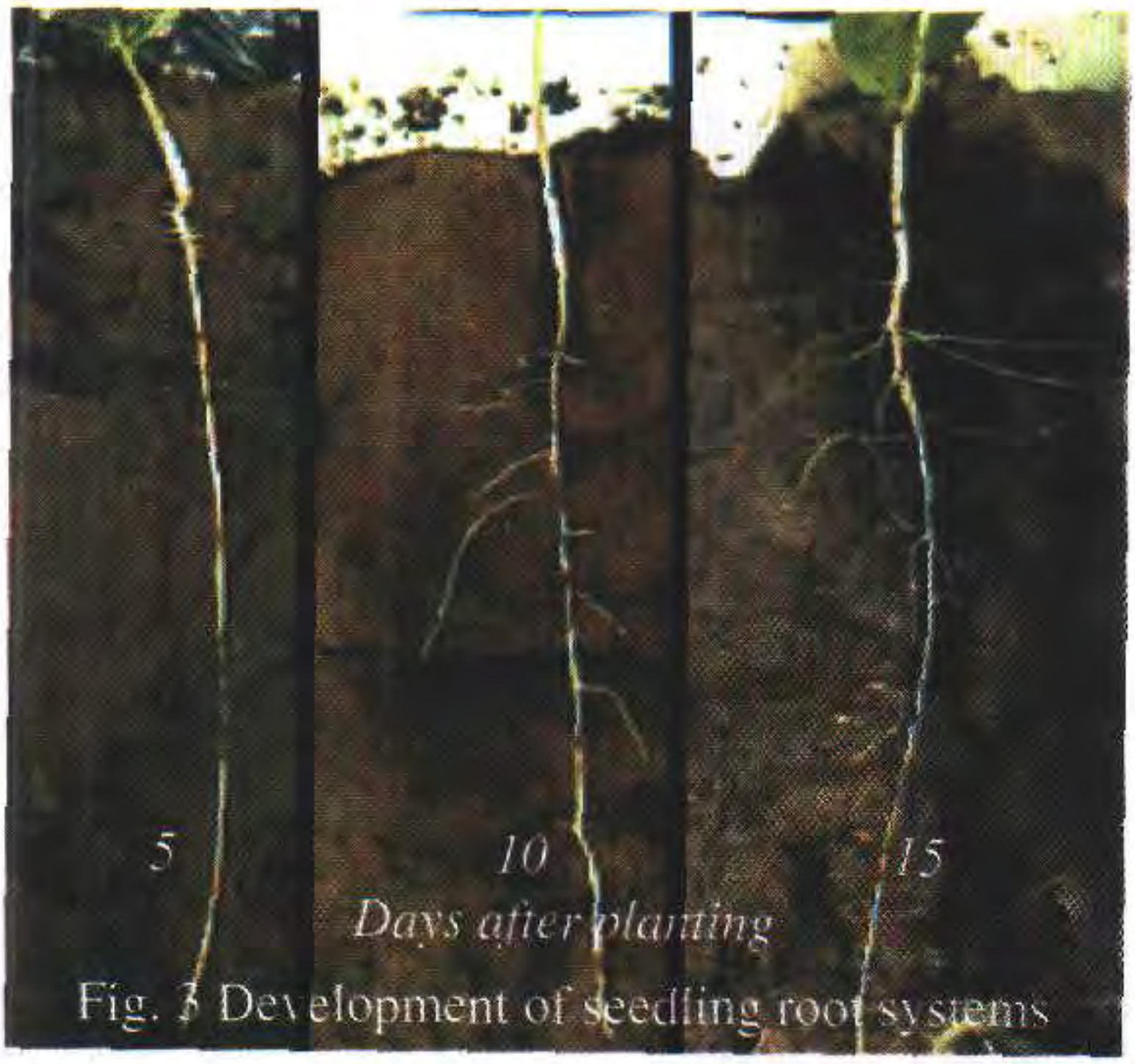
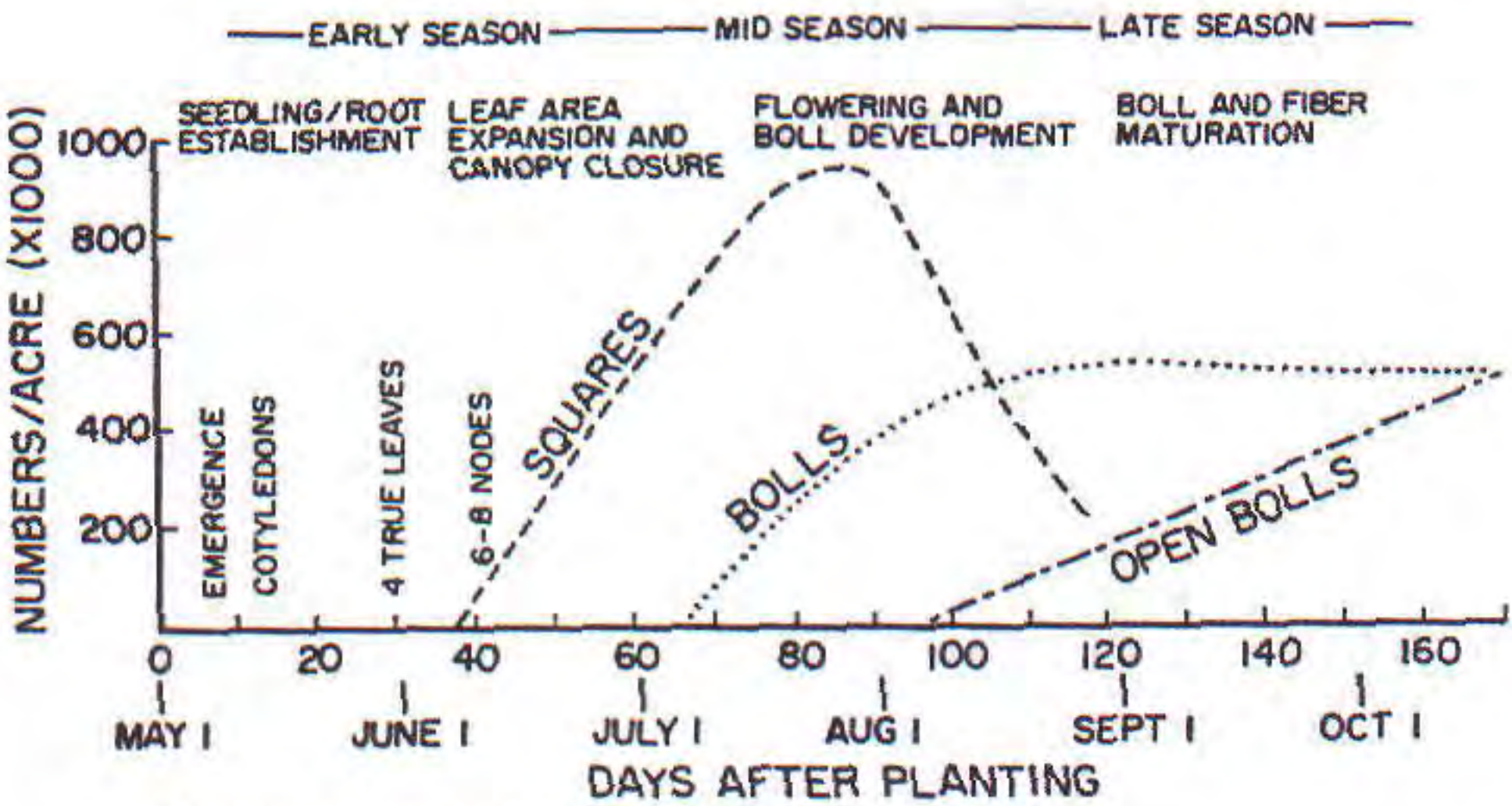


Fig. 3 Development of seedling root systems

soil physical structure, and vigor of the plant itself. Root distribution within the soil profile (root length density = length of root in volume of soil) is usually about 24 inches of root per cubic inch of soil but can vary considerably with soil and plant conditions. The total root weight comprises approximately 10-20% of the total dry weight produced by the plant during the growing season. However, the total root length continues to increase as the plant develops until the maximum plant height is reached and fruit begins to form. Root length then begins to decline as older roots die. Furthermore, root activity begins to decline as the boll load develops and carbohydrates are increasingly directed towards the fruit.

Introduction (continued)



(Used with permission from ASA.)

Fig. 4. Seasonal development of cotton in the Mid-South showing the production pattern of squares, bolls and open bolls.

Seasonal Developmental Events

The overall growth and development of the cotton plant follows a typical sigmoid curve. It begins with a relatively slow start during emergence and root growth. This is followed by an exponential increase in growth rate during canopy formation, flowering and boll development. It is concluded by a slowing down in boll maturation. Both genotype and environment affect this pattern. Each stage may have different physiological processes operating with specific requirements (Fig. 4). A knowledge of these growth patterns will aid greatly in crop management decisions.

Conclusions

Understanding cotton growth and development is critical in implementing sound management strategies for maximum yields and profits. Plant development proceeds through various developmental phases including germination and emergence, seeding establishment, leaf area and canopy development, flowering and boll development, and maturation. The growth of the root system varies during these stages as the development focus changes from vegetative plant establishment to boll development and maturation. Early root damage delays growth, often increases (raises) the node of 1st retained square, and is difficult to overcome. Management strategies need to take this shoot and root development and associated requirements into consideration to optimize yields.

Herbicide Injury

Introduction

Integrated pest management procedures are vital to accomplishing environmentally sound pest management. It is important to recognize all the parts of integrated weed management when employing any weed control program. These integrated approaches include mechanical, cultural, physical, chemical, and biological methods.

Herbicides have been an important tool for management of weeds in urban and rural environments for many years. Since the 1940's, herbicides have become more sophisticated with regard to what weeds they control, length of control, and how they might affect desirable vegetation. Although the use of herbicides is widely accepted and practiced, it is probably the least understood segment of an integrated weed management program. There are many publications available that describe how herbicides work and their mechanism of selectivity.

Classification of herbicides by mode-of-action gives us an in-depth appreciation of how the herbicide affects susceptible plants from the time it is absorbed until plant death. Knowledge of herbicide mode-of-action helps us to understand the relationship that some herbicides have to others with regard to activity and selectivity. It also helps

us to recognize what type of noticeable effects herbicides will have on plants either at lethal or sublethal doses.

Although there are many ways to classify herbicides, using and understanding herbicide mode-of-action can help diagnose injury problems. Mode-of-action groups include growth regulators, photosynthetic inhibitors, pigment inhibitors, seedling growth inhibitors, cell membrane disrupters, lipid synthesis inhibitors, and amino acid synthesis inhibitors.

It must be understood that other symptoms caused by insects, diseases, and abiotic stresses can mimic the effects of some herbicides. Therefore, diagnosis of herbicide injury should include a careful consideration of other biotic and abiotic possibilities. The following information describes some of the common herbicide injury problems to cotton. Remember to always carefully read and follow label instructions for safe and effective use of herbicides.

All photographs in "Herbicide Injury" taken by LeAnna Lyon.

Seedling Growth Inhibitors

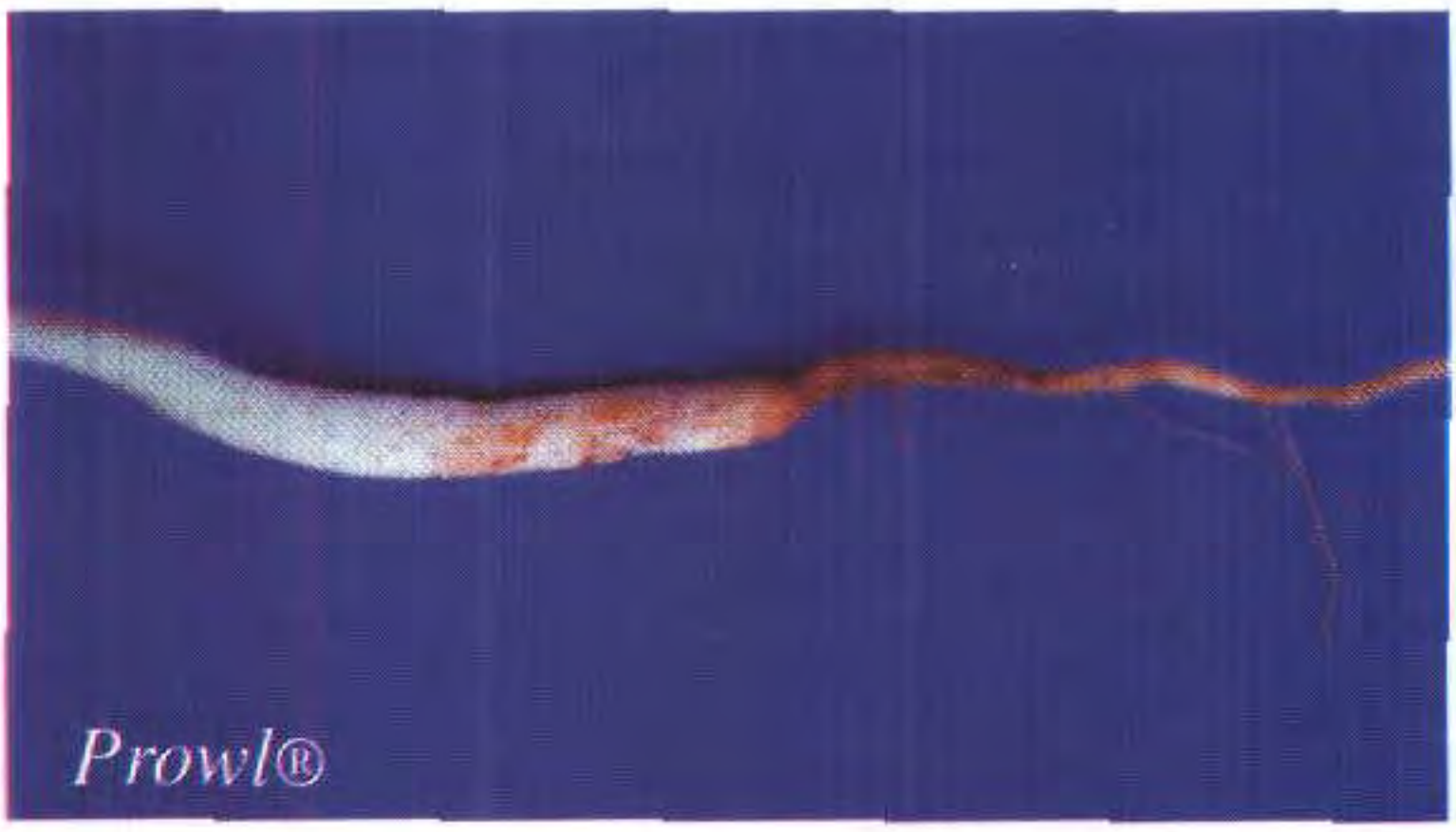
Dinitroanilines (Treflan®, Prowl®)

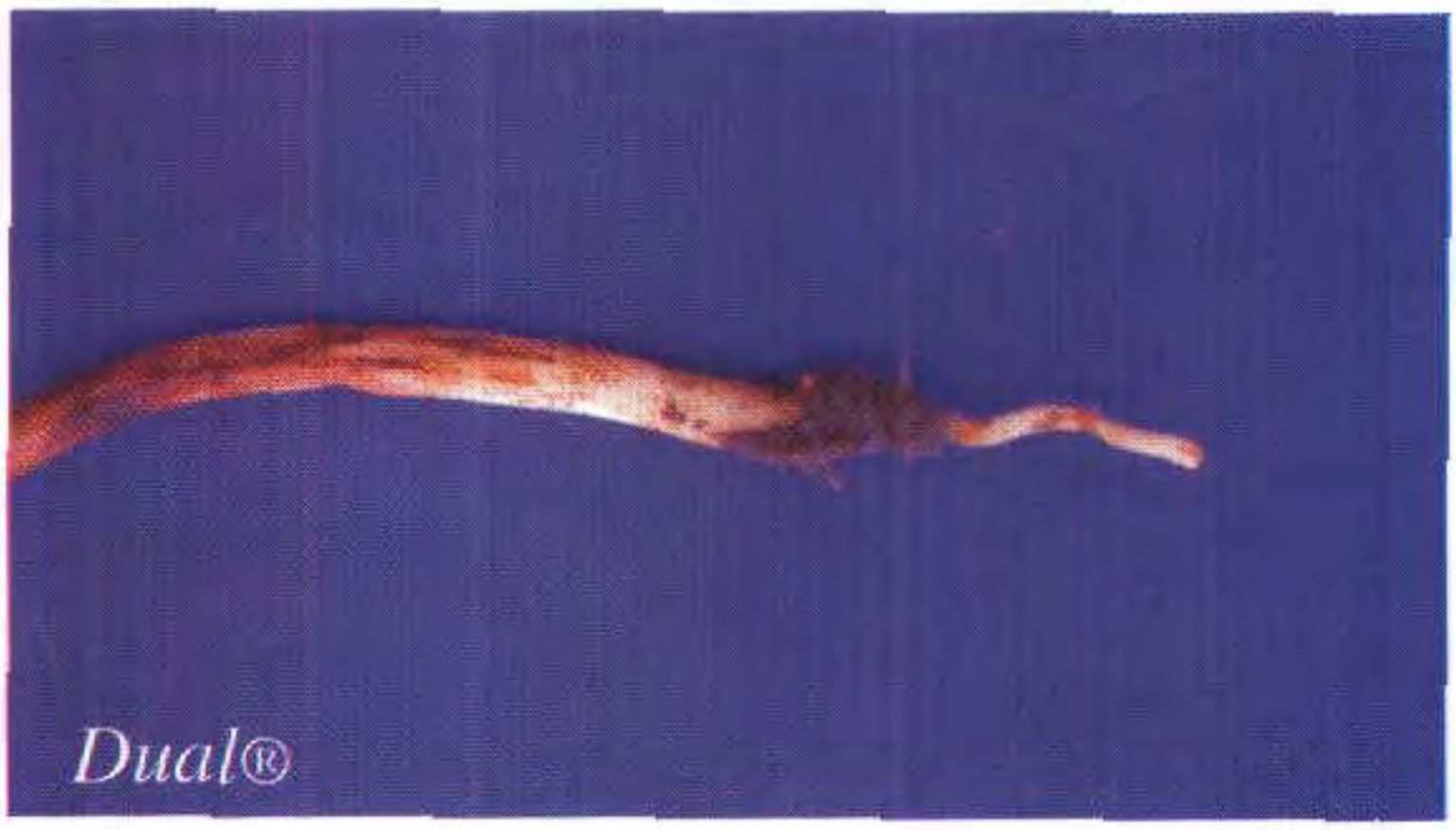
These herbicides interrupt mitosis (cell division), which stops root growth. Susceptible plants will die due to their limited ability to take up sufficient water and nutrients to sustain growth. Cotton root growth and development will be severely limited in the herbicide zone, and roots in the herbicide zone will be stubby and thick, especially the first-order laterals. Normal roots can be found above and below the treated zone. Callus tissue (tumors) may form on the stem at the soil surface if these herbicides are not properly incorporated. This may result in lodging due to the stem breaking. Affected plants will appear dark green and may be stunted.

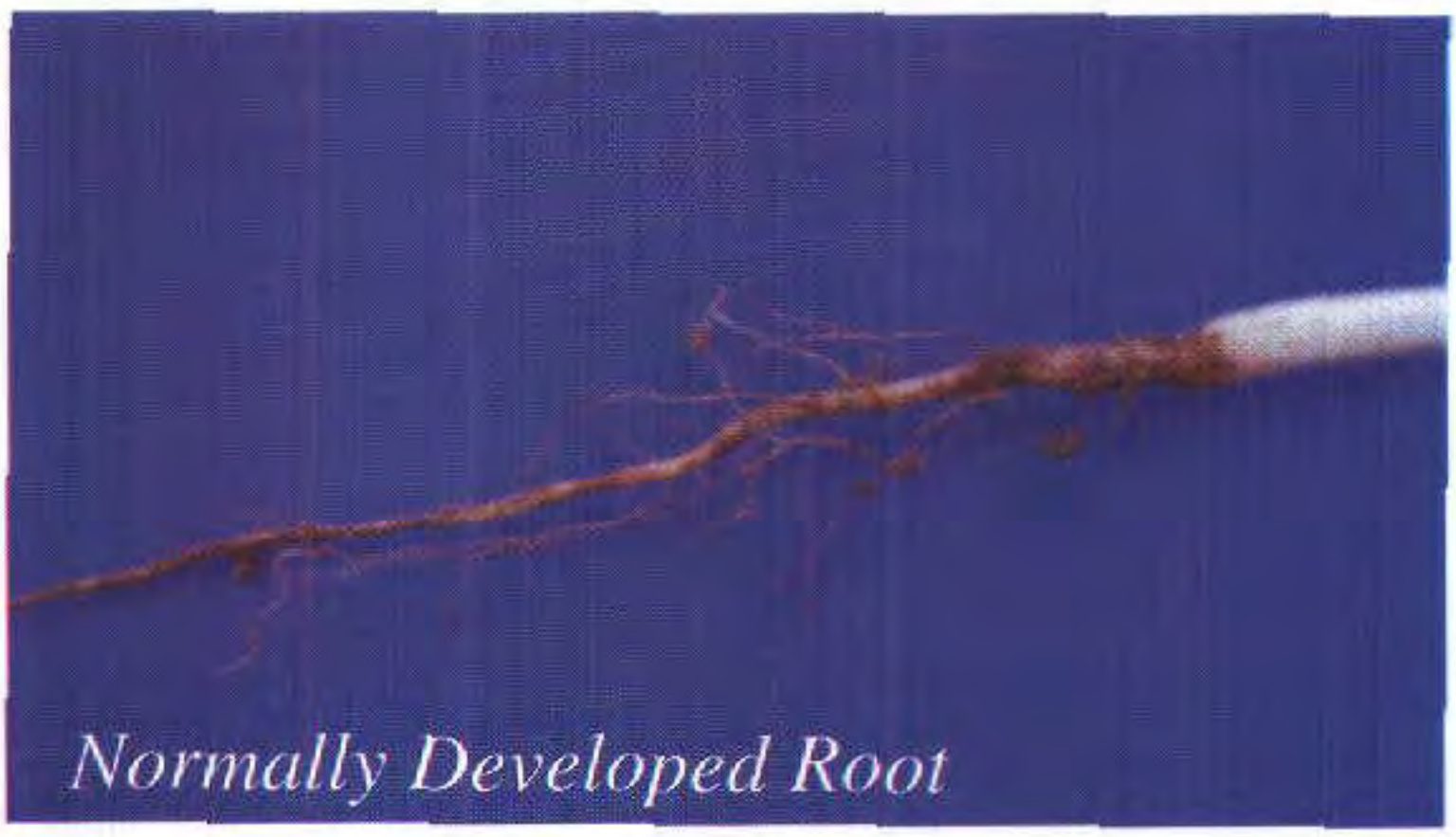
Chloroacetamides (Dual®)

These herbicides act on germinating seeds. They disrupt protein synthesis, which slows cell division and enlargement. Injury may be observed as root growth inhibition, although most of the symptomology will be improper leaf unfurling, leaf cupping, crinkling, and overall plant stunting. Some plants will produce leaves that do not emerge above the soil surface.

Seedling Growth Inhibitors







Growth Regulators

Phenoxy Acetic Acids (2,4-D)

These herbicides upset the normal hormonal balance that regulates plant processes such as cell division, cell elongation, protein synthesis and respiration. It is easy to see aerial drift characteristics, as the leaves will appear strapped. However, it is more difficult to see slight injury initiated from soil uptake. Cotton roots will be twisted (epinasty), swollen and appear disoriented. Roots that penetrate into a herbicide area from a spot treatment will cease growing and the root tip will swell and turn necrotic. Callus growth may appear on roots as well as stems.

Benzoic Acid (Clarity®)

This is similar to the phenoxy acetic acids above. Leaves will be cupped more than strapped. The root characteristics are similar to the phenoxy acetic acids.

Carboxylic Acid (Tordon®, Paramount®)

This is also similar to the phenoxy acetic acid damage described above. In general, these herbicides are considered more herbicidally active pound-for-pound compared to the benzoic and phenoxyacetic acids.

2,4-D treatment

2,4-D treatment

2,4-D treatment

Paramount®

Amino Acid Synthesis Inhibitors

Imidazolinones, Sulfonylureas, Triazolopyrimidines (Pursuit®, Ally®, Scepter® and others)

Herbicides in these families act by inhibiting amino acid biosynthesis. Meristematic tissue is affected first. Cotton roots will take on a "bottle brush" appearance. First-order laterals will be short and numerous.

Photosynthetic Inhibitors

Triazines, Substituted Ureas, Uracils and Amides (atrazine, Cotoran® and others)

Since these herbicides affect the photosynthetic apparatus first, the disruption of root growth is a secondary effect. Because roots need carbohydrates from above ground tissue, the disruption of photosynthesis will slow root growth.

Amino Acid Synthesis and Photosynthetic Inhibitors

Treflan®, Tordon® - Dow AgroSciences
Prowl®, Clarity®, Pursuit®, Scepter®,
Paramount® - BASF
Ally® - DuPont
Meturon® - Griffin
Dual Magnum® - Syngenta

Pathogens

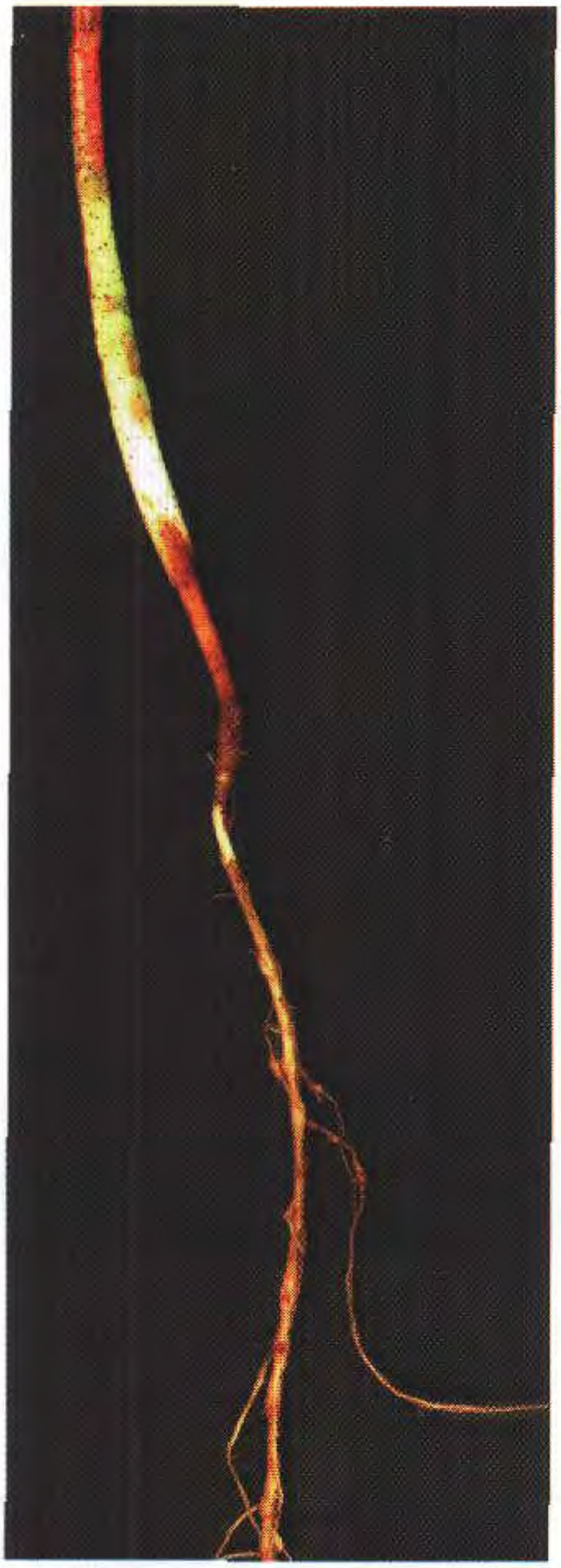
Introduction

Root diseases of cotton can occur during all phases of the growing season. Once a seed begins to germinate, fungi and nematodes will move to infect the roots. During the first two weeks after planting, most plant pathogens are already colonizing roots. Seedling disease, which can include root discoloration (necrosis) and sunken lesions on the root and hypocotyl, is usually the first root disease problem observed. Later in the season other symptoms can be found such as galling from root-knot nematodes or complete root death from the fungus causing Texas root rot. Once the plant is dead, it is difficult to determine what caused the root problem. However, if roots are examined when plants first begin to show above ground symptoms of stress, it is often possible to diagnose a root disease problem.

Pathogens

Rhizoctonia solani

Rhizoctonia solani



This fungus causes cotton seed rot, lesions on the hypocotyl and root rot in cotton seedlings. *Rhizoctonia solani* can cause disease under a range of environmental conditions, but is most damaging in cool, wet soil. Hypocotyl lesions are generally reddish brown in color and sunken. Root lesions can be wet areas where the root appears as a string (the surrounding tissue has rotted away) or darker colored lesions. When more than one seedling disease

pathogen is present, such as *R. solani* and *Thielaviopsis basicola*, then root lesions are brown in color. As the plant matures, the hypocotyl area hardens and is not susceptible to damage. Management of *R. solani* involves planting high quality seed, using a fungicide seed treatment with activity on *R. solani,* planting when soil conditions are warm and rain is not imminent and, in severe cases, using an in-furrow fungicide at planting.

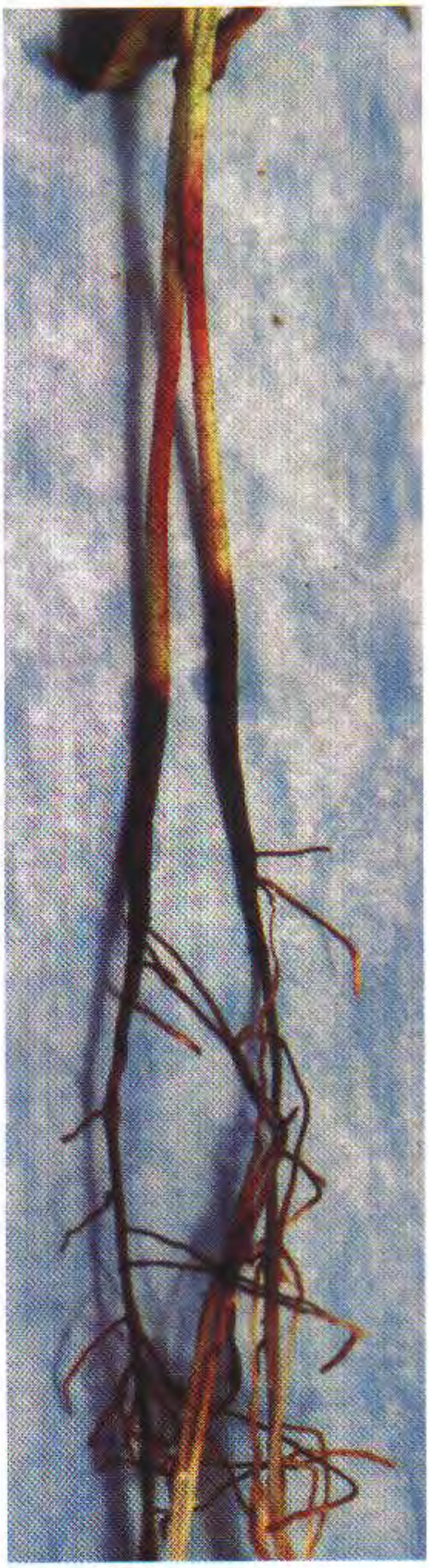
Black Root Rot

Thielaviopsis basicola

This fungus causes a disease known as black root rot. The root system turns black, particularly in young plants, but the root tissue remains firm. It does not rot. However, if there is a disease complex involving several different fungi, then the black color (necrosis) can be combined with actual root rot (softening of the tissue) and root death. This disease can be severe when soil temperatures are cool. Generally, soil moisture is not necessary to have serious black root rot, though disease symptoms may be more severe when cool temperatures are combined with wet soil. Once the soil temperatures warm, the black root systems will be sloughed off and the roots will appear white and healthy colored. An unusual exception is seen when soils are heavily infested with this fungus, or when root-knot nematode is present with *T. basicola*. Then, root symptoms may persist all season.

Plants with black root rot can recover and produce high yields. However, if cool spring weather is prolonged, plants may be sufficiently delayed in their maturity and growth to the point that they will remain stunted all season. Management of this disease involves planting

Black Root Rot



when soil temperatures are warmer. Generally crop rotation of 1-2 years is not sufficient to significantly reduce disease pressure. Seed applied fungicides like triademenol can provide limited protection, but only under low disease pressure.

Cotton Root Rot

Phymatotrichum omnivorum

This lethal disease of roots is caused by the fungus Phymatotrichum omnivorum. The fungus lives deep in the soil and grows as mycelia strands (threadlike structures) upwards towards the taproot. Once it infects a root it can move down and across rows killing additional plants. The symptoms of wilt start usually in midsummer. The plant dies soon after wilt symptoms start. The leaves of the plant generally remain attached to the plant. The roots are darkened with a reddish stain and mycelia strands (called rhizomorphs), which are tan in color, can be seen on the roots. Under very moist conditions, mats of white to tan mycelia can be found on the soil around the dead plants. This disease is worse in summers when there is good rainfall. Dead areas of the field can run from several feet to acres. It is possible to lose more than 50% of the cotton in a field to this disease. The dead stalks also create a problem with harvest since they get stuck in cotton strippers.

Management of cotton root rot is nearly impossible when weather is conducive for the disease. The most effective control is to deep plow the field and plant varieties which mature

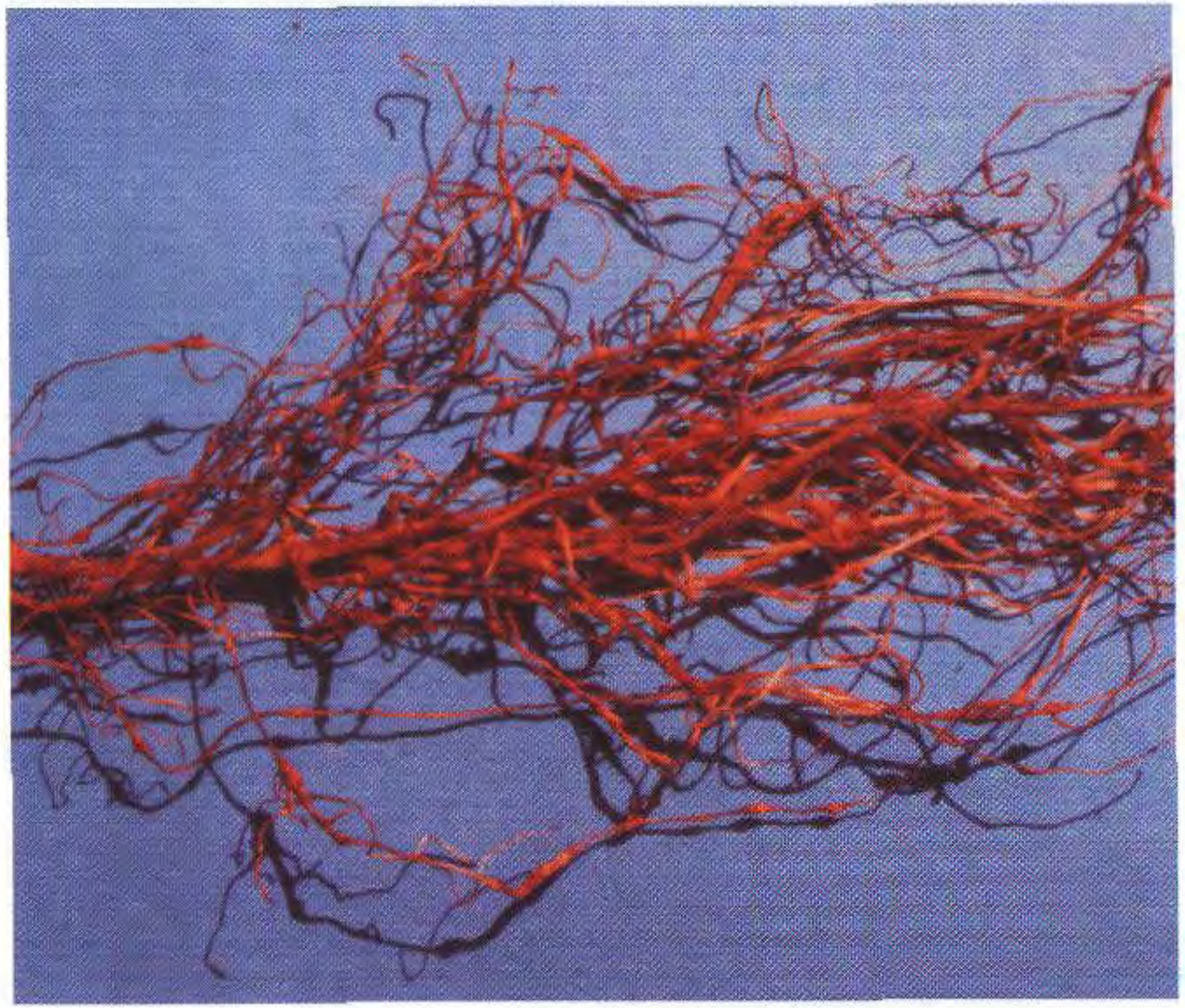
early. This fungus produces a long-term survival structure called a sclerotia, which can survive for years deep in the soil. The depth that this fungus survives is one of the main reasons that control is so problematic.

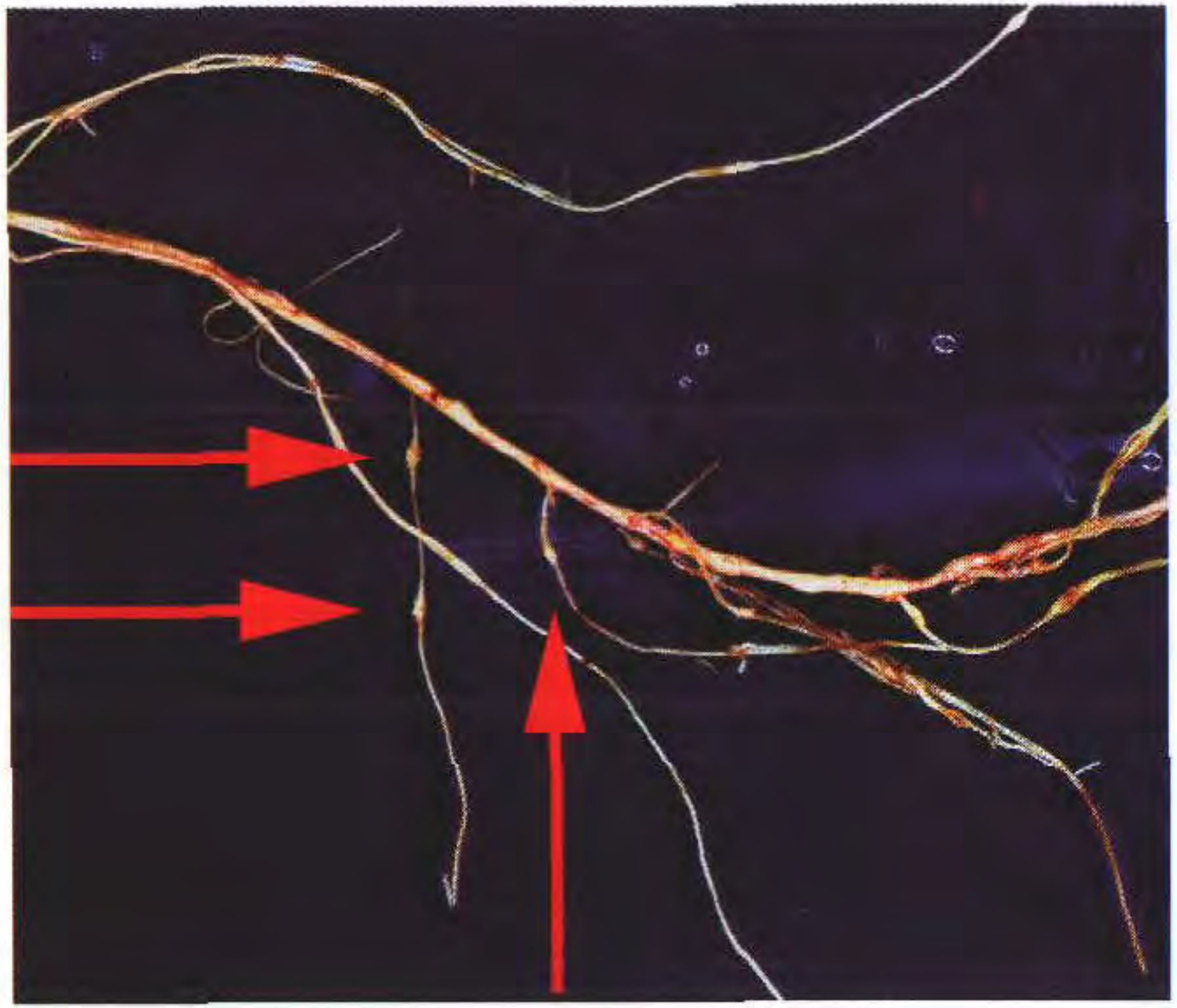
Root-knot Nematode

Meloidogyne incognita

The root-knot nematode of cotton is *Meloidogyne incognita*, or the southern root-knot nematode. The nematode eggs survive in roots or soil during the winter and hatch in the spring to produce second-stage juveniles. These nematodes can move to cotton roots and infect them. They cause the root to swell and form galls around the nematodes as they mature. A mature nematode can produce hundreds of eggs that hatch and go through another life-cycle. The galls can reduce plant performance if formed in high numbers on young cotton plants. Generally, root-knot nematodes do not build up to high numbers until mid-season or later, when the plant can tolerate more galling. The galls make it more difficult for the plant to transport water and nutrients from the soil to the above ground plant parts. Since the plant has to expend more energy to remove water from the soil, it may be less productive. Management of root-knot nematode involves crop rotation (primarily with peanuts) and chemical control with Temik® 15G (Aventis) at planting or Telone II® (Dow AgroSciences) before planting as a fumigant.

Root-knot Nematode





Fertilizer Injury

Introduction

Fertilizers in general are applied as a preplant application. The material used may be put down in one application or split and applied as a side-dress later in the season. The material can also be applied in-furrow at planting in proximity to the seed. The formulations used in terms of the percentages of the major nutrients (N, P and K) can vary depending on a number of factors such as soil type and soil test results. The form of the material used can also vary from granules to fluid fertilizers. Some possible formulations may include 32-0-0 (fluid urea ammonium nitrate), 10-34-0 (fluid ammonium polyphosphate), 18-46-0 (dry diammonium phosphate) and 11-52-0 (Dry monoammonium phosphate). These formulations may also be used in conjunction with applications of micronutrients as required. Choice of fertilizer carrier (formulation) depends on cost and ratio.

The following photographs represent the response of cotton seedling root systems to various in-furrow applications of both liquid and dry formulations. The plants shown were grown under optimum soil temperature conditions with adequate soil moisture. In each case the fertilizers were applied to simulate an in-furrow treatment. They consisted of 50, 100 or 200 lbs/acre of each fertilizer material.

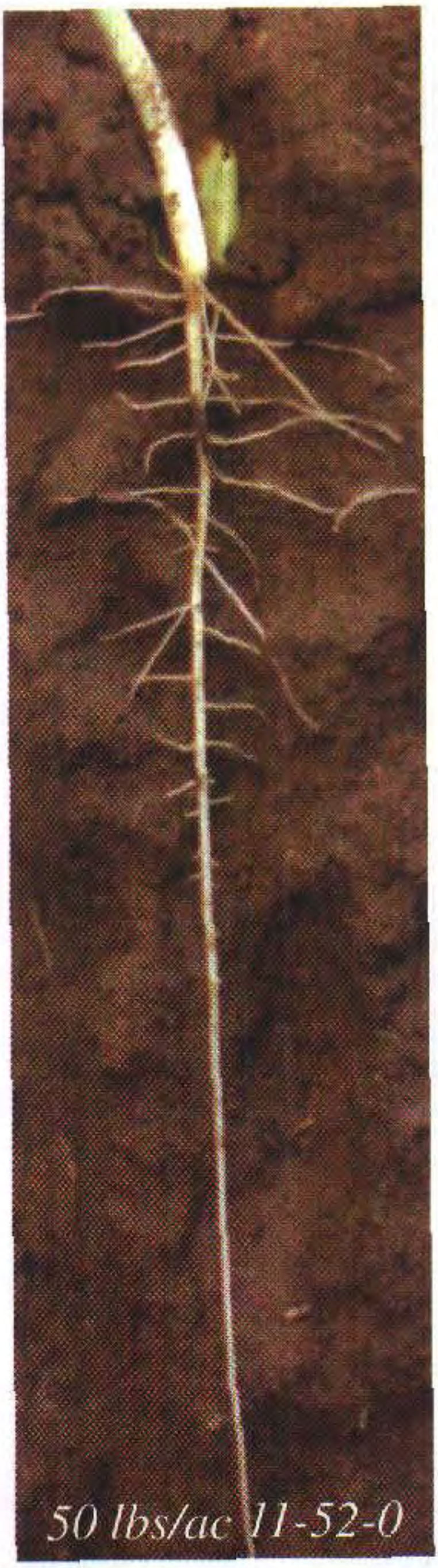
Fertilizer Injury

Fertilizer Injury

50 Pounds per Acre

The growth of the taproot and initiation of primary lateral roots were not restricted when 50 lbs/acre of each fertilizer (either liquid or granular) was applied in-furrow at planting. Growth of lateral roots were restricted when the formulation 18-46-0 was applied compared to applications of 10-34-0 or 11-52-0. This may be caused by concentrated N carrier osmotically shocking (burning) the developing root tissue. Therefore the starter should not be placed in seed furrow. Place in "classic" 2x2 band (two inches out and two inches below seed furrow).

50 Pounds per Acre



50 lbs/ac 11-52-0

50 lbs/ac 18-46-0

Fertilizer Injury

100 Pounds per Acre

The growth of the taproot was significantly reduced as well as lateral root initiation when 100 lbs/acre of 10-34-0 and 11-52-0 were applied in-furrow. There was no seed germination when 100 lbs/acre of 18-46-0 was applied in a similar manner.

100 lbs/ac 10-34-0

100 Pounds per Acre

100 lbs/ac 11-52-0

100 lbs/ac 18-46-0

Fertilizer Injury

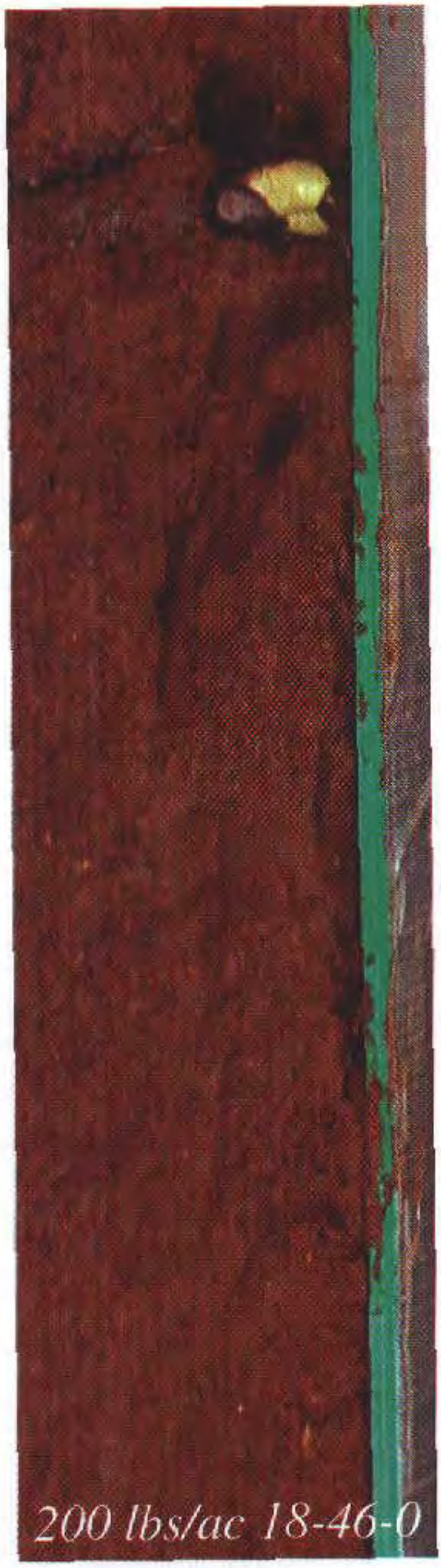
200 Pounds per Acre

Germination did not occur when 200 lbs/acre of either 10-34-0 or 18-46-0 was applied in-furrow. Germination and limited taproot elongation occurred when 11-52-0 was applied but no lateral roots were initiated.

200 lbs/ac 10-34-0

200 Pounds per Acre

200 lbs/ac 11-52-0



200 lbs/ac 18-46-0

Chilling Injury

Introduction

Cotton, by origin, is a tropical plant and does best under warm temperature conditions during both the vegetative and reproductive growth stages. This includes the germination and emergence phases of plant growth. Cotton germinates and emerges poorly under cool conditions, especially when the soil temperature is below 65° Fahrenheit.

Cool soil temperatures have a detrimental effect on the germination of cottonseeds in two ways. First, cool soil temperatures at the time of planting and until the seeds are hydrated, can cause imbibitional chilling injury. This occurs when dry seeds imbibe cool water. If this imbibition of cool water occurs too rapidly, the embryo cells may be injured or killed due to membrane stretching and rupture. The second mechanism by which germination and emergence are slowed under cool conditions is through the effect of low temperatures on slowing the metabolic events occurring during this phase. Both of these components, either individually or together, will result in slower emerging seedlings.

Chilling Injury

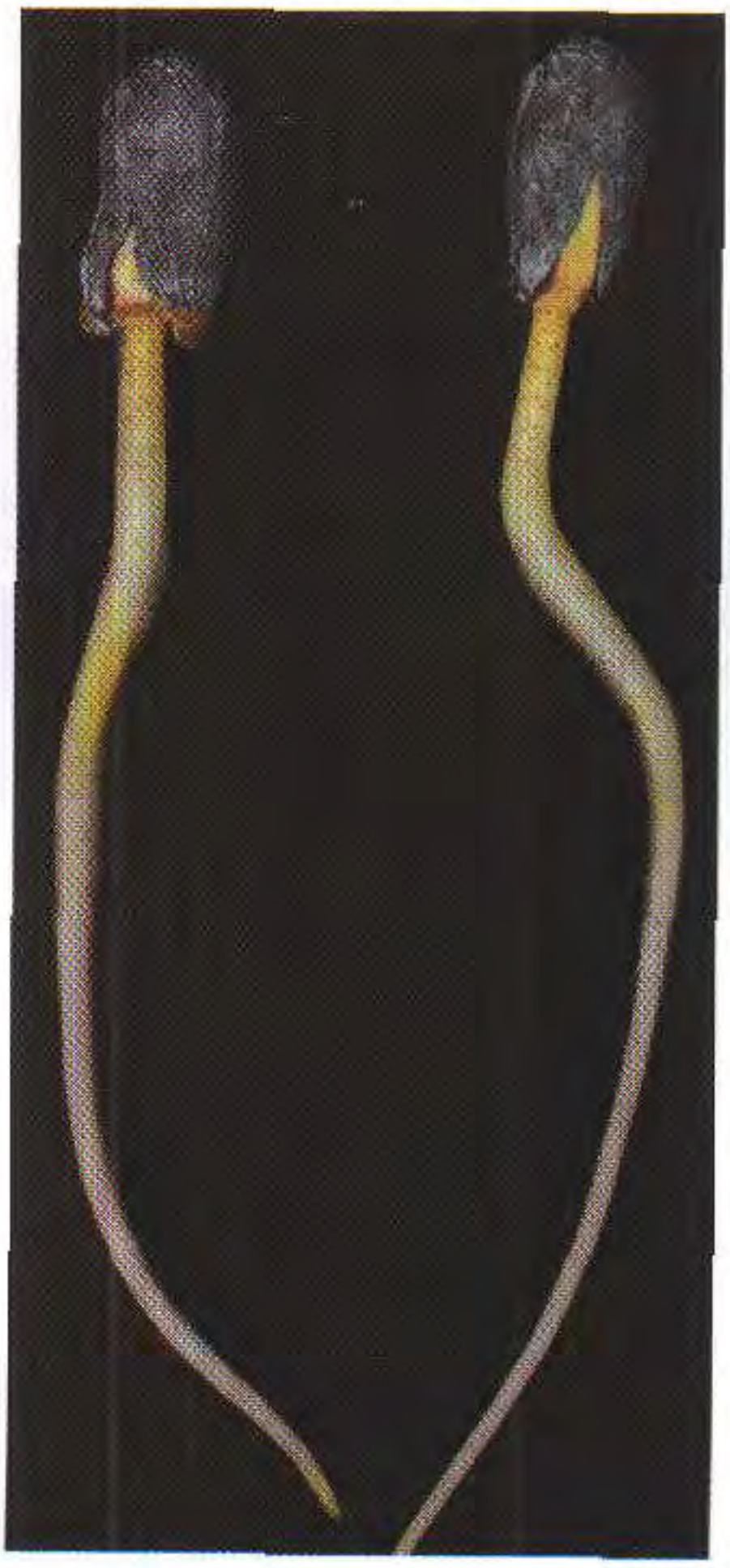
Chilling Injury

The three seedlings below were subjected to chilling temperatures while the three seedlings on the next page were not chilled during the imbibition phase (normal seedlings). During the first six hours of imbibition, the damaged seedlings were exposed to a temperature of 40° Fahrenheit. After the chilling period they were moved to a chamber set at 86° Fahrenheit for two to four days. The curling, shortening and thickening of the roots are typical of imbibitional chilling injury. The chilling during this phase of imbibition injures and

typically kills the root tip meristematic tissue. This results in cessation of normal taproot growth. Subsequently, lateral roots develop to compensate for this loss. Typically these seedlings may survive and produce productive plants if additional stresses such as water deficit or disease are not encountered.

Chilling Injury

The picture to the right is a close-up view of a seedling injured by chilling. The root tip meristematic tissue is dead, which results in the brown color. In many cases, the root tissue behind the dead root tip will be enlarged. Presumably, this results from a buildup of food reserves mobilized to the root meristematic tissue for growth. However, with a dead tip, these materials are not used and, therefore, accumulate.



The two seedlings to the left show normal root development. When the two groups are compared it may be noted that seedlings injured by chilling are often short with thickened hypocotyls and radicles, dead root tips, and show some

signs of lateral root growth. The six seedlings pictured above depict various morphological responses to chilling injury.

Soil Compaction

The presence of compacted layers such as plowpans can significantly affect the growth of cotton roots. The depth of these layers or zones of high soil strength can range from a few inches to a few feet below the soil surface.

Generally, as soil resistance increases, the root elongation rate decreases, which can cause the root system to extract water and nutrients from only a limited soil volume. Thus, the plant will be more susceptible to drought stress later in the season. Rooting density is also generally lower in the compacted zones.

The pictures shown depict some of the responses of young cotton roots to zones of high soil strength. These plants were grown under conditions of optimum temperature and moisture.

In Figure A, the growth of the taproot was root stopped when the seedling system encountered the

Figure A

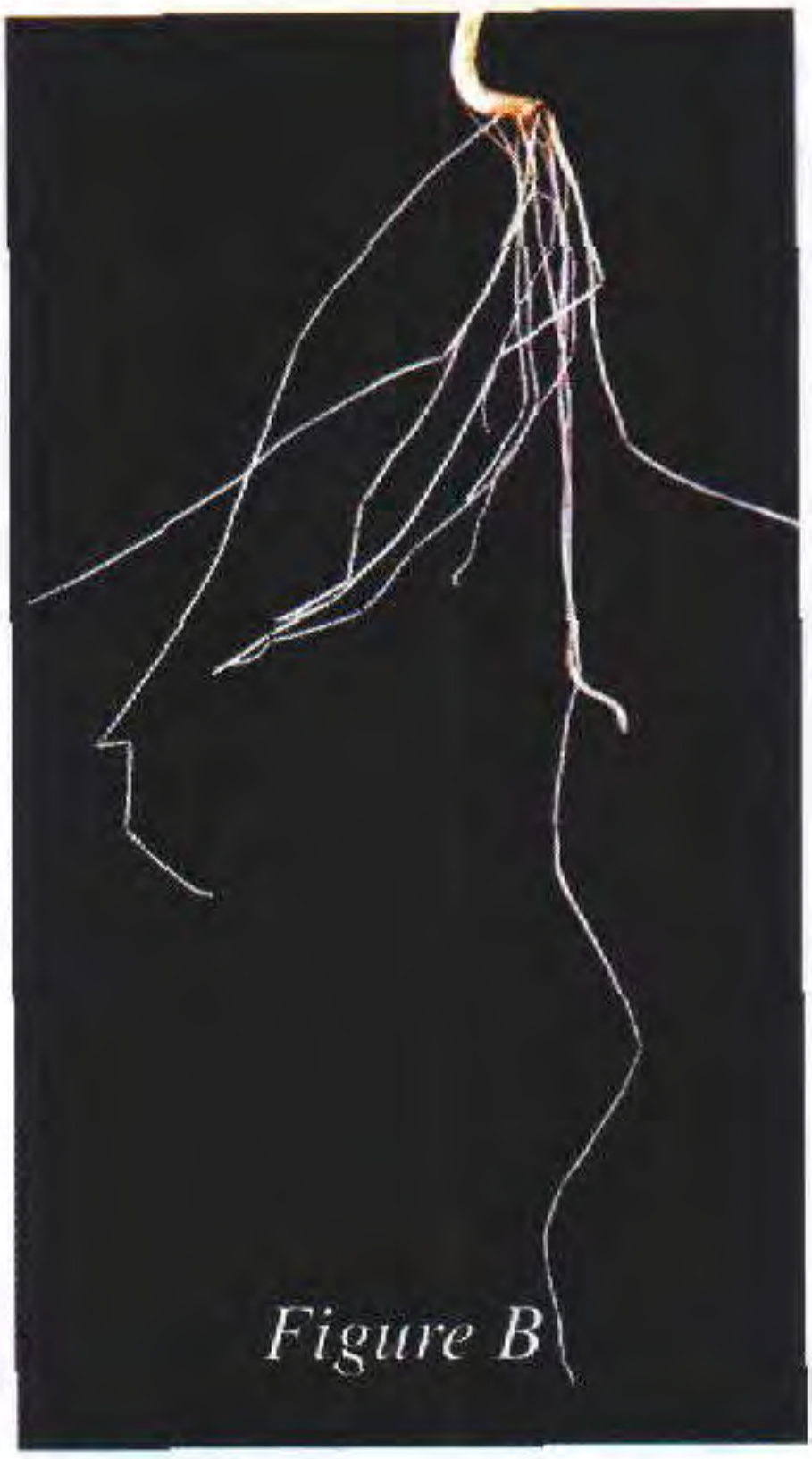


Figure B

compacted zone. These zones are not always distinguishable by color changes, so it may be difficult to determine exactly where the compacted layer begins and ends. In Figure A there was an increase or "flush" of lateral root growth along the surface of the compacted zone in both seedlings which severely limited growth to lower depths. A similar situation is shown in Figure B.

Figure C shows that the taproot encountered a zone of high soil strength which deflected the growth of the root until the root tip encountered a nearby zone of lower strength and the root continued to grow downward. Other variations of these typical responses may be observed but in general the growth of the taproot will either stop or be deflected at the surface of the compacted zone.

Figure C

Notes