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Morphology and Anatomy of Texas Persimmon

(Diospyros texana Scheele)

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Cover Photographs

Top, a typical infestation of multi-stemmed Texas persimmon plants on the D. B. Wood Ranch near Georgetown, Texas. Bottom, Sam Barkley, owner, with the largest recorded Texas persimmon plant in Texas near Uvalde.

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SUMMARY

Texas persimmon (*Diospyros texana* Scheele) is an important, largely undesirable woody species which has invaded about 6 million acres of Texas, mostly on the Edwards Plateau, Central Basin and South Texas Plains. It also occurs in nothern Mexico.

Texas persimmon produces male and female flowers on separate plants (dioecious). Most flowers appear from March to May. The fruit, a black, depressed globose berry, ripens in August through October. The seed are dark red and glossy; they contain an embryo and food reserves stored as a hard, lustrous endosperm. Seed germinate much more readily when washed free from the fruit pulp than when left in the fruit. Seedlings grow most rapidly at 80° F, but almost no growth occurs at 65° F.

Seed were fed to a Jersey steer *(Bos taurus* L.), a Spanish goat *(Capra hircus* L.) a Rambouillet sheep *(Ovis aries* L.) and a whitetail deer [*Odocoileus virginianus* (Boddaert)]. Also, seed were collected in the field after they had passed through the digestive tracts of cattle and raccoons *(Procyon lotor* L.). Of 600 seed fed to the steer, only 289 were recovered, and only about 1 percent of these subsequently germinated. Of seed collected from cattle feces in the field, 22 percent germinated compared to 64 percent of the unfed seed. Twelve percent of the seed washed from raccoon droppings germinated. The Spanish goat, Rambouillet sheep and whitetail deer masticated and digested essentially all the seed fed.

Texas persimmon occurs both as individual plants and as mottes. Most are multistemmed plants 8 to 12 feet tall. However, the largest tree recorded in Texas is 26 feet tall with a crown diameter of 31 feet. Texas persimmon is seldom the height-dominant species, except where other woody plants have been removed.

In Central Texas, new stems begin growth from apical buds in March and April, and complete elongation of about 5 centimeters by the end of May. Flowers are located at the base of the new stem and at buds, primarily on the 1- and 2-year-old stems. Many stems produce short lateral shoots. At first the stem is green, but in May or June a simple periderm forms, turning the stem gray and slightly furrowed. Stems 1 to 2 centimeters in diameter are relatively smooth, as the surface periderm and outer phloem strip off annually in late summer.

The apical stem meristem elongates, producing an axillary bud and a leaf at each node. Some axillary buds produce a short lateral shoot the first year, and some produce stems, leaves and flowers the second year. However, most remain dormant until released from apical dominance. When the stem is severed in the top of the plant, usually about four new stems are produced; when the entire top is removed, as many as 20 vigorous stems are produced on the base of the stem and on the root.

Texas persimmon generally produces adventitious buds on the root either along cut edges or where branch roots join the main root. These buds apparently arise on potentially meristematic tissue in the phellogen, phloem or cambium. When the plant is cut off at the root, sprouts arise near the end of vertical roots but may occur all along the horizontal roots. Plants can be propagated in the greenhouse by holding 3- to 4-inch-long stem or root segments at least 0.5-inch in diameter in soil for 2 to 6 months. However, greenhouse plants 1 year old sprouted from the stem, but not from the root, when the plant was clipped at the soil level.

One leaf is produced at each node on new stems. The leaves expand to full size within 3 weeks after emergence. At first they are light green; later they turn dark green. The largest leaves occur in the midsection of the stem; younger and older leaves are smaller. Most other leaves are produced on the next two older stem increments. These leaves are alternate but appear almost whorled on foreshortened shoots; usually three to five leaves are produced on these short shoots.

The leaf blade arises on a 2-millimeter-long petiole. The leaf blade is simple and obovate, with an entire margin, acute base and an acute, obtuse or emarginate apex. The upper blade surface is usually glabrous, but the lower surface varies from glabrous to highly pubescent. Leaves vary from 1 to 4 centimeters long, but most are 2 to 3 centimeters long. They are slightly more than twice as long as wide. The lower surface of the blade has 219 to 329 stomata per square millimeter.

Seedling plants produce a prominent taproot. Plants in the field also generally produce a taproot. However, plants growing in areas with shallow soil over rock generally have spreading, shallow root systems until the roots can penetrate deeper into the soil. The structure of the root body is similar to that of the stem, except that it produces no axillary buds and contains no pith.

Of the herbicides tested on seedling plants, tebuthiuron [1-(5-*tert*-butyl-1,3,4-thiadiazol-2-yl)-1,3-dimethylurea] and the potassium salt of picloram (4-amino-3,5,6-trichloropicolinic acid) were the most effective for controlling Texas persimmon.

Morphology and Anatomy of Texas Persimmon

(Diospyros texana Scheele)

R. E. Meyer*

Texas persimmon (*Diospyros texana* Scheele) is an increasingly important woody plant which infests many areas of Texas. It is also known as Mexican persimmon, chapote and chapote prieto (15). It is beneficial by producing fruit that is readily eaten by many birds and mammals. Generally, however, Texas persimmon is considered undesirable because it readily invades grassland, is difficult to control and is toxic in that the fruit causes scours in cattle. Texas persimmon commonly persists where chemical or mechanical measures have been employed to control brush. It readily resprouts from roots. Consequently, any measure that fails to kill the roots allows it to become reestablished, frequently with significantly less competition from other woody plants than before.

The aim of this study was to describe the plant structure, seasonal growth patterns and seedling response to herbicides to provide a basis for developing better methods of control. This study supplements general information on woody species presented by Metcalfe and Chalk (7) and Panshin and de Zeeuw (11). The objectives were (a) to determine the morphological and anatomical structure of the fruit, seedling and mature plant; (b) to determine the seasonal growth pattern and factors affecting growth; and (c) to determine the response of greenhouse seedlings to herbicides. The response of Texas persimmon to herbicides in the field has been studied by others (5, 10, 17). This study was undertaken in the field at Georgetown, Llano, Marble Falls, Sonora and Uvalde, Texas, and in the greenhouses at College Station, Texas.

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EXTENT OF INFESTATION

Texas persimmon grows in central, southern and southwestern Texas and in northern Mexico (16). Hoffman[1] estimates that about 6 million acres of Texas rangeland are infested with Texas persimmon in the counties shown in Figure 1. Wilson (16) described Texas persimmon as a problem on the eastern edge of the Edwards Plateau and the Central Basin, including the following counties: Bandera, Blanco, Burnet, Comal, Gillespie, Hays, Kendall, Kerr, Kimble, Llano, Mason, McCulloch and San Saba. Scattered plants grow north of the Rio Grande River from Hidalgo County on the southeast to Terrell County on the west. Plants occur as far east as Dewitt, Goliad and Gonzales counties. Plants also have been observed in Brewster, Coleman, Concho, Tom Green and Travis counties. In a recent survey by Scifres and Hoffman,[2] range workers in Texas felt that density increases of Texas persimmon can be attributed primarily to overgrazing and the use of mechanical brush control methods that fail to kill the plant. Texas persimmon occurs in the states of Nuevo León, Coahuila and Tamaulipas in northern Mexico (15), but no information was found on its distribution in those States.

GENERAL MATERIALS AND METHODS

Sites

The research was conducted in the greenhouse facilities at College Station and at field sites in Georgetown, Llano, Marble Falls, Sonora and Uvalde, Texas. Most plant samples were collected at the D. B.

[1]Hoffman, G. O. 1974. Private communication; Texas Agricultural Extension Service, Texas A&M University, College Station, Texas 77843.

[2]Scifres, C. J. and G. O. Hoffman. 1974. Distribution of Texas Persimmon (Unpublished Survey), The Texas Agricultural Experiment Station (Department of Range Science), Texas A&M University, College Station, Texas 77843.

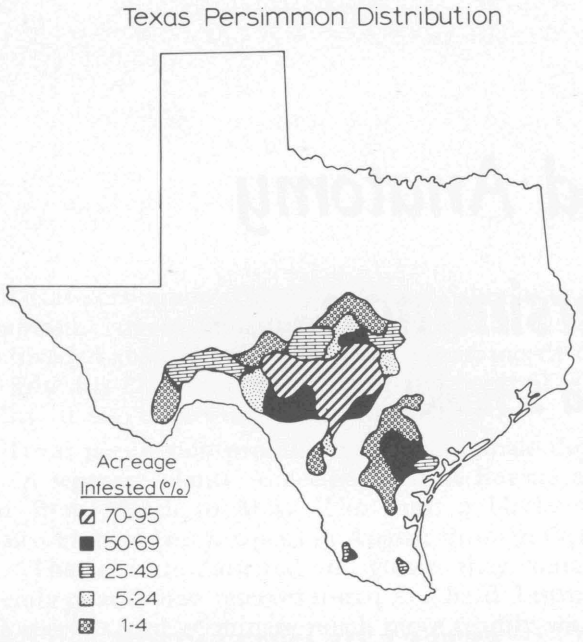


Figure 1. Infestation of Texas persimmon (*Diospyros texana* Scheele) in Texas, 1974. (Courtesy of C. J. Scifres and G. O. Hoffman).

Wood Ranch near Georgetown, on the eastern edge of the Edwards Plateau. On this ranch, Texas persimmon was a scattered infestation of about 20 plants per acre. The plants were 6 to 12 feet tall and grew on rocky loam soil. Other woody species on the area included live oak *(Quercus virginiana* Mill.) with scattered cedar elm *(Ulmus crassifolia* Nutt.) and pricklypear *(Opuntia* sp.). The remaining plant samples were collected in the Central Basin on the Ann Etta Hall Ranch near Llano and the Fred Horlen Ranch near Marble Falls. Other woody species in these areas were largely honey mesquite [*Prosopis juliflora* (Swartz) DC. var. *glandulosa* (Torr.) Cockerell], whitebrush *(Aloysia lycioides* Cham.) and tasajillo *(Opuntia leptocaulis* DC.).

Field Plant Collection

Immature and ripe fruit were collected from plants near Georgetown, Llano, Marble Falls or Sonora from 1967 through 1973. Stem and root samples were collected at the D. B. Wood Ranch near Georgetown 14 times in 1969 and 13 times in 1970. Twigs, stems 1, 2, 4 and 8 centimeters in diameter, and roots of various sizes were collected at each date. The twigs included tip growth from the previous year and new shoots when they occurred. The twig samples contained leaves and buds; flowers were collected when present. Segments about 1 centimeter long were cut from stems 1 and 2 centimeters in diameter. On 4- and 8-centimeter-diameter stems, sections were removed by sawing transectional cuts with a hand saw and chipping out the tissue with a hammer and chisel. Root samples were often difficult to secure because of the rocky soil. However, root samples 0.5, 1 and more than 2 centimeters in diameter were collected on each date. Samples were taken from two or three trees on each date. Miscellaneous other stem and root samples were collected at Georgetown and Llano until early in 1973. The tissue was placed in a Craf fixing solution (13) immediately after cutting.

Morphological and Anatomical Methods

All photographs were made with 4- by 5-inch cameras. Overall photographs were made with Kodak Plus-X Pan Professional film. Enlarged plant surfaces and histological sections were photographed with either Kodak Panatomic-X or Ektapan Professional film, which was developed either in Kodak DK-50A or DK-60A for adequate contrast in detail.

Anatomical sections were prepared by fixing the tissue in a Craf solution (13) comprised of 30 percent of a 1-percent aqueous chromium trioxide solution, 3 percent concentrated acetic acid, 10 percent of a 40-percent formalin solution and 57 percent water by volume. The tissues were dehydrated in ethanol and tertiary butyl alcohol and embedded in Paraplast (m.p. 101° to 104° F). The embedded samples were microtomed 8 to 20 microns thick. The tissues were stained with safranin (30 minutes) and fast green (3 to 5 minutes) (13).

Stomatal counts were made on three fields, using an ocular-mounted rectangular reticle on each of five leaves. Stem and root tissue dimensions were measured either on transections of stored tissue, which had been fixed in the Craf solution and partially dehydrated to 70 percent ethanol in water, or on fresh tissue held in water. The blocks of stem or roots were mounted directly into a rotary microtome, and sections 20 microns thick were prepared. The sections either were left unstained or were stained with safranin and mounted in a glycerol:water (1:1) solution. Dimensions were measured on three radii for each stem or root in each size group at every date.

Animal Feeding

Texas persimmon fruit and/or washed seed were fed to a 400-pound Jersey steer *(Bos taurus* L.), a Spanish goat *(Capra hircus* L.), a Rambouillet sheep *(Ovis aries* L.) and a whitetail deer [*Odocoileus virginianus* (Boddaert)]. The numbers of fruit and seed fed are included with the results. All animals were kept in pens with concrete floors. The fruit for all but the whitetail deer was force-fed, and washed seed were mixed with feed grain. The deer readily ate the fruit. Feces were collected daily for 5 or 6 days after feeding. All experiments were repeated.

The seed recovered daily from each animal species were counted, washed and germinated in the greenhouse. No more than 25 seed were planted in a pot. Also, 100 or 200 washed, unfed seed were planted as a control with each experiment. The pots were placed in a warm greenhouse and kept watered for at least 3 months.

Growth Chamber and Greenhouse Plant Propagation

Plants were propagated from seed that had been washed free from the fruit pulp and stored at 41° F.

Usually 10 seed were placed on the surface of a soil mixture comprised of Houston clay loam soil, washed sand, peatmoss and Perlite at a 10:6:3:3 volume to volume (v/v) ratio in a plastic pot 5 inches in diameter. The seed were covered with 1 inch of sand. This soil mixture and sand potting procedure was used throughout the study. The pots were kept in the greenhouse. The seedlings were subsequently thinned to three to five per pot.

Three growth chambers were used for temperature and fruit inhibitor experiments and for preconditioning plants before spraying with herbicides. The plants were kept on a 12-hour light (1,000 foot candles) and dark cycle at 80° F. A mixture of fluorescent and incandescent illumination was used.

Herbicide Spraying and Evaluation

Plants were propagated from seed in the greenhouse. Because of their slow growth rate, they were preconditioned in growth chambers for 2 months until 10 to 18 inches tall. Eight pots of plants (replications) were sprayed with a laboratory sprayer (1) for each treatment. All herbicides were applied at 1 pound per acre in water at a spray volume of 20 gallons per acre. The plants were subsequently kept in the greenhouse for 3 months. They were then evaluated for percentage defoliation and percentage dead plants. The experiment was repeated.

The herbicides used included amitrole (3-amino-*s*-triazole); atrazine [2-chloro-4-(ethylamino)-6- (isopropylamino)-*s*-triazine]; bromacil (5-bromo-3-*sec*-butyl-6-methyluracil); cacodylic acid (hydroxydimethylarsine oxide); dicamba (dimethylamine salt of 3,6-dichloro-*o*-anisic acid); 2,4-D [butoxy ethanol ester of (2,4-dichlorophenoxy)acetic acid]; dichlorprop [butoxy ethanol ester of 2-(2,4-dichlorophenoxy)propionic acid]; 2,4-DB [butoxy ethanol ester of 4-(2,4-dichlorophenoxy)butyric acid]; fenac [sodium salt of (2,3,6-trichlorophenyl)acetic acid]; karbutilate [*tert*-butylcarbamic acid ester with 3-(*m*-hydroxyphenyl)-1,1-dimethylurea]; MCPA [dimethyl amine salt of [(4-chloro-*o*-tolyl)oxy]acetic acid]; mecoprop [butoxy ethanol ester of 2-[(4-chloro-*o*-tolyl)oxy]propionic acid];MCPB [butoxy ethanol ester of 4-[(4-chloro-*o*-tolyl)oxy]butyric acid]; picloram (potassium salt of 4-amino-3,5,6-trichloropicolinic acid); picloram + 2,4,5,-T [triethylamine salts of picloram + (2,4,5-trichlorophenoxy)acetic acid]; silvex [butoxy ethanol ester of [2- (2,4,5-trichlorophenoxy)propionic acid]; tebuthiuron [1-(5-*tert*-butyl-1,3,4-thiadiazol-2-yl)-1,3-dimethylurea]; and 2,4,5-T (butoxy ethanol ester of 2,4,5-T).

FLOWER, FRUIT AND SEEDLING

Flower, Fruit and Seed Morphology and Anatomy

Flower

Texas persimmon is dioecious, in that male and female flowers are produced on separate trees. At Georgetown, male and female trees were intermingled and were about equal in numbers. Most flowers appear from March to May; however, a few open later in the growing season after periods of abundant rainfall. The flowers appear either solitary or in clusters of 2 or 3 on the distal end of branches that were produced either the previous two seasons or early in the same season (Figure 2).[3] According to Britton (2)

> The staminate flowers are on nodding hairy pedicels, usually in clusters of 2 or 3; the calyx is about 3 mm. long, deeply 5-lobed, and silky; the corolla is urn-shaped, twice the length of the calyx, white, scarcely 5-lobed; the 16 stamens are distinct, in two rows; the anthers are linear-lanceolate, and open at the apex; the pistillate flowers are usually solitary on shorter pedicels, their calyx silky, half the length of the hairy corolla, which is nearly 12 mm. across; ovary ovoid, 8-celled, with 1 ovule in each cavity, and 4-spreading, 2-lobed styles; there are no stamens nor staminodia.

Floral structures are shown in Figure 3. Figure 3A shows an overall view of male flowers on April 15, 1971. Typical male flowers with part of the corolla and calyx removed are shown in Figure 3B. Large numbers of male flowers are frequently produced on one stem but fewer female flowers are produced (Figure 2). Mature, intact female flowers are shown in Figure 3C and with part of the corolla and calyx removed in Figure 3D.

Fifteen male stems with four elongation-growth increments each were collected from plants at Georgetown on April 1, 1971. Branch increments, beginning at the youngest (the one produced in 1971), averaged 1.6, 5.4, 7.0 and 9.9 centimeters in length and had 4.0, 15.5, 6.5 and 0.4 flowers, respectively. The flowers on the youngest increment were at the base. Fifteen similar female stems had branch increments 1.5, 5.7, 6.8 and 8.4 centimeters long with 2.1, 3.3, 1.4 and 0.3 flowers, respectively.

The flowers of Texas persimmon produce nectar, and when open, are visited by numerous insects. On April 1 and 5, 1974, insects were captured on flowering plants at Georgetown. The most numerous insects visiting the flowers were the honey bee and the two types of halictid bees (Table 1). However, a number of other insects were present which probably are important for pollination. Consequently, Texas persimmon may be either partially or entirely insect pollinated.

Fruit

The fruit ripens from August through October. "The fruit . . . is a depressed globose berry, 2 cm. in diameter, black and tipped by the style and subtended by the enlarged, reflexed calyx-lobes; the skin is thick, the pulp sweet, dark colored, and contains 3 to 8 triangular seeds" (2). Figure 4A shows the intact fruit in various stages of maturity. The immature fruit is green and pubescent. The fruit turns from entirely green to splotchy green and black before turning completely black at maturity. The fruit is firm when green, and soft when black and mature.

Figure 4B shows a transection of a fruit that produced five seeds. The fleshy mesocarp turns darker

[3]Figures are placed at the end of the respective sections. Lettering on photographs is identified on page 55.

Table 1. Insects captured on Texas persimmon plants, April 1 and 5, 1974 during the flowering period at Georgetown, Texas

Order	Family	Common name	Scientific name
Coleoptera	Cantharidae[1]	Soldier beetle	*Chauliognathus marginatus* Fab.
	Chrysomelidae	Leaf beetle	*Nodonata tristis* (Oliv.)
	Curculionidae	Weevil	*Anthonomus faber* Dietz
Diptera	Calliphoridae[1]	Blowfly	
	Chloropidae[1]	Frit fly	
	Tachinidae[1]	Tachinid fly	
Hemiptera	Coreidae	Leaf footed plant bug	*Acanthocephala terminalis* (Dallas)
	Lygaeidae	Lygaeid bug	*Nysius* sp
	Miridae	Plant bug	*Neurocolpus* sp
Hymenoptera	Apidae[1]	Honey bee	*Apis mellifera* L.
	Halictidae[1]	Halictid bee	*Agapostemon* sp
		Halictid bee	*Lasioglossum* sp
	Vespidae[1]	Vespid wasp	*Stenodynerus anormis* (Say)
Lepidoptera	Danaidae[1]	Monarch butterfly	*Danaus plexippus* (L.)
	Hesperiidae[1]	Skipper	*Atalopedes campestris* Boisduval
	Nymphalidae[1]	Painted beauty	*Vanessa virginiensis* (Drury)
	Pieridae[1]	Alfalfa caterpiller	*Colias eurytheme* Boisduval
		Sulfur butterfly	*Kricogonia castalia* Fab.
Neuroptera	Mantispidae	Mantispid	*Climaciella brunnea* (Say)
Odonata	Libellulidae	Dragonfly	

[1]Family members listed probably involved with pollination.

orange rapidly after being exposed to the air. Apparently colored oxidation products form rapidly in the mesocarp when it is exposed to oxygen upon cutting.

Figure 5 shows transections through a full-size but immature fruit collected at Georgetown April 21, 1969. The exocarp is a single layer of epidermal cells, with a cuticle and some trichomes. The mesocarp is comprised of a layer of about 40 parenchyma cells deep underneath the epidermis. They enlarge progressively from the outside toward the center, and most of these parenchyma are more or less spherical. Sclereids occur singly or in small groups about 5 cells deep from the epidermis.

Vascular bundles (Figure 5A) occur in the parenchyma in an undulating line outside the seed cavities and in a ring at the center (Figure 5B). The endocarp of the fruit consists of one layer of flat cells, with little or no cuticle to the inside of the mesocarp. Immature seed sections are shown in Figures 5B and 5C. Upon ripening of the fruit, the parenchyma become more irregularly shaped and more loosely packed than in the immature fruit.

Seed

The seed are triangular, about 8 to 10 millimeters long and 1 to 2 millimeters thick. The thin edge is almost straight (Figure 6A). The seed are dark red and glossy. The food reserves are stored as hard, lustrous endosperm, and an embryo lies in a hollowed area at one end of the seed (Figure 6B). The seed is similar to that of common or eastern persimmon *Diospyros virginiana* L.) (6, 14).

The outer covering of the seed (Figure 7A) is comprised of 1 or 2 layers of large cells which stain brown with safranin; they are covered with a cuticle. These cells are underlain by 10 to 15 smaller cells, which are either cubical or elongated on the transection. The endosperm is white, lustrous and hard (Figures 7A and 7B) and forms a protective covering as well as a food supply for the embryo (Figure 6B). The endosperm comprises the bulk of the seed volume and consists of a network of elongated cells, which stain green with fast green (Figure 7A).

The embryo occurs in a hollow of the endosperm at one end of the seed (Figure 6B). The embryo has two cotyledons with net veination (Figure 7C). The veins converge at the base of the cotyledons upon entering the primary root (Figure 7D). The embryonic root narrows to a point near the edge of the seed coat (Figure 7E). Frequently, the embryo will be released to the outside if the seed is killed and subsequently placed in water.

Figure 8 shows histological longitudinal sections of the embryo through the apical meristem at the base of the cotyledons (Figure 8A), the primary root midsection (Figure 8B) and the primary root tip (Figure 8C).

Seed Germination

Seed in mature fruit did not germinate readily when planted in soil in the greenhouse; subsequently, germination of seed under different environmental conditions was studied.

Physical and Chemical Treatments

Two experiments were conducted to evaluate germination of washed seed and seed in intact fruit. In the first, 140 pots were filled with the soil mixture. Ten washed seed were placed in each of half the pots. Two fresh, chilled (41° F) fruit, each containing about five seed, were placed in each of the other half of the pots. The seed were then covered with 1 inch of washed sand. The seed or fruit were planted and placed in the greenhouse on September 7, 1968. Seed

Table 2. Percentage germination, root length and percentage Texas persimmon seedlings with stems after several physical and chemical treatments

Treatment[1]	Germination	Root length	Seedlings with stems
	(%)	(mm)	(%)
	Plated October 4 and rated December 30, 1968		
1. Unscarified control	92	20	6
2. Scarified tip	97	17	13
3. Top third of seed removed	97	6	4
4. Hot water, 10 min	93	21	9
5. Hot water, 60 min	94	17	3
	Plated September 18 and rated November 18, 1968		
1. Untreated	89	41	20
2. Fungicide control[2]	87	11	5
3. Concentrated H_2SO_4, 2 min[2]	80	10	4
4. Concentrated H_2SO_4, 10 min[2]	68	12	15
5. Concentrated H_2SO_4, 30 min[2]	32	3	4
6. Concentrated H_2SO_4, 60 min[2]	42	2	0

[1]Temperature 72°±5° F.

[2]Thiram was applied as a fungicidal slurry.

and seedlings were washed from five of the pots from each group weekly for 14 weeks. The seedlings were placed in a fixing solution for subsequent anatomical studies. At the end of 14 weeks, 88 percent of the washed seed and 13 percent of the seed in fresh, chilled fruit had germinated.

A second, similar experiment was conducted wherein air-dried fruit were included, as well as washed seed and fresh, chilled fruit. At the end of 14 weeks, 43, 16 and 3 percent of the washed seed, seed in fresh, chilled fruit and seed in air-dried fruit, respectively, had germinated. Thus, the fruit pulp contained an inhibiting mechanism which prevented most seed from germinating.

A third experiment was conducted to study the influence of scarification and hot water treatments on germination and seedling growth. The treatments included an unscarified control, scarification of the seed coat tip at the end of the embryonic root, removal of the top third of the seed at the end opposite the embryo and immersion of the seed in hot (136° F) water for periods of 10 and 60 minutes. Twenty washed seed were placed on filter paper in each of five plastic petri dishes, 9 centimeters in diameter, per treatment. The dishes were placed on a naturally lighted laboratory bench at 72±5° F and were kept moist with distilled water for 6 weeks.

All treatments gave 92 percent or more germination, but low production of stems (Table 2). No treatment was superior to the control. Root length was about the same in most treatments, except that removal of the top third of the seed reduced the root growth. Apparently, the reduction in food materials and/or exposure to diseases resulted in less root growth. At the end of the experiment, 5 to 20 percent of the surfaces of all petri dishes were contaminated with a white fungus.

A fourth experiment was conducted to investigate the possibilities of reducing fungus contamination and accelerating seed germination. The petri-dish technique was similar to that used in the scarification and hot water treatments. On September 18, 1968, five plastic petri dishes, each with 20 Texas persimmon seed, were prepared for each of six treatments at three temperatures. The seed treatments consisted of the following: an unscarified control, an unscarified control with a thiram [bis(dimethylthiocarbamoyl)disulfide] fungicide slurry treatment and immersion in concentrated sulfuric acid (H_2SO_4) for 2, 10, 30 and 60 minutes. The seed treated with acid were subsequently rinsed with tap water and treated with the fungicide slurry. One set each was placed in dark growth chambers at 60° and 86° F. A third set of dishes was placed on a naturally illuminated laboratory bench at 72° F.

The results of holding the seedlings at 72° F are presented in Table 2. The concentrated H_2SO_4 treatments for 30 and 60 minutes reduced seed germination and root length. Thiram did not affect germination, but it did retard root growth compared to the untreated control. At 60° F, none of the seed germinated (data not shown). Apparently the temperature was too low for growth. Seedlings held at 86° F germinated about the same as those held at 72° F but failed to elongate as well, probably because of the inability to photosynthesize. Comparisons between the two highest temperature regimes are limited because the seedlings were grown under different light conditions, which were undoubtedly important during a 2-month period.

In summary, Texas persimmon seed germination is markedly inhibited by the fruit pulp. None of the scarification, hot water or acid treatments promoted earlier germination, longer root growth or earlier stem production. Microbial contamination was abundant in the petri dishes and was not satisfactorily controlled by a fungicide treatment.

Fruit Pulp Inhibitor Study

Further research was conducted on the inhibitor in the fruit pulp (8). Crude extracts were made by macerating the fruit pulp (without seed) in water with a blender. The macerated mixture formed a chartreuse foam above a dark yellow liquid. Ten milliliter volumes of 5, 1, 0.1 and 0.01 milligram per milliliter concentrations of the extract were pipetted into plastic petri dishes with two pieces of filter paper. Distilled water was subsequently added to keep the seeds moist.

In the first experiment, mechanically scarified honey mesquite, sorghum [*Sorghum bicolor* (L). Moench.] and wheat (*Triticum aestivum* L.) seed were germinated in extracts of the fruit pulp. Twenty-five seed of each species were placed on filter paper in each of the four plastic petri dishes for each treat-

Table 3. Root length and percent germination of honey mesquite, sorghum and wheat seedlings germinated 4 to 6 days at 80° F[1]

Concentration[2]	Species					
	Honey mesquite		Sorghum		Wheat	
	Root length	Germination	Root length	Germination	Root length	Germination
(mg/ml)	(mm)	(%)	(mm)	(%)	(mm)	(%)
0	18.6 a	99 a	14.1 a	69 a	22.0 a	50 a
0.1	14.3 b	100 a	12.9 a	61 a	12.2 b	30 b
1	3.7 c	94 a	6.6 b	28 b	11.0 b	28 b
5	0.9 d	63 b	1.2 c	11 c	0.1 c	1 c
10	1.1 d	70 b	0.3 d	8 c	0 c	0 c

[1]Means within columns followed by the same letter are not significantly different at the 5% level, as determined by Duncan's multiple range test.

[2]Ten ml of the extract were added initially; subsequently, distilled water was added as required.

ment, and the extract was added. Seed were germinated at 80° F. Root length and percent germination were recorded 4 to 6 days after exposure to the various fruit extracts.

Germination and root elongation of all three species were strongly inhibited by the Texas persimmon fruit extract (Table 3). As concentration of the extract was increased, growth inhibition of roots increased. Root-length measurements were more usable as a bioassay than was percentage germination, although germination was inhibited at the higher concentrations of extract.

Texas persimmon fruit were collected at various stages of development on May 20, June 6, July 7, August 26, September 10 and October 1, 1969, at Georgetown and stored at 41° F. Fruit were macerated as in the previous experiment. The entire fruit were macerated at the first two dates; the seed were removed at all other dates. Honey mesquite root length was used as the bioassay.

Averaged over six dates, concentrations of 0.01, 0.1, 1 and 10 milligrams of fruit pulp per milliliter reduced honey mesquite root length markedly to 68, 46, 23 and 12 percent of that of the control, respectively. The inhibitor was about equally effective at all stages of fruit development.

In other experiments, extracting the fruit pulp with hexane or a 1:1 mixture of diethyl ether:hexane did not affect the recovery of the inhibitor compared to water. Filtering and freezing the extract for 5 hours likewise had no effect. However, the inhibitor was lost by boiling the extract to dryness and resuspending in distilled water. Further research is needed to characterize this inhibitor fully.

Seed Passage Through Animals

Cattle

A 400-pound Jersey steer was fed three lots of 200 washed Texas persimmon seed in 1972. The seed were mixed with small amounts of grain and fed on April 11, 19 and 25. The steer was kept in a pen with a concrete floor, and all feces were collected daily during the 6-day period after each feeding. The results are presented in Table 4. In the three runs, 289 or 48 percent of the number of seed fed, were recovered. Of the 200 fed each time, the numbers recovered varied from 68 to 142. The largest number of seed was excreted the second day after feeding. However, some were recovered as long as 6 days after feeding. The gradual passage of seed is caused by the continuous mixing of the feed in the rumen. Since the seed are heavier than the other rumen contents, some of the seed probably were retained for varying lengths of time. Remastication destroyed others. The digestive system reduced the germination from 36 percent in the unfed controls to less than 1 percent when passed through the steer.

On September 15, 1972, Texas persimmon seed were collected in cattle feces in the field at Georgetown and Marble Falls. Some lots of feces had great numbers of seed, indicating the animals had fed abundantly on the Texas persimmon fruit. One hundred seed from feces, as well as 100 seed washed from fruit at each location, were planted, 25 per pot, in the greenhouse at College Station. On November 29, 1972, the seedling stems were about 4 centimeters tall. Again, germination of seed from feces (22 percent) was markedly less than that from fresh, washed fruit (64 percent). There was no difference in results between the two sites.

Table 4. Texas persimmon seed recovered from a 400-pound Jersey steer in 1972, after feeding 200 seed at each of three dates

Days after feeding	Date fed[1]			Seeds recovered on days given
	April 11	April 19	April 25	
	(Number)	(Number)	(Number)	(Number)
1	0	2	3	5
2	21	92	27	140
3	26	24	14	64
4	13	22	15	50
5	18	2	7	27
6	1	0	2	3
Total	79	142	68	289

[1]Fewer than 1 percent of the seeds recovered had germinated on July 20, 1972, whereas 36 percent of the unfed seeds had germinated.

Table 5. Texas persimmon seedling length during a 14-week period after germination

Age	Germination	Seedling organ length		
		Root	Hypocotyl	Stem
(Weeks)	(%)	(mm)	(mm)	(mm)
1	0	0	0	0
2	5	2	0	0
3	14	28	6	0
4	8	17	7	0
5	19	56	8	0
6	24	88	30	10
7	33	91	35	12
8	38	91	30	24
9	36	76	29	24
10	52	88	21	33
11	69	99	20	31
12	79	142	23	45
13	83	122	20	53
14	88	128	19	51

Thus, cattle appear to spread Texas persimmon readily. They reduce germination markedly, but enough seeds remain viable to infest the area, particularly when large numbers of the fruit are eaten. Apparently cattle like the fruit. Unfortunately, calves get the scours after eating large numbers of fruit.

Spanish Goat

In February 1969, one Spanish goat was fed 100 washed seed in feed, and another was force-fed 10 intact, mature fruit (about 50 seed). Feces were collected daily for 5 days. The experiment was repeated. No seed were recovered from either source of seeds in either run. Consequently, goats do not appear to be important for spreading Texas persimmon.

Rambouillet Sheep

In February 1969 and April 1972, a Rambouillet ewe was fed 200 washed seed in a grain mixture. Feces were collected daily for 5 days. Each experiment was repeated each year. Only two seed were recovered in each year. These may have been dropped on the concrete floor from the feed tray and mixed with the feces without actually being ingested. Therefore, sheep do not seem to be an important source of spreading Texas persimmon, because first, they do not eat the fruit freely when herbaceous vegetation is available, and second, they masticate and digest the seed.

Whitetail Deer

In February 1969 and 1970, a whitetail deer was fed 100 washed seed in the feed, and another was fed 10 intact, mature fruit (about 50 seed). The penned deer eagerly ate the fruit from hand feeding. The feces were collected for 5 days. The experiments were repeated. No intact seeds were recovered in either year. Only seed fragments ever were found. Consequently, whitetail deer are not an important means of spreading Texas persimmon, even though they eat the fruit in large numbers.

Raccoon

On September 15, 1972, raccoon feces contining large numbers of Texas persimmon seed were collected at Marble Falls. The seed were washed from the feces; 25 were subsequently planted in each of four plastic pots containing the soil mixture. On November 29, 1972, 12 percent of the seed had germinated, in comparison to 64 percent of the seed washed from the fruit before planting. Consequently, raccoons could be an important means of spreading Texas persimmon even though they reduce germination of the seeds markedly during digestion.

Summary of the Feeding Experiments

These experiments indicate that cattle readily pass about half the number of seed eaten, but markedly reduce the viability of most that do pass. However, because of passing large numbers of seed, they could readily spread Texas persimmon. Raccoons readily pass the seed, leaving about 12 percent viable for germination. The Spanish goat, Rambouillet sheep and whitetail deer destroy all or almost all of the seeds consumed. Hamilton (4) reported that nine-banded armadillos *(Dasypus novemcinctus* var. *texanus* L.) readily ate Texas persimmon fruit near San Antonio, Texas, but he did not check the resulting seed for germination.

Seedling Morphology

Seedling Growth Rate

An experiment was conducted in the greenhouse to determine the growth rate of Texas persimmon. Nylon screen packets containing 100 seed treated with thiram were buried in damp peatmoss in a refrigerator at 41° F. Initially and at weekly intervals, a packet of seed was removed. Twenty seed were then planted in each of five plastic pots filled with the soil mixture. The experiment was initiated October 2, 1968. Percent seedling emergence and average seedling height were recorded 14 weeks later.

At 14 weeks, 88 percent of the seed had germinated (Table 5). The first seed germinated in about 2 weeks. The number generally increased progressively during the remainder of the 14-week period. Apparently these seed with endosperm require a longer period to germinate than seed of honey mesquite (9) and other species that have food reserves stored in their cotyledons. No reason was found for the characteristic variation in germination time for the Texas persimmon seed.

Figure 9A shows a series of typical seedlings 2, 3, 4, 5, 6, 8, 10, 12 and 14 weeks old. Upon germination, a black taproot emerges and elongates continuously during the 14-week period. In fact, appreciable taproot elongation occurs before the epicotyl begins elongation. Generally the taproot reaches the bottom of the pot before much lateral root growth occurs. Subsequently, in the pot, the major emphasis on root growth is on lateral root production.

The hypocotyl emerges from the seed coat about the third week. The hypocotyl straightens out the fifth or sixth week, pulling the cotyledons covered with the empty seed coat from the soil. The hypocotyl ceases elongation at 19 to 35 millimeters. Most

Table 6. Texas persimmon seedling growth at three temperatures over a 121-day period[1]

Measurement	Temperature	Date sampled in 1968 and 1969			
		Dec 17	Jan 20	Mar 4	Apr 17
	(° F)				
Plant fresh weight (g)	95		0.83 a	1.42 b	1.58 b
	80	0.42[2]	1.10 b	2.02 c	3.54 c
	65		.84 a	.73 a	.76 a
Stem length (cm)	95		6.6 b	9.8 b	13.5 b
	80	3.9[2]	5.4 ab	12.4 c	15.4 c
	65		4.4 a	4.4 a	5.8 a
Root length (cm)	95		36 a	37 a	38 a
	80	30[2]	43 a	47 b	70 b
	65		37 a	39 a	35 a

[1]Values in the same column for each measurement followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[2]Plants sampled at the beginning of the experiment.

cotyledons abscise from the stem the fourth through the sixth week.

The epicotyl was green and began elongating about the sixth week; it attained a mean length of 51 millimeters by the 14th week. The new stem produced 4, 5, 8 and 16 leaves at 8, 10, 12 and 14 weeks, respectively. The first four to seven leaves above the cotyledons became progressively larger. Subsequently leaves were the same size.

Growth of Texas persimmon seedlings is erratic in the greenhouse. Stems continue to elongate, but at various rates. Most greenhouse plants 1 year old were 18 to 24 inches tall (Figure 9B). The stems are gray. Some plants become long and spindly, whereas others are shorter and branched. Older leaves abscise periodically, and new ones are subsequently produced. The new leaves are light green and gradually turn darker.

Temperature Effects on Growth Rate

An experiment was conducted using growth chambers to determine the influence of temperature on seedling growth. On December 17, 1968, 15 plastic pots filled with the soil mixture, each with five Texas persimmon seedlings with stems 2 to 3 inches tall, were placed in growth chambers set at 65°, 80° and 95° F, respectively, with 12-hour light and dark periods. Five pots of plants were used initially, and five pots of plants were taken from each growth chamber on January 20, March 4 and April 17, 1969. The seedlings were washed free from the soil, and the surface was allowed to air-dry. Stem and root lengths and seedling fresh weights were measured.

Texas persimmon seedlings grew best at 80° F and poorest at 65° F (Table 6). Plant fresh weight increased from 0.42 grams on December 17 to 0.76, 3.54 and 1.58 grams at 65°, 80° and 95° F, respectively, on April 17. Thus, the plant weight at 80° F was more than twice that of plants held at 95° F, and more than four times greater than that of plants held at 65° F.

Stem length was slightly longer for seedlings held at 80° F than for those held at 95° F; this represented an increase in stem elongation of about four times between December 17, 1968, and April 17, 1969, 121 days later. Stems of seedlings held at 65° F elongated no more than about 2 centimeters in the same period. Roots on seedlings held at 80° F were almost twice as long as those held at the higher and lower temperatures.

Seedling Surface

Typical views of a 13-week-old seedling are shown in Figure 10. Figure 10A shows the stem with its epidermis and numerous unicellular trichomes. The stem has very slight vertical ridges. A leaf branches to the right. Figure 10B shows the cotyledonary node area. The first true leaf is present. The cotyledons have since abscised, exposing one of the lateral buds. The leaves are arranged in an alternate pattern on the stem. Figure 10C shows the root midsection with its very slight vertical ridges. Figure 10D shows the root tip.

Seedling Anatomy

Figure 11 shows a series of transections from a 6-week-old seedling with a hypocotyl and root, a total of 70 millimeters long. The hypocotyl (Figure 11A) contains many starch granules in the cortical and pith parenchyma. The secondary phloem and xylem almost form a complete cylinder on either side of a well-defined cambium. Figure 11B shows a root transection 40 to 50 millimeters from the root tip. The tissues are similar, but less developed than those in the hypocotyl. In the transection taken 20 to 30 millimeters from the root tip (Figure 11C), the cambium forms a complete ring, and the xylem appears as eight groups of three or more vessels. In the section 3 to 10 millimeters from the root tip (Figure 11D), very little secondary tissue occurs. A well-defined pith is present. Few, if any, starch granules occur in the parenchyma of either the cortex or pith at this stage.

Figure 12 shows transections through a 13-week-old Texas persimmon seedling. Figure 12A shows a transection through the third internode. A periderm comprised of the phellem and phellogen has formed in the outer cortex. Bundles of lignified fibers lie just outside the phloem. The secondary xylem is well developed, being about 20 cells deep and lignified. The pith parenchyma have thick walls. The hypocotyl structure (Figure 12B) is similar to that of the third internode, except that the periderm is more developed.

The root section 10 to 20 millimeters below the hypocotyl (Figure 12C) has well-defined secondary phloem and xylem, but the outer tissues still are comprised of an epidermis and cortical parenchyma. A pith is present, and the parenchyma cells are filled with starch granules. The section 30 to 40 millimeters below the hypocotyl (Figure 12D) has an epidermis

and is about 10 xylem cells deep. The section 60 to 70 millimeters from the hypocotyl (Figure 12E) has barely a complete ring of secondary phloem and xylem. A pith is still present, and the constituent parenchyma cells contain starch granules. Pith varies in the root; however, it usually disappears 150 to 200 millimeters below the hypocotyl.

Figure 13 shows longitudinal radial views of a 13-week-old seedling stem at or near the growing point. Figure 13A is the growing point showing the apical meristem, several leaf primordia and two lateral bud primordia. Figures 13B and 13C show progressively more developed lateral bud primordia and leaf petioles. Figure 13D is a radial section of the stem about 2 millimeters from the growing point. Three entire or sections of trichome are present on the epidermis, which is one cell thick. The cortex is about six cells deep. At this stage of development, the pith and cortical parenchyma are almost cubical. Figure 13E is a longitudinal section of the hypocotyl. The periderm is being formed by cell division in the phellogen, and the cortex and epidermis are beginning to collapse. The pith cells are elongated. Figure 13F is a radial section of the root 2 millimeters above the tip. The epidermal, cortical and pith cells are elongated. The cortex and pith cells contain some starch granules. Figure 13G is a 2-week-old seedling root tip with a typical root cap. The cells elongate progressively behind the apical meristem.

An 8-month-old Texas persimmon stem had much more secondary tissue than the 13-week-old seedling. Figure 14 shows the third stem internode transection. The outer protective layer is a periderm of phellem cells produced by a phellogen in the outer cortex. The phloem and cambium are prominent because the stem was actively making radial growth when sampled. The xylem has two growth rings; the outer one is small, indicating a short period of radial growth and a larger inner growth ring.

Figure 14B is a xylem transection. The rays are one cell wide, with scattered vessels. The xylem parenchyma and pith parenchyma (Figure 14C) contain abundant numbers of starch granules. The pith cells have fully lignified cell walls.

Further development of mature Texas persimmon plants in the field is discussed in subsequent sections.

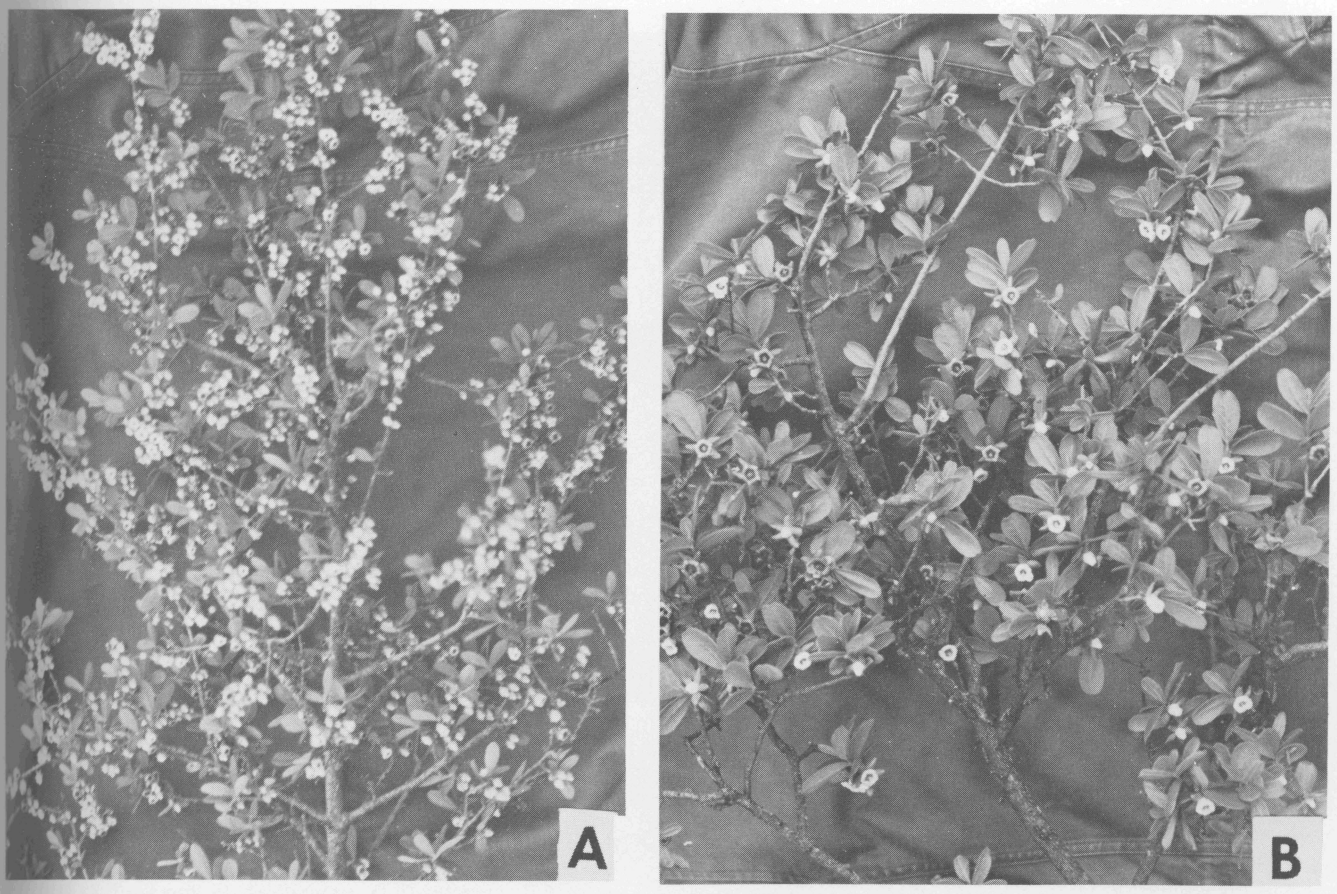


Figure 2. Branches of flowering Texas persimmon plants at Georgetown, Texas, March 24, 1972. A. Male flowers. B. Female flowers.

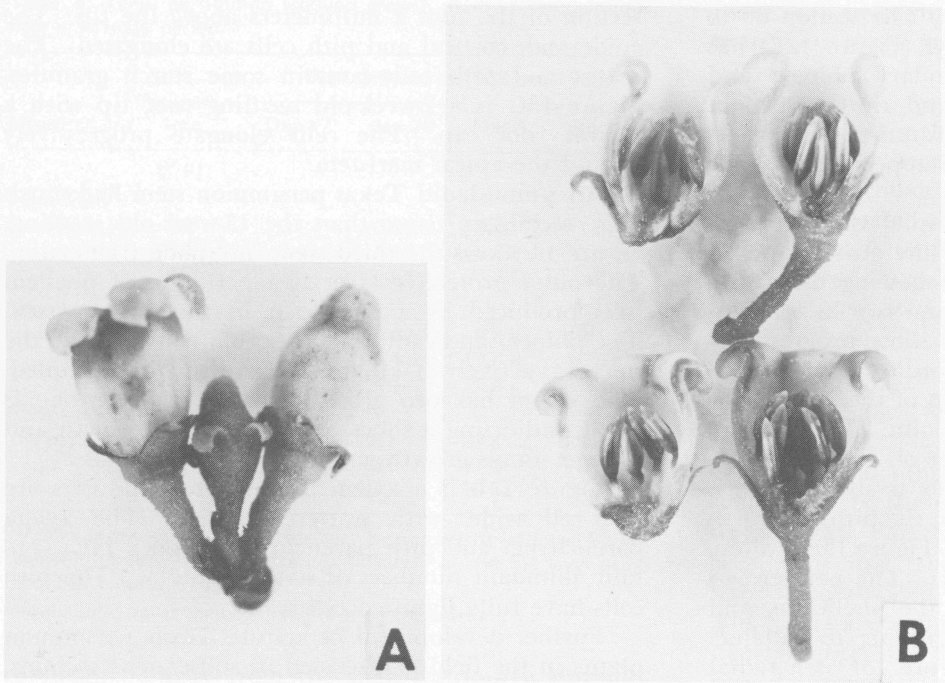
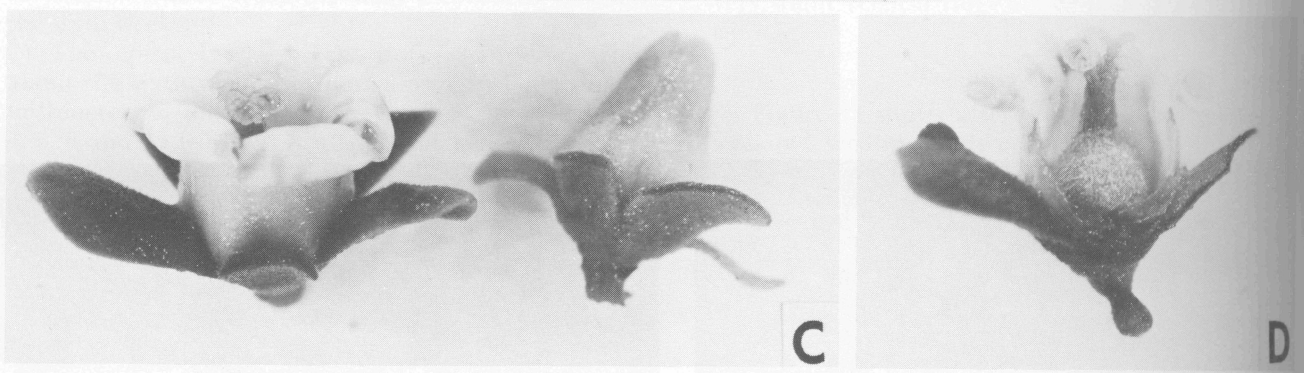


Figure 3. Flowers of Texas persimmon at Georgetown, Texas, April 15, 1971 (All 6.3X). A. Intact male. B. Male with side cut away. C. Intact female. D. Female with side cut away.



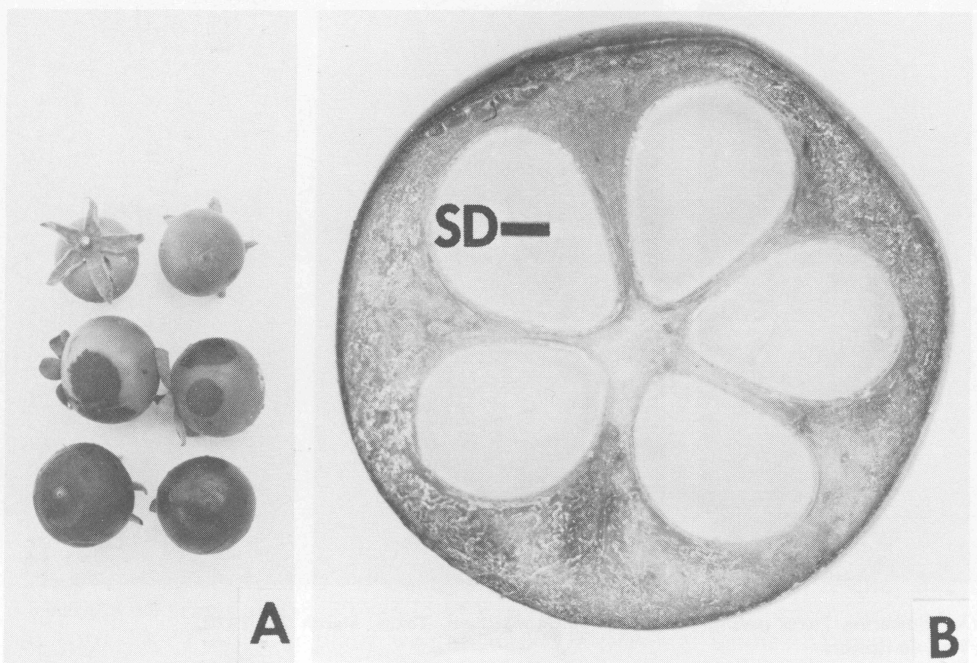


Figure 4. Fruit of Texas persimmon. A. Intact immature at top and middle and mature at bottom (0.5X). B. Transection of a mature fruit (3X).

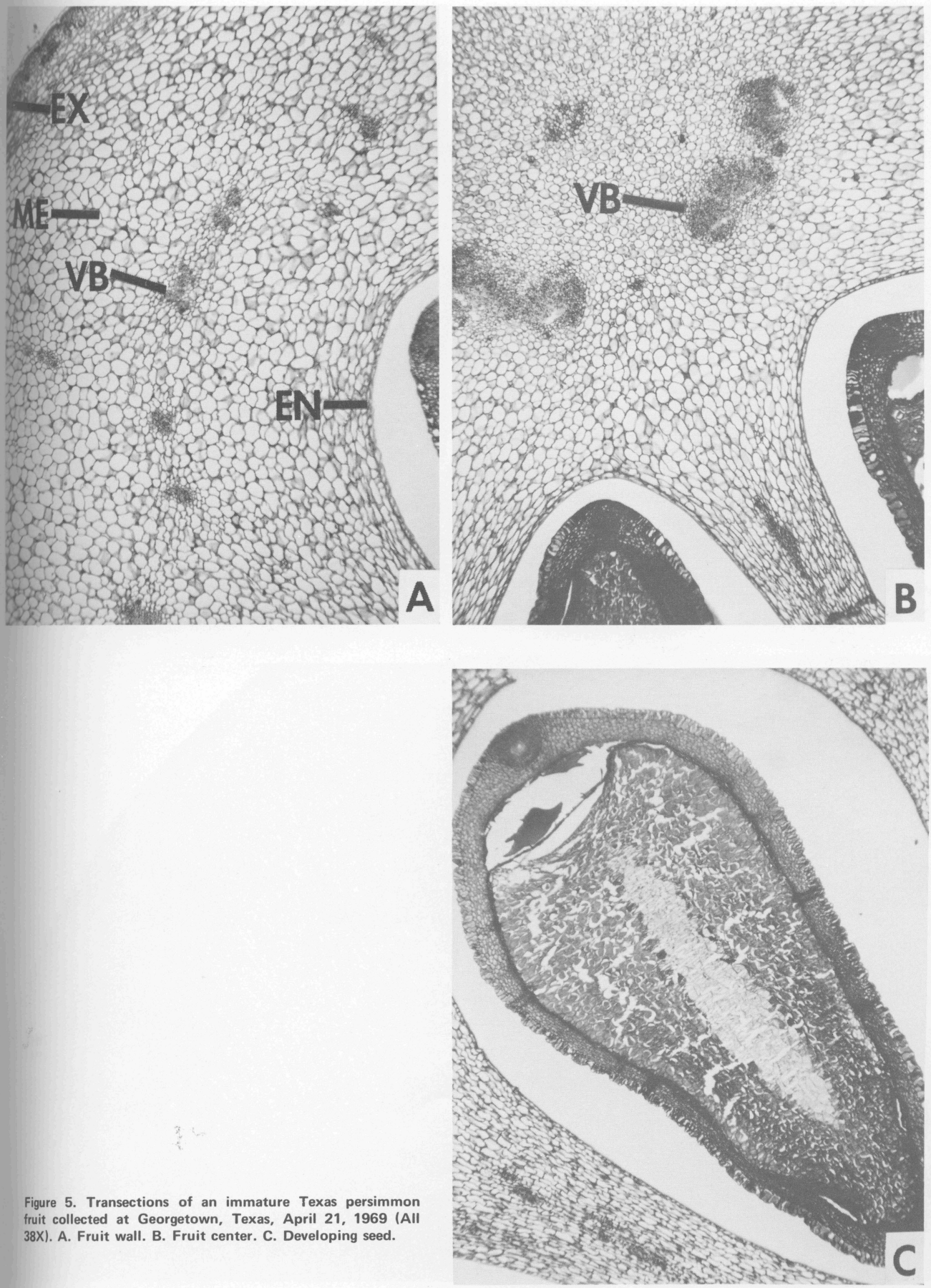


Figure 5. Transections of an immature Texas persimmon fruit collected at Georgetown, Texas, April 21, 1969 (All 38X). A. Fruit wall. B. Fruit center. C. Developing seed.

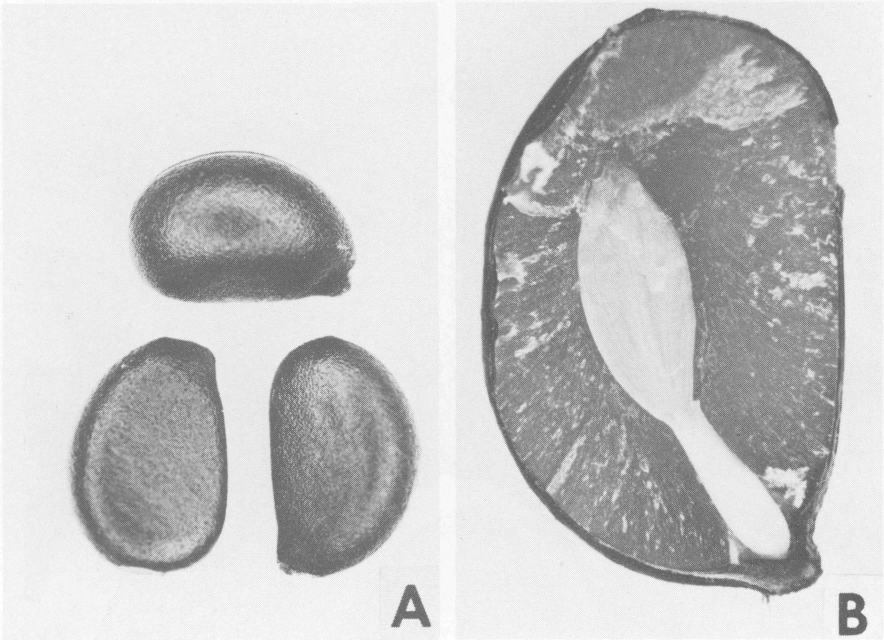
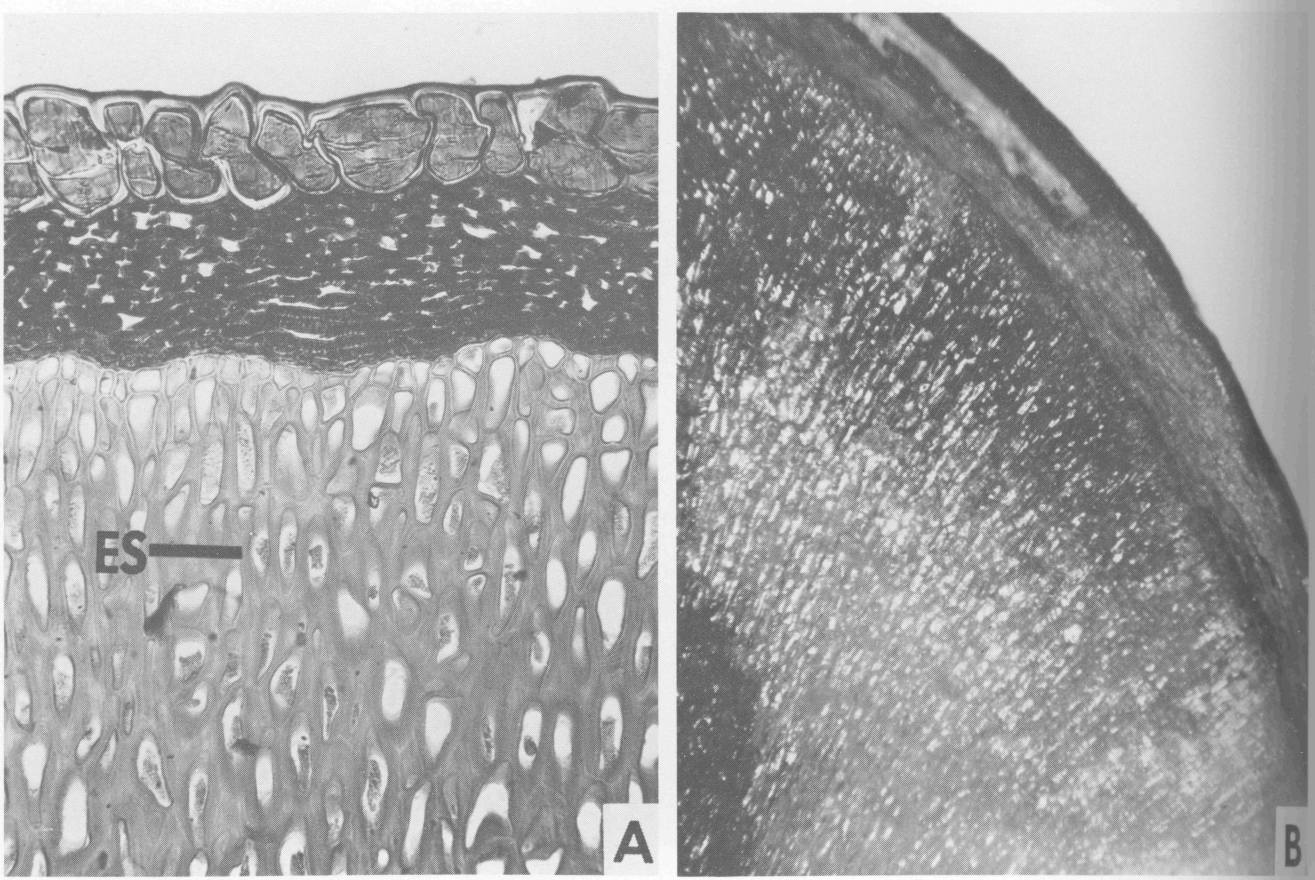
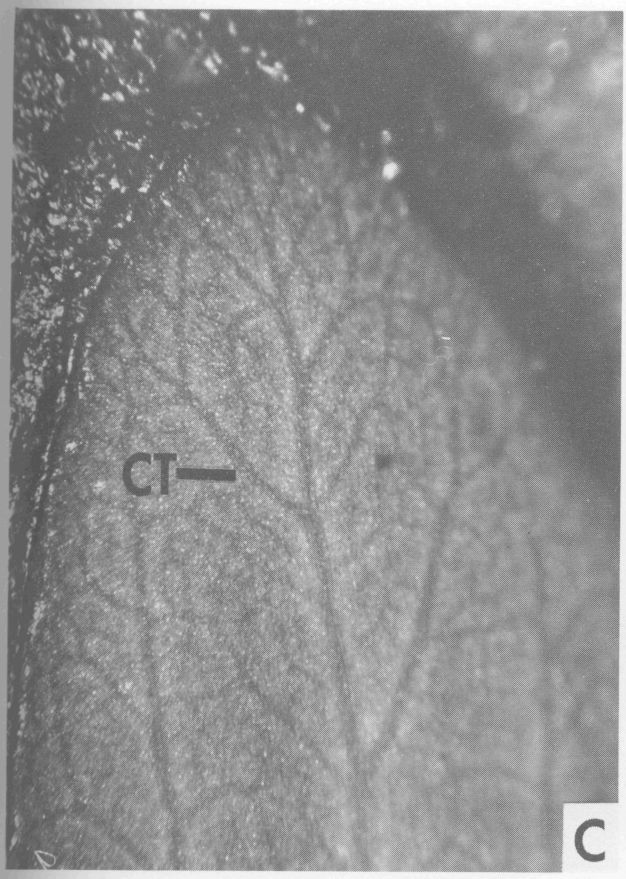


Figure 6. Seeds of Texas persimmon. A. Intact (2.8X). B. Split open (7.3X).





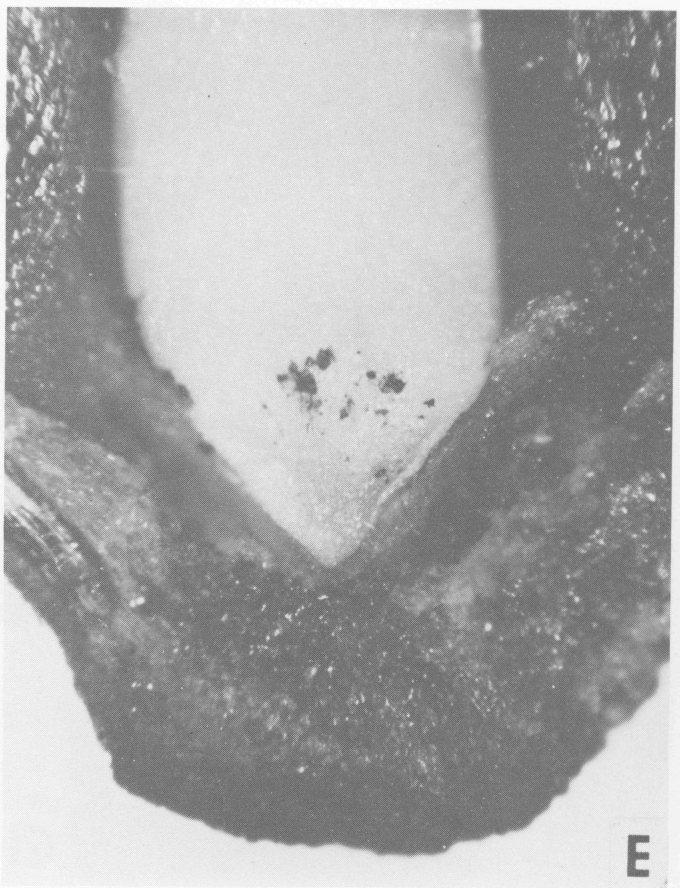
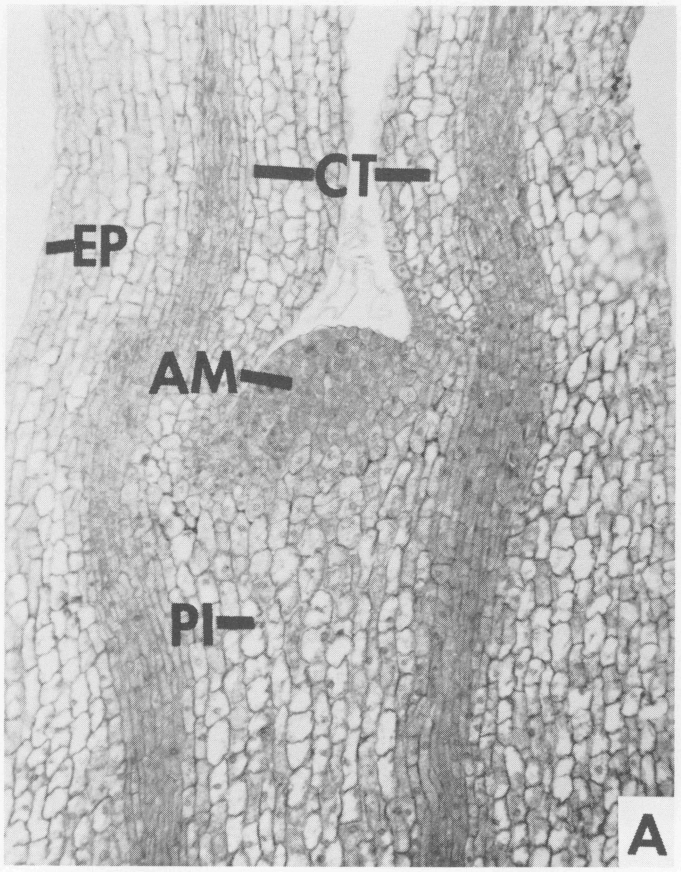
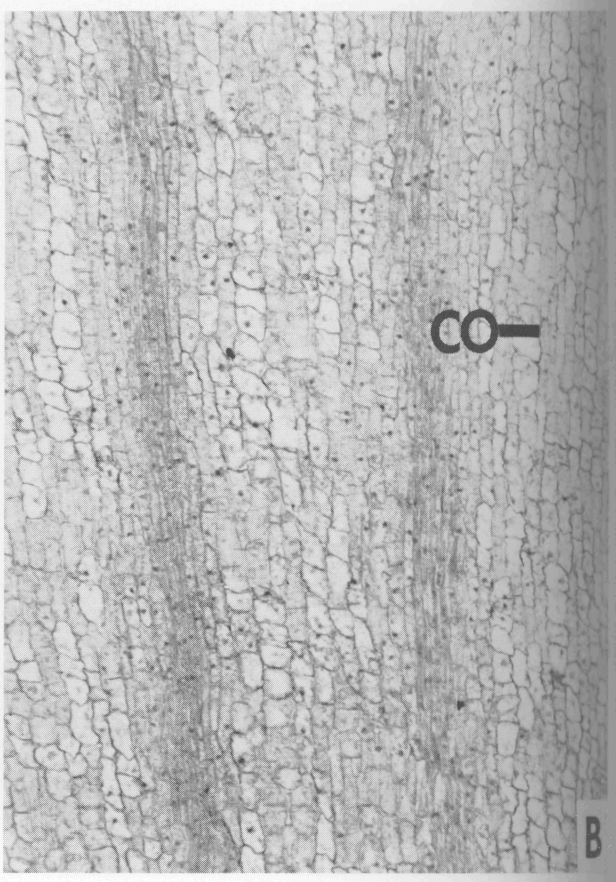


Figure 7. Seed of Texas persimmon. A. Histological section of the seed coat and endosperm (192X). B. Seed coat and overall endosperm (40X). C. Cotyledon tip of the embryo (40X). D. Cotyledon base and upper root of the embryo (40X). E. Root tip of the embryo and seed coat (40X).





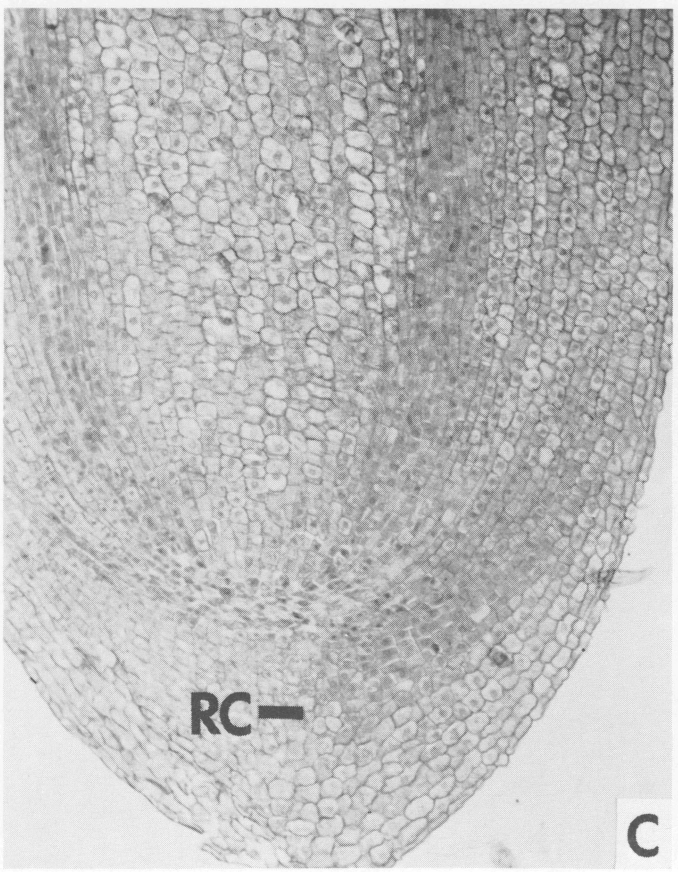


Figure 8. Longitudinal anatomy of the Texas persimmon seed embryo (All 170X). A. Apical meristem and bases of cotyledons. B. Middle of the root. C. Root tip.

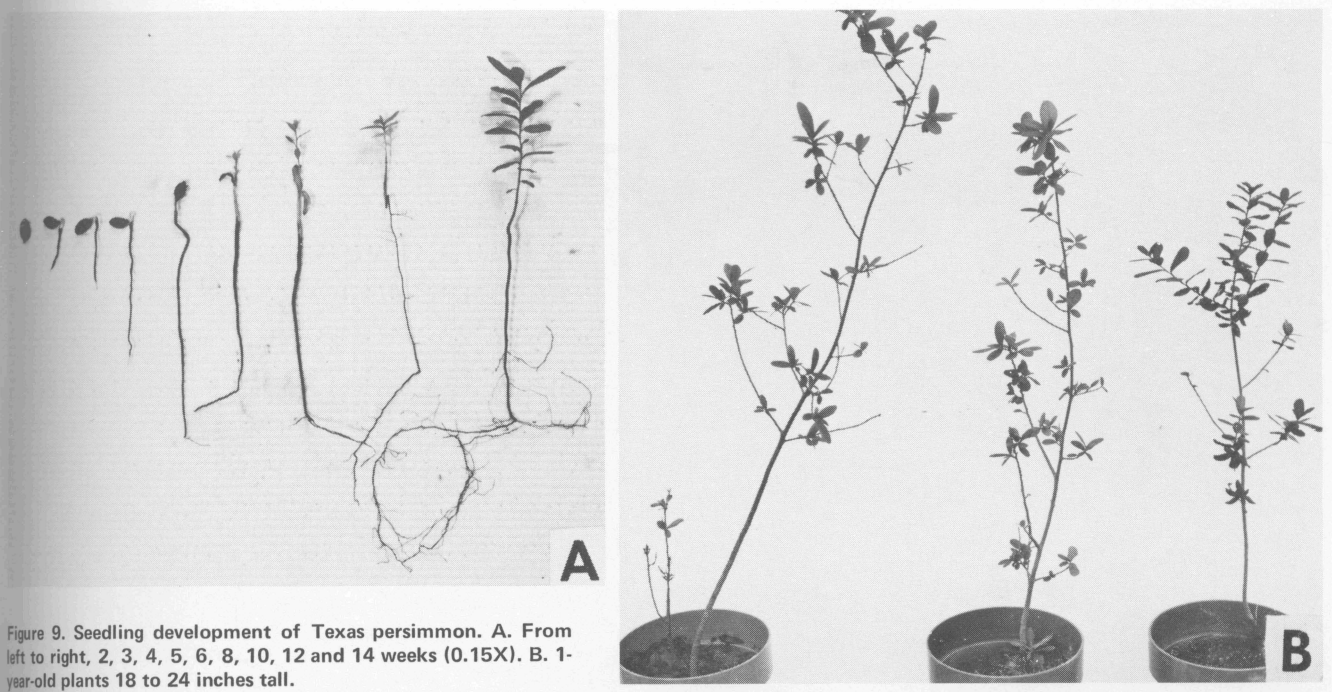
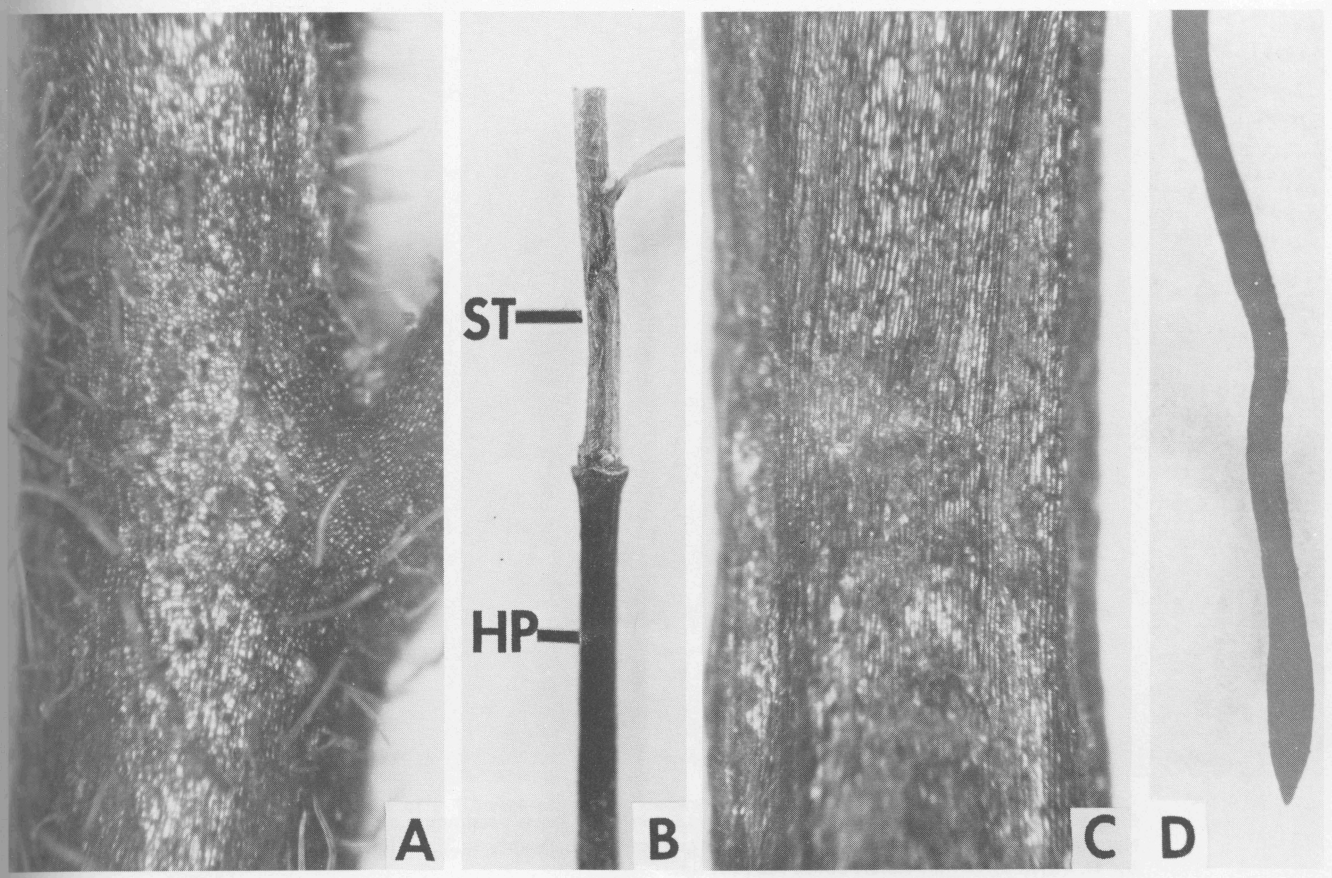


Figure 9. Seedling development of Texas persimmon. A. From left to right, 2, 3, 4, 5, 6, 8, 10, 12 and 14 weeks (0.15X). B. 1-year-old plants 18 to 24 inches tall.

Figure 10. Surface views of a 13-week-old Texas persimmon seedling. A. Stem (50X). B. Cotyledonary node (4X). C. Mid root (50X). D. Root tip (6X).



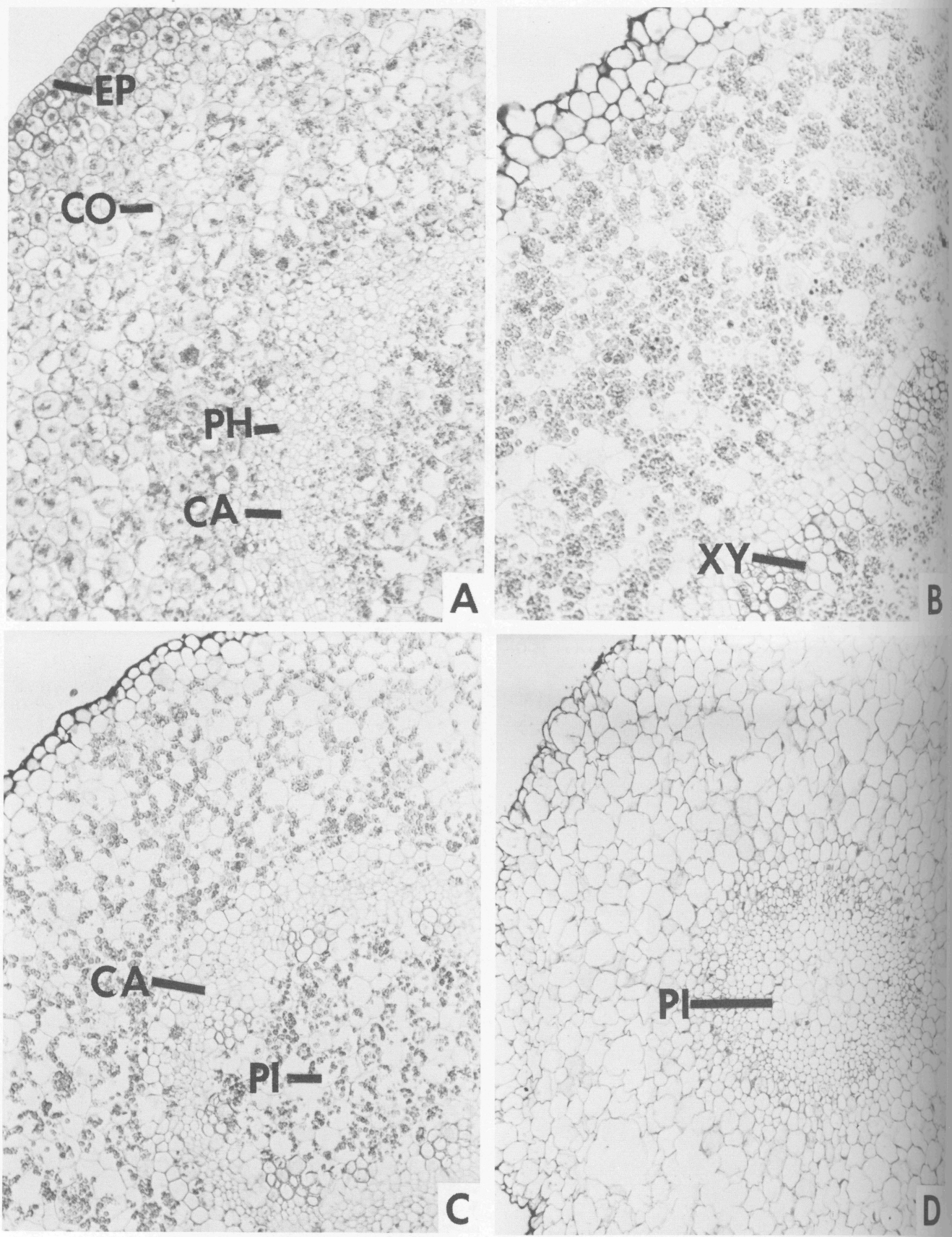


Figure 11. Transections of a 70-millimeter-long 6-week-old Texas persimmon seedling (All 170X). A. Hypocotyl. B. Forty to 50 millimeters above the root tip. C. Twenty to 30 millimeters above the root tip. D. Three to 10 millimeters above the root tip.

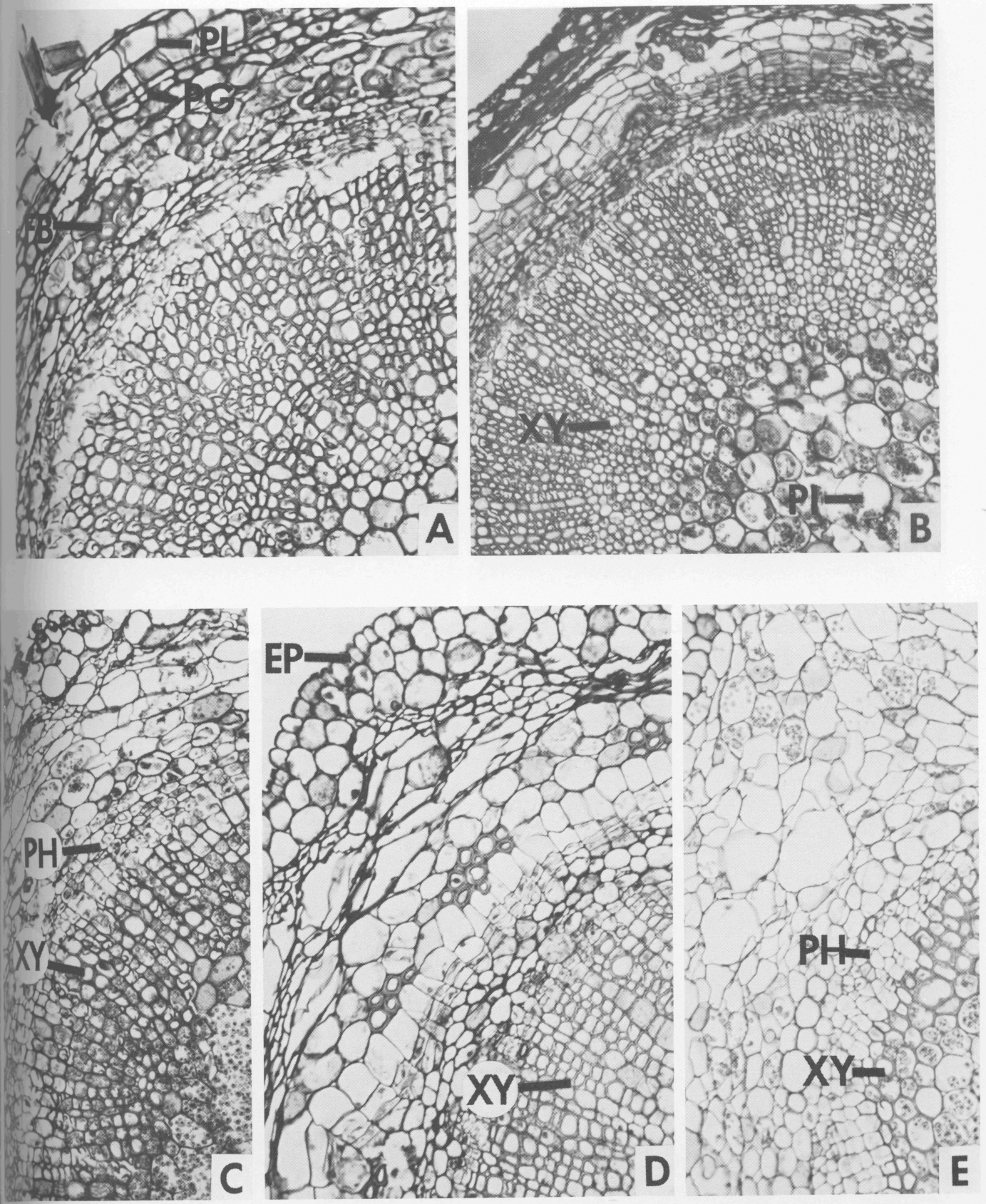
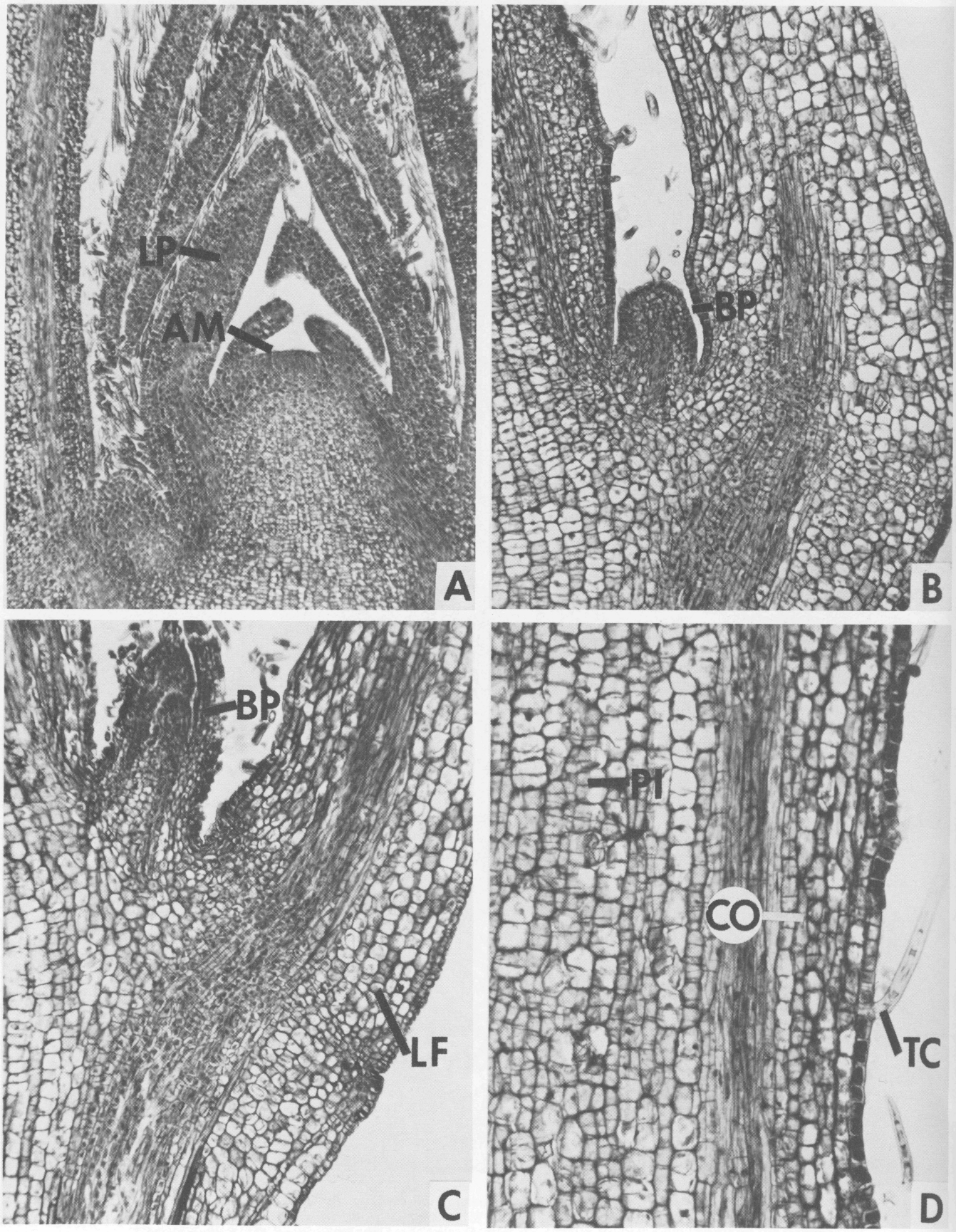


Figure 12. Transections of a 13-week-old Texas persimmon seedling. A. Third internode above the cotyledons (322X). B. Hypocotyl (195X). C. Ten to 20 millimeters below the hypocotyl (195X). D. Thirty to 40 millimeters below the hypocotyl (288X). E. Sixty to 70 millimeters below the hypocotyl (288X).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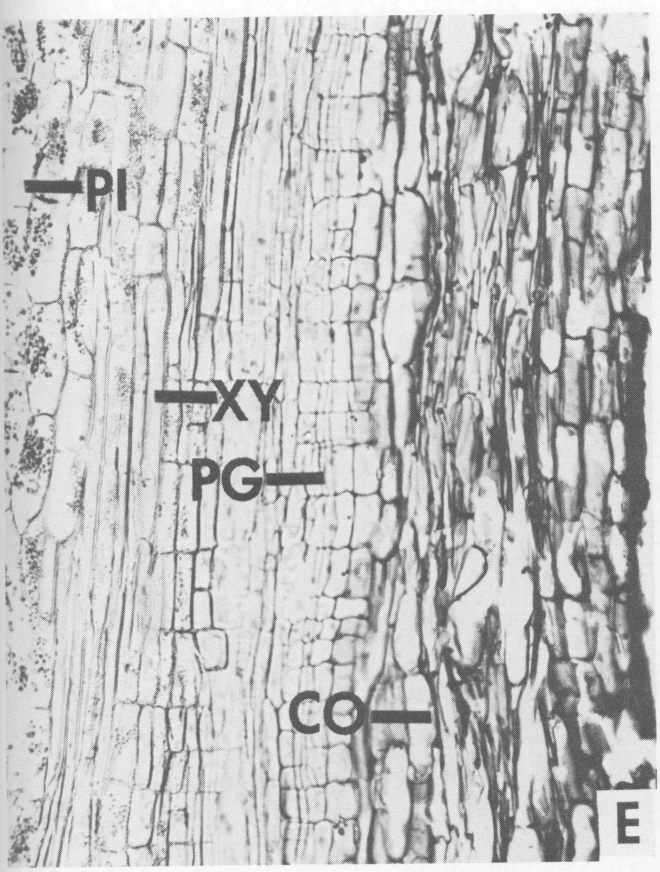
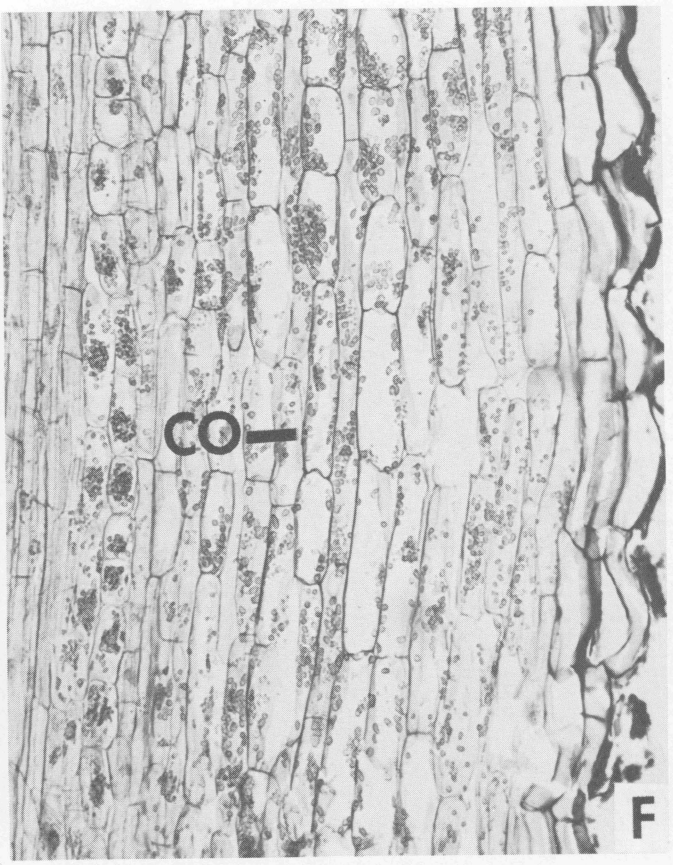




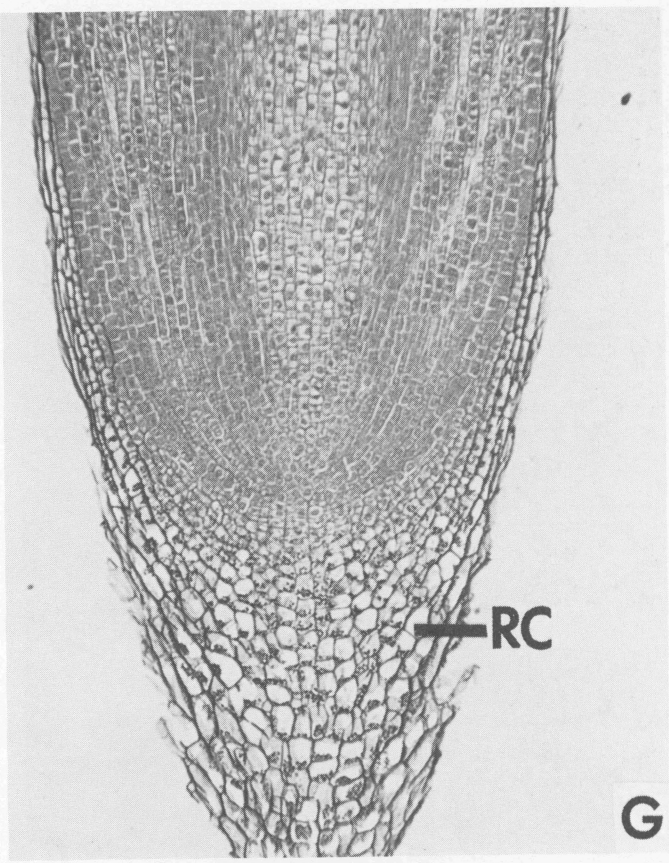
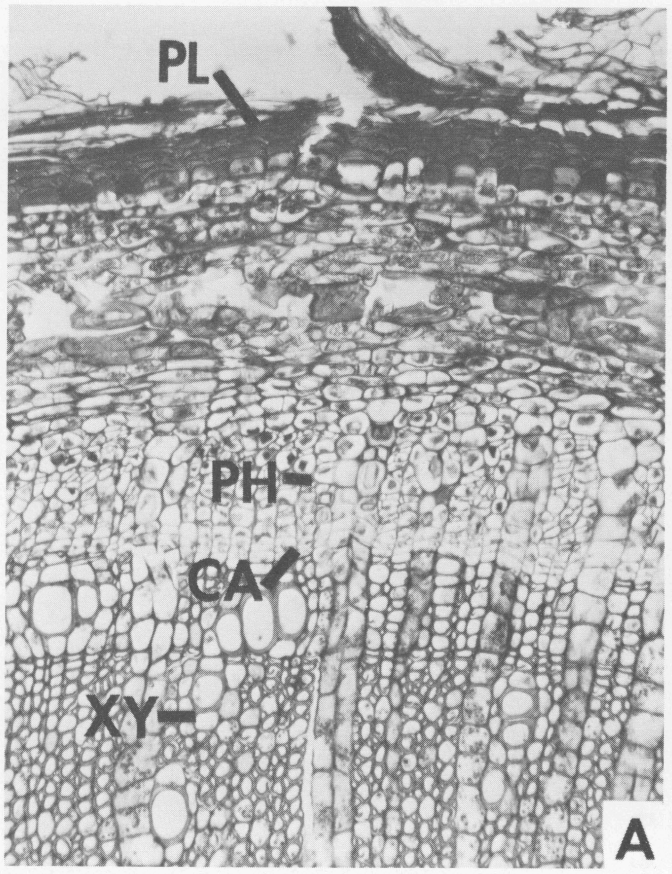
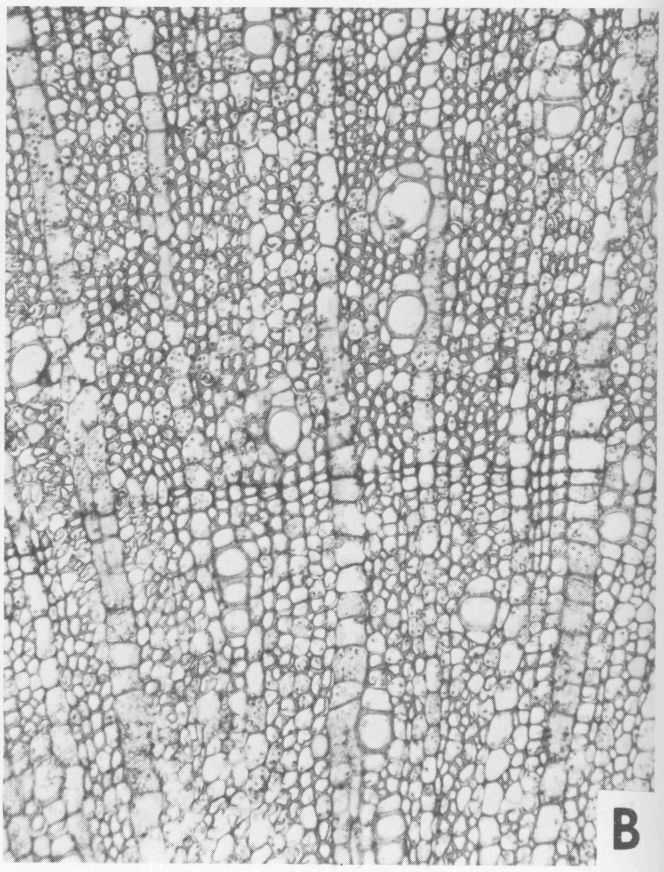


Figure 13. Longitudinal sections of Texas persimmon seedlings (A through F are from a 13-week-old seedling). A. Apical meristem (112X). B. Leaf and lateral bud 1 millimeter below the apical meristem (165X). C. Leaf and lateral bud 6 millimeters below the apical meristem (121X). D. Stem 2 millimeters below the apical meristem (242X). E. Hypocotyl (170X). F. Root 2 millimeters above the tip (190X). G. Root tip from 2-week-old seedling (116X).





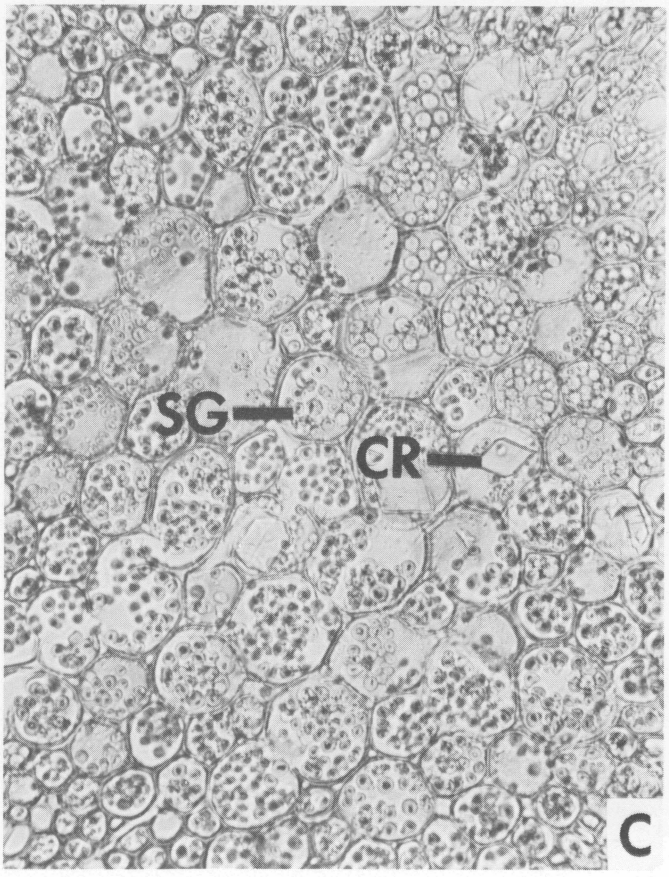


Figure 14. Stem transections 40 to 50 millimeters above the cotyledonary node of an 8-month-old Texas persimmon plant grown in the greenhouse. A. Periderm, phloem, cambium and outer xylem (170X). B. Inner xylem (170X). C. Pith (330X).

MORPHOLOGY OF THE STEM

Types and Sizes of Plants

Texas persimmon occurs both as individual plants and as mottes. Seldom, however, does Texas persimmon occur either as the most abundant or the height-dominant species, except where other woody plants have been removed previously. The largest persimmon plant reported in Texas has a height of 26 feet, with a crown diameter of 31 feet; it is located on a ranch owned by Sam Barkley near Uavlde (Figure 15A).[4] Other plants are taller, but not as large in diameter.

Various kinds of Texas persimmon plants are shown in Figure 15. Figure 15B shows a single-stem plant about 9 feet tall near Georgetown. This type of plant is a small proportion of most populations. More typical multistemmed plants are shown in Figure 15C—most have three to six stems and generally grow 8 to 12 feet tall. Figure 15D shows a particularly large multistemmed plant about 18 feet tall near Llano. Figure 15E shows a motte of male Texas persimmon plants at Georgetown. All plants in this motte are males, with the same particular leaf and stem characteristics. The large plant in the center of the photograph may have been the original plant.

In the field, nearly all Texas persimmon plants are multistemmed by the time they are 2 feet tall. On most plants, the main stem of the seedling has been either broken or chewed off by animals. The main stem of larger plants is generally killed either by fire or by mechanical and chemical control methods. These plants become multistemmed from the release of several buds at the base of the stem or occasionally on the roots.

New Stem Development

The new stems begin elongation growth from apical buds, primarily in March and April at Georgetown. Also, a few new stems are produced after periods of abundant rainfall in late summer and fall of some years. At Georgetown in 1971, new stems were initiated and elongated between March 15 and May 21. Twenty-five each of new male and female branches were tagged at the onset of elongation growth. There was no significant difference between sexes in length of shoots produced. The stem averaged 2.5, 4.3, 4.8 and 5.0 centimeters in length on April 1, April 15, May 5 and May 21, respectively. No further elongation growth occurred in 1971.

Figure 16A shows the new stem tip in July after elongation growth had ceased. The leaves are dark green, and the lateral buds are prominent. Figure 16B shows a typical new stem, this one from a greenhouse plant. These stems are green and generally have abundant numbers of unicellular trichomes on leaves, buds and stems. The youngest and oldest leaves are smaller than those in the middle. In May or June the periderm forms, giving the new stems a gray color. Also, frequently one to three short, lateral branches are produced on the new stems, such as those shown on some new stems August 30, 1972 (Figures 16C and 16D).

Older Stem Development

The overall structure of male and female branches, other than new growth in August 1970 at Georgetown, is shown in Figure 17. The male branch in Figure 17A has many dried flower stalk remnants, but no flowers. Many small branches are only 1 to 3 centimeters long. The leaves often are arranged in whorls from alternate buds on telescoped, short branches.

The female branch (Figure 17B) also has many lateral twigs. As on the male plants, the leaves often appear in whorls on the alternate buds of the telescoped new twigs. The fruit occur primarily at the basal end of the twigs produced during the current season.

Figure 18 shows typical Texas persimmon stem tissue in August 1970. In Figure 18A the new stem has already produced a gray periderm. The 0.6 centimeter-diameter, or 1-year-old stem, has a complete layer of slightly furrowed, gray periderm; this stem is further enlarged in Figure 18B. Stems 2 or more centimeters in diameter generally have patchy periderm as shown in Figures 18A and 18C. The furrowed periderm gradually peels off, leaving a relatively smooth surface. The larger stems 6 or more centimeters in diameter generally have only smooth periderm.

To document the diameter, length and branching of Texas persimmon, the researcher recorded the data from 10 branches on each of ten 5- and 10-foot tall plants. Half the plants were male and half female. Stem diameter was measured at the midpoint of the branch. The length was measured from the base of the stem either to the growing point or to the origin of the next branch. The total number of branches or remnants of branches, including the one leading to the next younger stem, was counted. Because the stem length was progressively more difficult to determine toward the base of the plant, a definite change in stem angle was considered as the criterion for branching. On the 5-foot-tall plants, the number of living branches was recorded, as well as the total number of branches.

The sexes did not differ in branching. Consequently, the data were combined (Table 7). The youngest stems were 0.2 to 0.3 centimeters in diameter for plants of both sizes. The stem diameter generally increased progessively from the tip to the base of the plant. At the plant base, the stem diameter was 5.9 and 11.2 centimeters for the 5- and 10-foot tall trees, respectively. The youngest stem was unbranched and 4.9 to 5.8 centimeters long. The older branches were 9.6 to 17.6 centimeters and 13.3 to 24.6 centimeters long on the 5- and 10-foot-tall plants, respectively.

[4]List of champion trees in Texas. 1971. Texas Forest Service, College Station, Texas 77843.

Branching, except for the youngest increment, occurred more on the younger branches than near the base of the plant. Presumably some of the older branches had died and broken off, and many stubs were subsequently buried by radial branch enlargement.

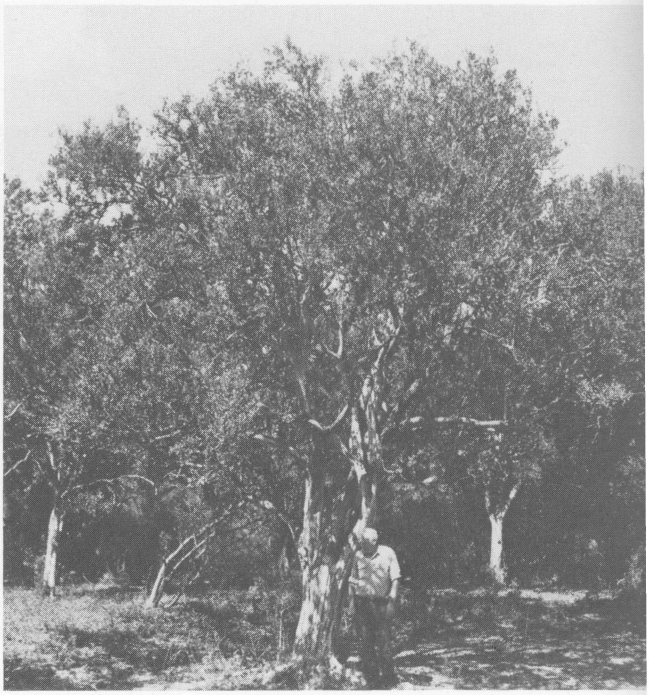


Table 7. Texas persimmon stem diameter, length and number of lateral branches on 5- and 10-foot-tall trees at Georgetown, Texas

Stem (increment numbered from tip)	Stem diameter	Stem length	Branches on stem	
			Total	Living[1]
	(cm)	(cm)	(Number)	(Number)
	5-foot trees			
1	0.2	4.9	0.0	0.0
2	0.4	11.9	6.0	5.6
3	0.6	13.2	7.7	7.6
4	0.8	14.6	8.6	7.9
5	1.0	12.5	7.9	6.7
6	1.2	16.6	9.6	8.3
7	1.5	16.3	8.6	7.7
8	1.7	14.8	7.8	5.5
9	2.0	17.6	7.5	5.3
10	2.4	16.0	6.6	4.0
11	2.9	16.1	6.2	4.0
12	3.4	13.9	6.2	3.0
13	3.3	13.8	5.6	3.3
14	4.3	13.9	3.5	2.0
15	4.7	9.6	4.6	3.8
16	5.5	12.0	3.0	2.0
17	5.9	15.5	4.0	2.0
	10-foot trees			
1	0.3	5.8	0.0	
2	0.4	17.5	8.6	
3	0.6	13.3	6.9	
4	0.9	13.3	7.2	
5	1.6	15.7	7.3	
6	1.5	14.6	6.3	
7	1.7	18.9	6.0	
8	2.1	17.9	5.9	
9	2.4	16.6	6.0	
10	2.6	16.8	5.1	
11	3.0	19.0	4.9	
12	3.4	20.0	3.9	
13	3.6	19.3	4.5	
14	4.6	21.4	4.1	
15	4.2	22.8	4.5	
16	5.5	22.2	3.1	
17	6.5	18.2	3.4	
18	7.8	24.6	4.2	
19	5.3	18.7	4.3	
20	6.4	21.3	3.7	
21	7.1	23.5	3.3	
22	10.4	23.4	4.0	
23	10.7	18.4	3.4	
24	11.5	22.5	3.2	
25	11.2	23.5	3.5	

[1]Number of living branches was not recorded for 10-foot tall trees.

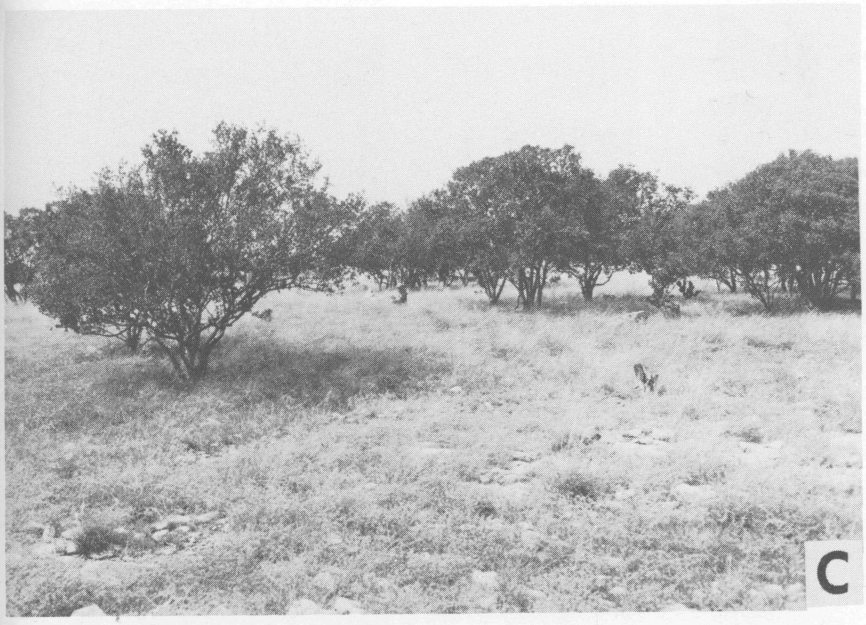
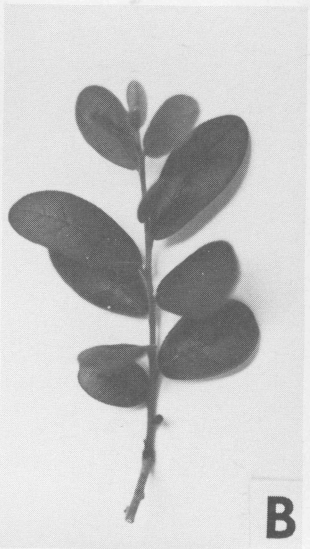


Figure 15. Texas persimmon plant forms. A. Largest recorded plant in Texas, near Uvalde, 26 feet tall, September 1972. B. Single-stem plant, Georgetown, Texas, April 1971. C. Typical multistemmed plant infestation, Georgetown, August 1972. D. Large multistemmed plant, Llano, Texas, July 1970. E. Motte formation, Georgetown, August 1972.



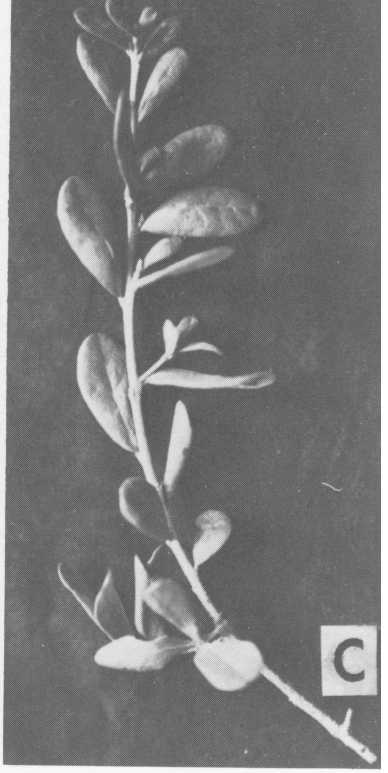


Figure 16. New stem development of Texas persimmon. A. Stem tip, Georgetown, Texas, July 1971 (2X). B. Overall stem from a greenhouse plant (0.5X). C. Stem showing short-shoot branching, Georgetown, August 1972 (0.8X). D. Four stems showing profuse lateral branching, Georgetown, August 1972 (0.3X).

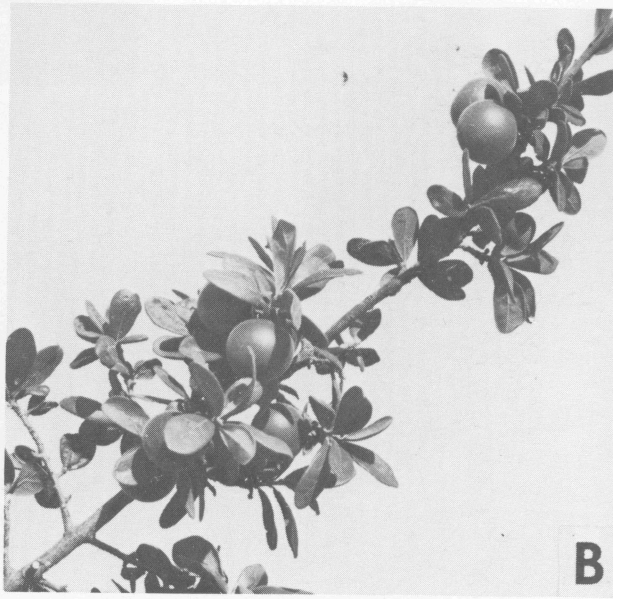


Figure 17. Branches of Texas persimmon, August 1970. A. Male branch. B. Female branch with fruit.

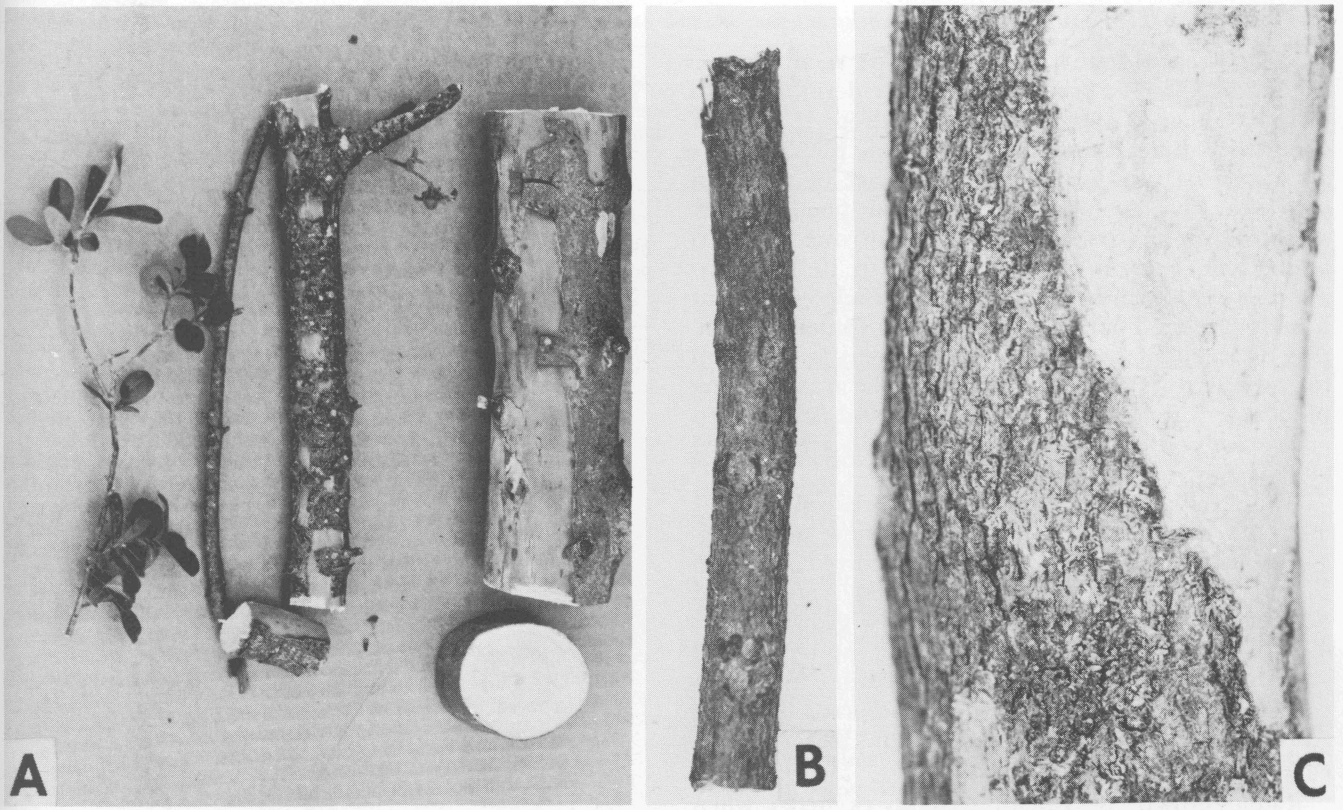


Figure 18. Stems of Texas persimmon, August 1970. A. New stem to 40-millimeter-diameter stem. B. A 6-millimeter-diameter stem (1.7X). C. A 20-millimeter-diameter stem (2.8X).

ANATOMY OF THE STEM

New Stem Transections

New stems are initiated in March and April and elongate until about mid-May at Georgetown. Radial enlargement commences soon after production and generally extends until late June. Average daily temperatures between 65° and 75° F and abundant soil moisture seem to favor new stem production and radial enlargement.

At first the new stems are green. At this stage, such as on April 7, 1970 (Figure 19A), the epidermis is one cell deep and has numerous trichomes. The cortex is about 10 parenchyma cells deep, and the cells are almost spherical. The secondary phloem, cambium and xylem have formed a cylinder. The phloem is about six cells deep. The xylem vessel elements occur in small radial rows among the thin-walled xylem parenchyma. The pith parenchyma have thin walls and are devoid of visible stored food materials.

By May 26 (Figure 19B) a phellogen has formed in the outer cortex and has begun producing phellem cells to the outside, thus commencing periderm formation. The cortical parenchyma are now slightly flattened, presumably from the pressure of growth of the phloem and xylem below and the periderm above. A tier of fibers and sclereids has matured between the inner cortex and the phloem. The xylem cells now have thick walls, and radial growth seems to have stopped. The enlarged xylem vessels are beginning to form in radial files, which is typical for the mature stem. The pith parenchyma have developed thick walls (Figure 19C).

By May 26 the stem has begun storing food material as starch granules in the xylem and pith parenchyma. Radial enlargement ceases by July 8. On October 12, the pith parenchyma are full of starch granules.

One-Year-Old Stem Transections

The 1-year-old stem is the youngest stem producing a new radial growth ring. The periderm is brown to gray and is 2 to 6 phellem cells deep; it forms a continuous tier around the stem. New phellem tiers appear to be produced near the surface of the stem each year for several years. The old phellem tiers shred off, giving the stem a slightly furrowed appearance. The cortex is present and is 6 to 10 parenchyma cells deep. Underneath is a tier of sclereids about 3 cells deep. The non-translocating phloem, comprised largely of parenchyma cells, seems to build up for several years and remain alive. The translocating phloem is 6 to 8 sieve elements deep and is produced anew each year. The xylem and pith cells are lignified and contain many starch granules.

Most radial stem growth occurs between April 1 and May 15, about the same time as new stem elongation. In 1969, radial growth occurred between March 24 and June 6. Stems sampled April 8 and May 20, 1969, were enlarging, with new growth layers 4 to 14 new xylem cells deep. In 1970, no new radial growth of 1-year-old stems was observed in the samples collected. In 1971 radial growth occurred between April 1 and 15. On April 15, new stems had a growth ring about 15 new xylem cells deep.

Radial growth of 1-year-old stems occurred when the average air temperature was 65° to 73° F in 1969 and 1971. Radial enlargement probably is limited earlier in the year by low temperature and later by limited soil moisture. However, radial stem growth was not well correlated with rainfall that occurred at Georgetown during the 2-week and 2-month periods before measurement. Apparently radial growth is limited in late spring by a number of factors, rather than by soil moisture only.

Older Stem Transections

The older stems have a gray periderm (Figure 18). The outermost four to eight cells deep are phellem cells, which stain red with safranin (Figure 20A). Underneath is a tier of parenchyma, 6 to 10 cells deep, that stain green with fast green. These are presumably phelloderm cells, which arise to the inside of the phellogen. A tier of sclereids 3 to 5 cells deep then develops; these cells seem to be part of the innermost phelloderm. The phloem consists of non-translocating and translocating portions. The non-translocating portion of the phloem consists largely of parenchyma with scattered small groups of sclereids. The translocating phloem consists largely of sieve tubes, companion cells and parenchyma. The translocating phloem comprises from about one-third to two-thirds of the total phloem thickness. The cambial zone is usually three cells deep.

The xylem (Figure 20B) contains lignified fibers, parenchyma and vessel elements. The characteristics of the xylem are summarized in Table 8. The xylem is either semi-diffuse-porous to diffuse-porous with the vessels, either solitary or in small groups, arranged in radial files, with about 40 per square millimeter. The early wood vessels are generally only slightly larger and more numerous than the late wood vessels. The perforations are simple (open). The longitudinal parenchyma are vasicentric paratracheal, apotracheal-banded and marginal. The wood rays are simple and generally unstoried; they are homogenous and generally two-seriated in stems 2 years old or more.

The pith parenchyma are lignified. They generally contain abundant numbers of starch granules and rhomboidal crystals until the stem is at least 2 centimeters in diameter. Phenolic-type materials become more abundant as the stem grows larger.

In most ways, wood anatomy of Texas persimmon is similar to that of common persimmon. The main

Table 8. Classification of stem wood (xylem) structure according to Commercial Timbers of the United States (3)

I. Topography of wood – Semi-diffuse-porous to diffuse-porous

II. Vessels
- A. Arrangement of pores in summer wood – solitary or in radial rows of 2 to 5 with about 40 per mm^2
- B. Size – 54±8 μ wide (tangentially) by 50±6 μ thick (radially)[1] by 253±32 μ long; walls 3.3 μ thick
- C. Spiral thickenings – absent
- D. Shape and arrangement of intervessel pits – round, minute, in transverse rows
- E. Nature of perforations – simple
- F. Inclusions
  1. Tyloses – absent
  2. Gum – present

III. Tracheids – None found

IV. Longitudinal parenchyma
- A. Arrangement – vasicentric paratracheal, 1- to 2-seriate; apotracheal-banded parenchyma very abundant, 1- to 2-seriate; marginal parenchyma 1- to 2-seriate
- B. Number of cells in wood parenchyma strands – mostly 4, although 5 were occasionally observed
- C. Fusiform parenchyma cells are present
- D. Inclusions – rhomboidal crystals

V. Fibers
- A. Type – libriform fibers 13.6±4 μ in diameter by 711±95 μ long
- B. Thickness of walls – 3.9±0.6 μ

VI. Wood rays
- A. Number per mm tangentially – 16.4±1.3 μ
- B. Kind – simple
- C. Arrangement – unstoried
- D. Seriation – mostly 2-seriated, some 1-seriated, very few 3-seriated
- E. Composition – homogeneous
- F. Size[2]
  1. Average width – 24±7 μ
  2. Average height – 221±73 μ

[1]Measured as individual pores. Single pores were slightly thicker than wide, whereas vessels in groups were usually wider than thick.

[2]Makes up about 22% of the wood volume.

Table 9. Texas persimmon stem transectional dimensions from samples collected near Georgetown, Texas

Stem diameter	Phellem thickness	Phelloderm thickness	Sclereid thickness	Phloem		Cambium thickness	Xylem ring thickness		
				Non-translocating thickness	Translocating thickness		New	All other rings	Pith
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
8 to 15	0.041	0.102	0.071	0.186	0.208	0.019	0.21	0.49	0.90
16 to 30	.035	.083	.096	.236	.201	.023	.30	.61	.94
40	.030	.073	.102	.321	.236	.026	.36	.80	
80	.032	.077	.117	.370	.265	.028	.41	.80	
Mean	.035	.084	.096	.278	.228	.024	.32	.68	.92

difference, however, is that Texas persimmon xylem is not storied, whereas xylem rays, parenchyma and vessel elements of common persimmon are highly storied. Also, the vessel walls of Texas persimmon are thinner (about 3.3 microns thick) than those of common persimmon (about 7.5 microns thick).

Transectional tissue dimensions of four size classes of stems 8 to 15, 16 to 30, 40 and 80 millimeters in diameter are presented in Table 9. The periderm consists of the phellem, which is on the outside of the phellogen and the phelloderm parenchyma on the inside. The phellem and phellogen layers remain nearly constant in thickness. The sclereid tier, xylem growth rings, non-translocating part of the phloem and translocating part of the phloem increase generally with increasing stem size. Pith, being a primary tissue, is nearly constant in diameter in all sizes of stems.

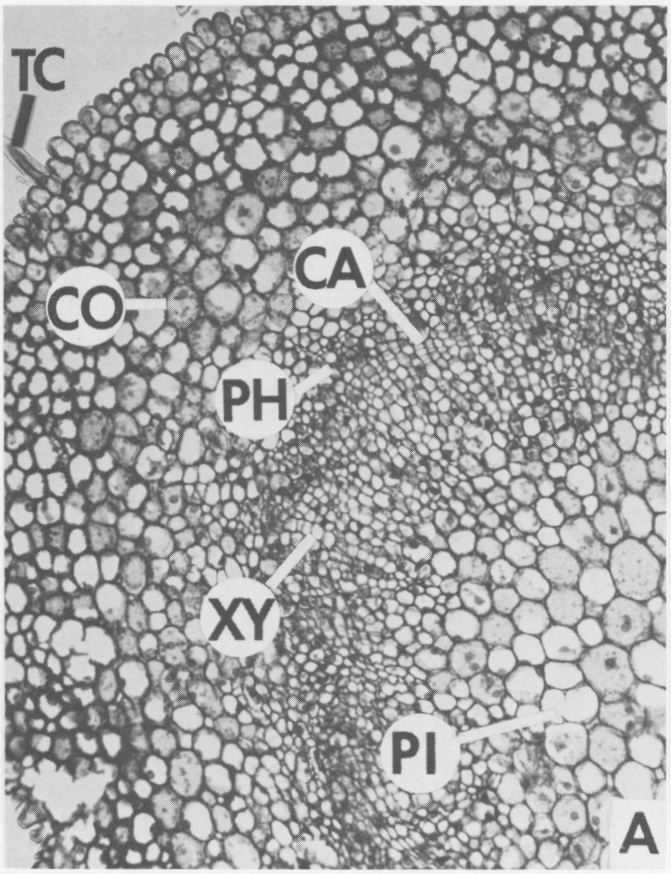
The periods of radial stem growth seem quite variable. Stems 1 centimeter in diameter were enlarging radially May 11, June 8 and June 23 in 1970 and on April 15, 1971; no radial enlargement was occurring in the samples collected in 1969. In stems 2 to 8 centimeters in diameter, radial enlargement occurred on May 20, June 6, July 8, August 9 and September 23, 1969: In 1970, new growth was occurring June 7 and 23; no samples were collected in 1971. Thus, radial growth in larger stems occurs in May through September in at least some years. This growth occurs later than in stems 1 year old.

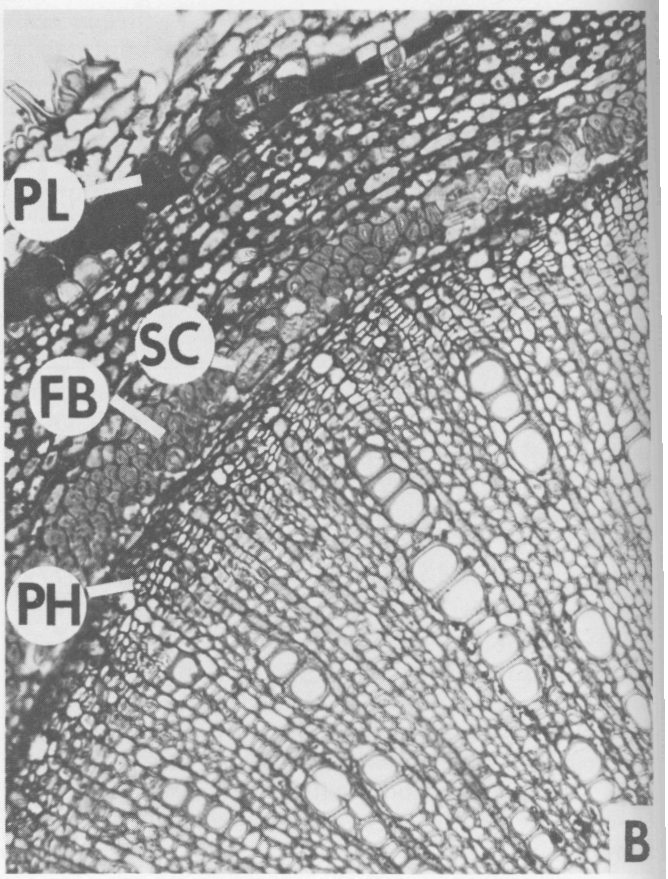
Figure 20 shows a series of transections of stems 2 to 8 centimeters in diameter, showing the seasonal cycle of radial growth. Figure 20A shows the stem on March 13, 1969, before growth occurred. Figure 20C shows a stem June 6, 1969, with an active cambium producing new phloem and xylem. Figure 20D is a transection of a stem collected July 8, 1969, showing the simultaneous production of new phloem and xylem, as well as a new phellogen with phellem to the outside and phelloderm to the inside. After the stem is 1 to 2 centimeters in diameter, these phellogens arise deep in the phloem, cutting off large areas of old phloem and periderm. The new phellogens begin at the margins of the old phellogens. Figure 20E shows the mature new phloem layer and phellogen just before cleavage through the phellem. Usually the old phloem-periderm tier strips off the plant in July or later during dry weather. The stems appear smooth, once these phellogens form deep in the phloem and cause the thick layers to peel off (Figure 18C). It is different from common persimmon, which maintains a rough, blocky-type periderm throughout the life of the tree.

Tangential and Radial Stem Sections

Tangential views of the stem are presented in Figure 21. The phellem cells are more or less spherical (Figure 21A). Sieve-tube members, companion cells and a dense concentration of rays can be seen in the phloem in Figure 21B. The cambium has typical fusiform and ray initials (Figure 21C). The xylem has vessels, fibers and parenchyma (Figure 21D). All these cells are lignified. Several rhombic crystals are present.

Views of radial sections of a stem 2 centimeters in diameter, which was harvested October 19, 1972, are shown in Figure 22. Figure 22A is the xylem. A large proportion is composed of rays. Figure 22B shows the area from the outer xylem outward, including the periderm. The rays progress outward to the sclereid tier. The parenchyma inside the periderm occur in files; presumably they arise inward from the phellogen.





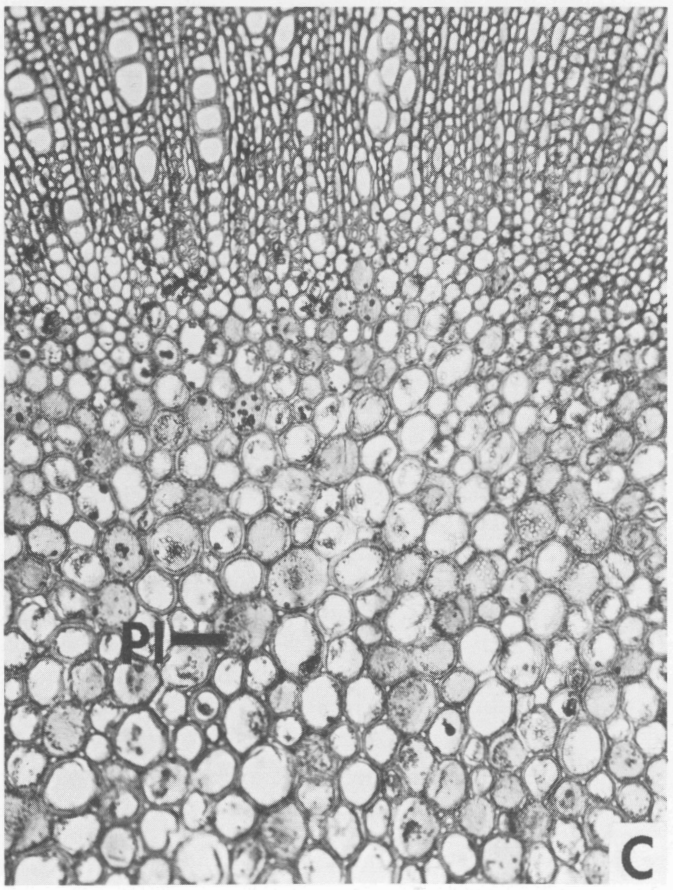


Figure 19. Transections of Texas persimmon new stems of various sizes from Georgetown, Texas (All 170X). A. Epidermis to pith, April 1970. B. Periderm to outer xylem. May 26, 1970. C. Pith and inner xylem, May 26, 1970.

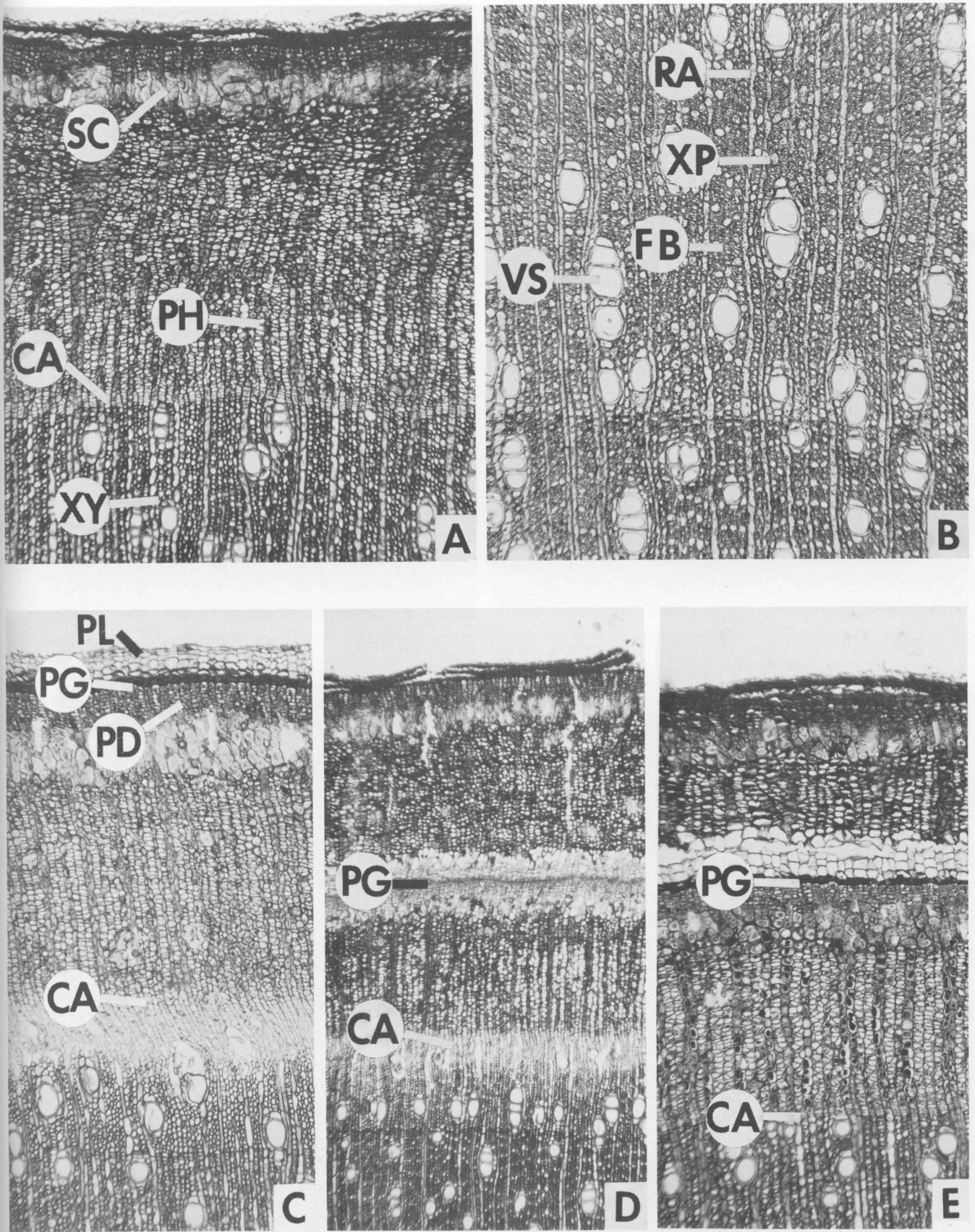


Figure 20. Transections of 2- to 8-centimeter-diameter Texas persimmon stems from Georgetown, Texas. A. March 13, 1969 (82X). B. Xylem, July 7, 1970 (85X). C. June 6, 1969 (80X). D. July 8, 1969 (39X). E. August 6, 1969 (82X).

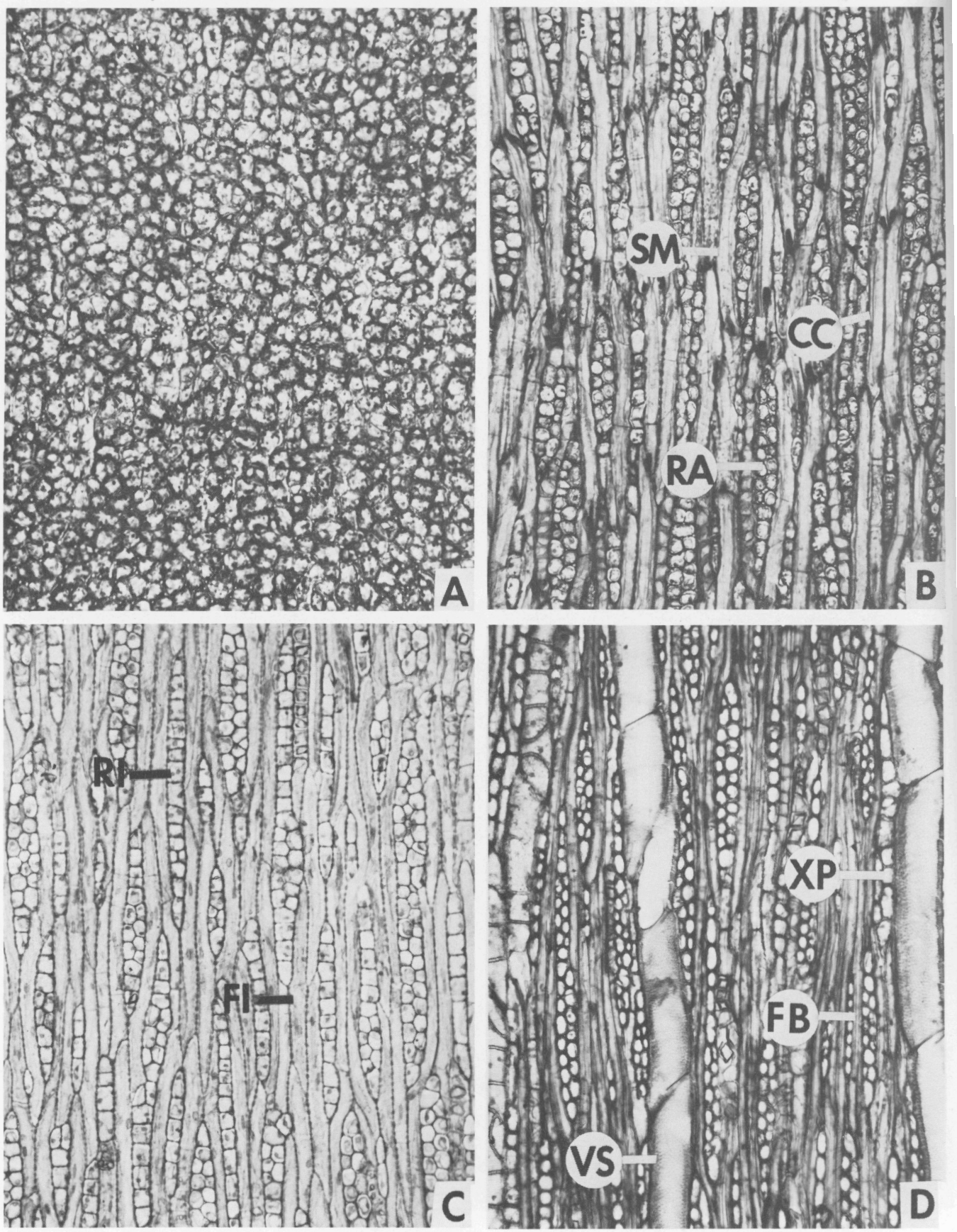


Figure 21. Tangential views of a 4-centimeter-diameter Texas persimmon stem collected at Georgetown, Texas, May 1971 (All 170X). A. Periderm. B. Phloem. C. Cambium. D. Xylem.

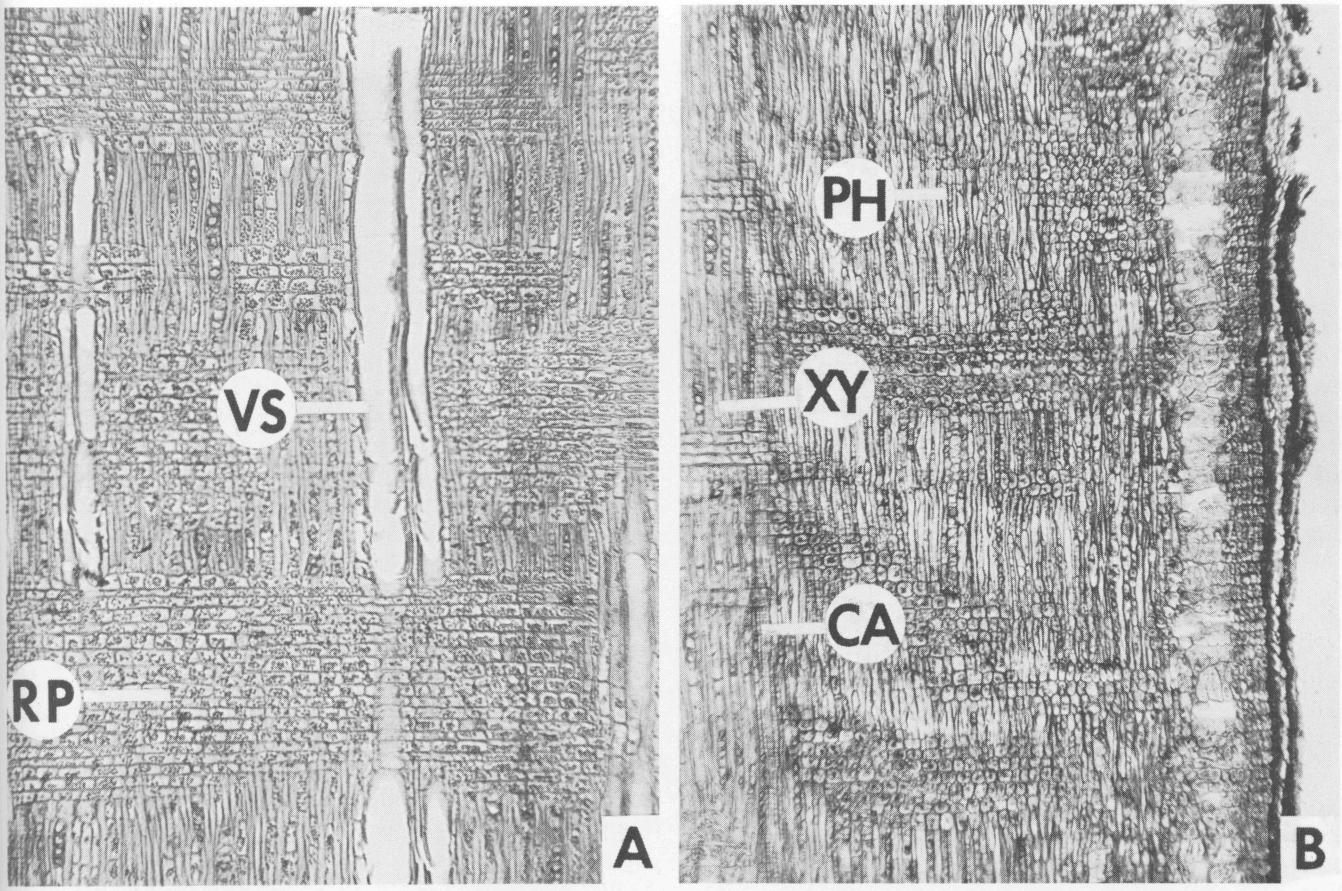


Figure 22. Radial views of a 2-centimeter-diameter Texas persimmon stem collected at Georgetown, Texas, October 19, 1972 (Both 82X). A. Xylem. B. Cambium, phloem and periderm.

BUDS

Stem Buds

The overall branching habit of the Texas persimmon plant was discussed in the sections on stem morphology and anatomy.

Romberger (12) defined a bud as "an unextended, partly developed shoot having at its summit the apical meristem which produced it. The latter is usually covered and protected by primordial leaves and by cataphylls (scales) initiated by the meristem at some earlier time. The subapical region of the meristem includes the internodes between primordial leaves and cataphylls and makes up the mass of the tissue in the central axis of the bud. Internodes in the subapical region are very short."

In Texas persimmon, as in other species, the growing apical bud produces the new stem, as represented by a greenhouse-grown plant stem (Figure 23A). This is not a true terminal bud; rather it is a lateral bud. Subsequent axillary or lateral buds are produced in the axil of the leaf at each node. The axillary buds at first are indistinct. By May 28 at Georgetown (Figure 23B), the new stem had fully elongated, and the axillary buds had become prominent. This stem and leaves were covered with trichomes. By October the apical bud had formed on stems at Georgetown (Figure 23C). The axillary buds seemed to be fully developed. In January the buds were prominent, and all the leaves had abscised (Figure 23D).

As the stem enlarges radially, the axillary buds subsequently become embedded in the periderm. The bud continues to produce a trace, as shown in a stem 30 millimeters in diameter (Figure 24A). The trace originates back at the pith. The bud does not seem to produce prominent primordial leaves. Rather, it appears to occur as a group of more or less undifferentiated cells (Figure 24B). The stem area at the bud is slightly raised.

Root Buds

Buds on roots are adventitious, in that they arise from potentially meristematic tissue, rather than from apical or axillary meristems. Presumably these buds arise from the phellogen, phloem or vascular cambium. Adventitious buds normally arise in two places. First, they arise along exposed edges of roots that have been cut off. Second, they arise from raised portions of roots at the point of emergence of smaller lateral roots. After the root has been cut off, these buds usually take 2 to 6 months to develop and begin producing new stems.

Sprouting Characteristics of Stems and Roots

Texas persimmon readily sprouts from both stems and roots in the field. At Georgetown, stem and root sections were collected periodically in 1969 and 1970. On July 15, 1971, one of these plants, which had been pruned in October 1970, was photographed (Figure 25A). About four new stems, each approximately 8 inches long, had been produced at each stub. Other pruned plants responded similarly.

In March 1969, 20 Texas persimmon plants, all about 9 feet tall, were cut off level with the soil surface at Georgetown. By August 27, 1970, they had sprouted profusely, primarily from the base of the stem. Two typical plants are shown in Figure 25B. As many as 20 new shoots were produced on the stem below the soil surface. Also, some short root sprouts had been produced by the plant at the left. The stems were as long as 15 inches. On August 30, 1972, the sprouts on most plants were 3 to 4 feet tall; however, one plant in the same area had stems 6 feet tall. There was no apparent reason for the difference in plant size. When cut off, Texas persimmon sprouts primarily in an incomplete apical-dominance pattern from the stem. However, plants readily sprout from the roots if all of the stem is removed or killed.

Texas persimmon plants sprouted from roots at Georgetown, Llano, San Marcos and Sonora — all places inspected. Sprouts grew from both vertical taproots and horizontal roots. On vertical or steep-angling roots, several new stems arise near the cut end (Figure 26A). However, on horizontal roots, sprouts may arise all along the root, as shown by some roots collected at Llano in May 1973, after the stems had been severed by bulldozing 6 months earlier (Figure 26B).

The sprouts are white, some with a black base. They produce unexpanded leaves until the apex emerges from the soil surface, as in Figure 26C. Subsequently, normal green leaves are produced (Figure 26D). In the field, sprouts were found on roots as small as 6 millimeters in diameter.

In the field, sprouting occurs naturally on many Texas persimmon plants. Apparently, plants that tend to sprout vigorously ultimately produce mottes, as shown in Figure 15E. Mottes are most evident in areas of shallow soil above rock. Several examples of sprouting in the field are shown in Figure 27. Figure 27A shows a root, found near Sonora, which was 1 inch in diameter and had two sprouts. The longest sprout was about 12 inches and was highly branched, presumably a result of grazing. Figure 27B shows a root obtained near Georgetown which was 1 inch in diameter and produced one large and two small stems. Figure 27C shows a plant at Georgetown, which was 7 feet tall and had produced a number of stems from horizontal roots. Figure 27D shows a number of new stems on the root of an uncut plant 26 feet tall, growing near Uvalde.

In the greenhouse, sprouts can be produced from root sections 4 inches long and about 0.75 inches or more in diameter, if they are brought in from the field and planted in flats containing a 1:1 mixture of Houston clay loam soil and sand. Figure 26C and 26D show such sprouts from roots collected at Georgetown on October 13 and December 28, 1972, respectively. The photographs were taken on April 13, 1973. Only about 5 to 10 percent of the root segments produced sprouts. Karr and Scifres[5] earlier found similar sprouting from root segments 4 inches long and about 1 inch in diameter collected from Kerrville, Texas, August 25, 1972. They planted the root segments about 1 inch deep in clay loam soil from Kerrville in plastic pots 5 inches in diameter. The pots were placed outside in a lath house at College Station. By November 16, some shoots as long as 8 inches had been produced. About 60 percent of these root segments produced stems.

All factors affecting sprouting are not clearly understood. In a greenhouse study, three groups of eight Texas persimmon plants 1.5 years old and about 24 inches tall were cut off, each at 4 inches above the soil surface, 1 inch above the soil surface and 1 inch below the soil surface on January 7, 1972. The plants cut off 1 and 4 inches above the soil surface sprouted about equally well, producing 4.2 shoots per plant, which averaged 10.4 centimeters in length by August 24, 1972 (Figure 28). No sprouting occurred on plants cut off 1 inch below the soil surface. This experiment was repeated with similar results. Perhaps lack of adequate reserve food supply in the roots prevented those greenhouse plants cut off below the soil surface from producing sprouts on the roots.

[5]R. Karr and C. J. Scifres. 1972. Unpublished information. Texas A&M Univ., College Station, TX 77843.

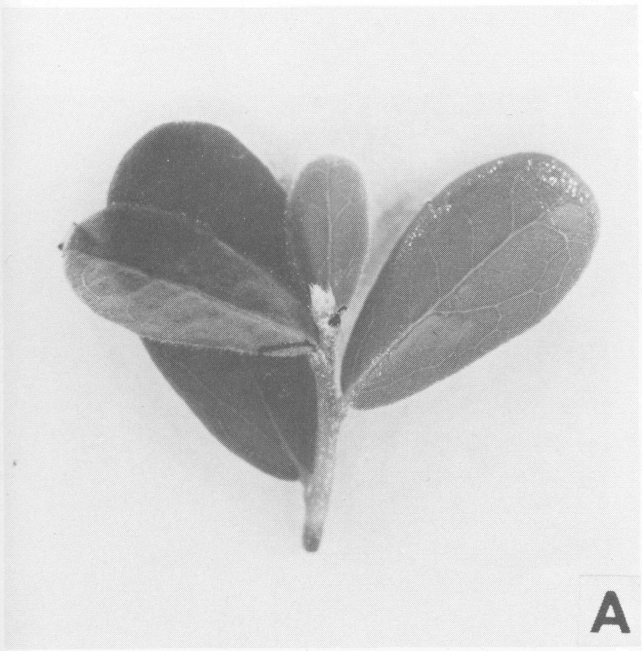


Figure 23. Terminal stems of Texas persimmon. A. An elongating greenhouse plant stem (3X). B. A stem from Georgetown, Texas, May 1971 (3X). C. A stem from Georgetown, October 1972 (7.3X). D. A stem from Llano, Texas, January 1972 (3X).

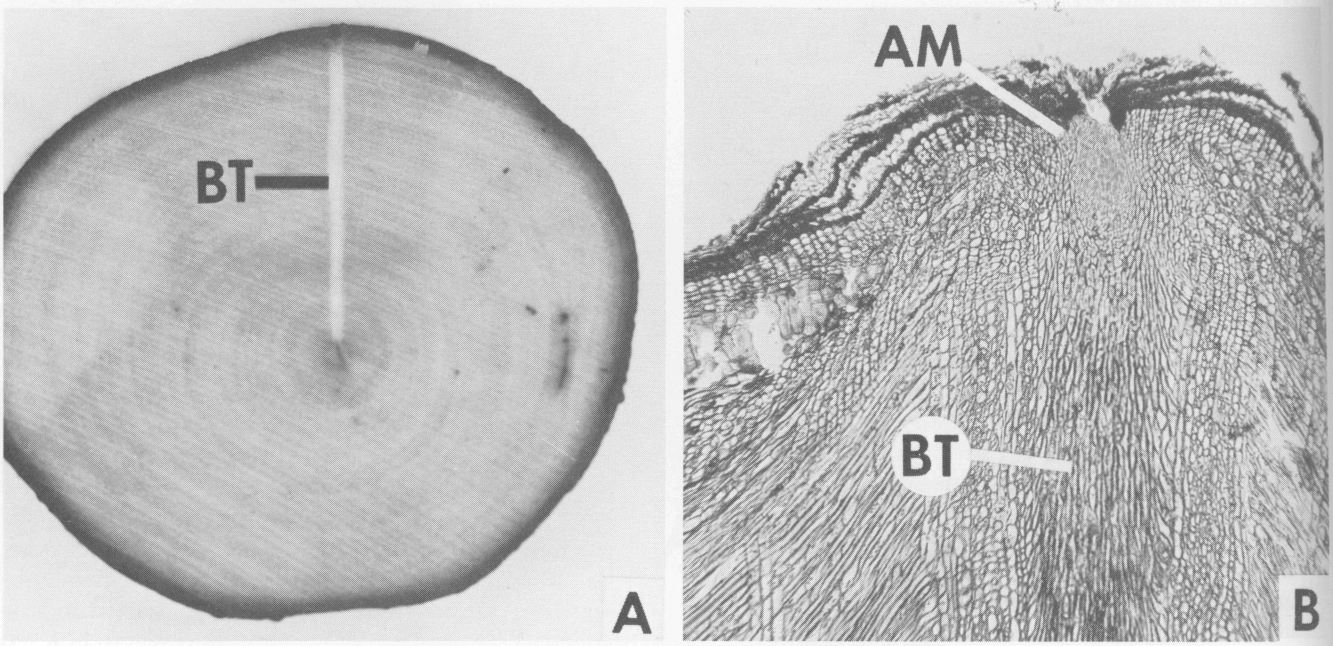


Figure 24. Texas persimmon stem bud and trace. A. Transection of a 3-centimeter-diameter stem with a bud trace (2.8X). B. Radial section of a 4-centimeter-diameter stem with a bud and trace terminus (82X).

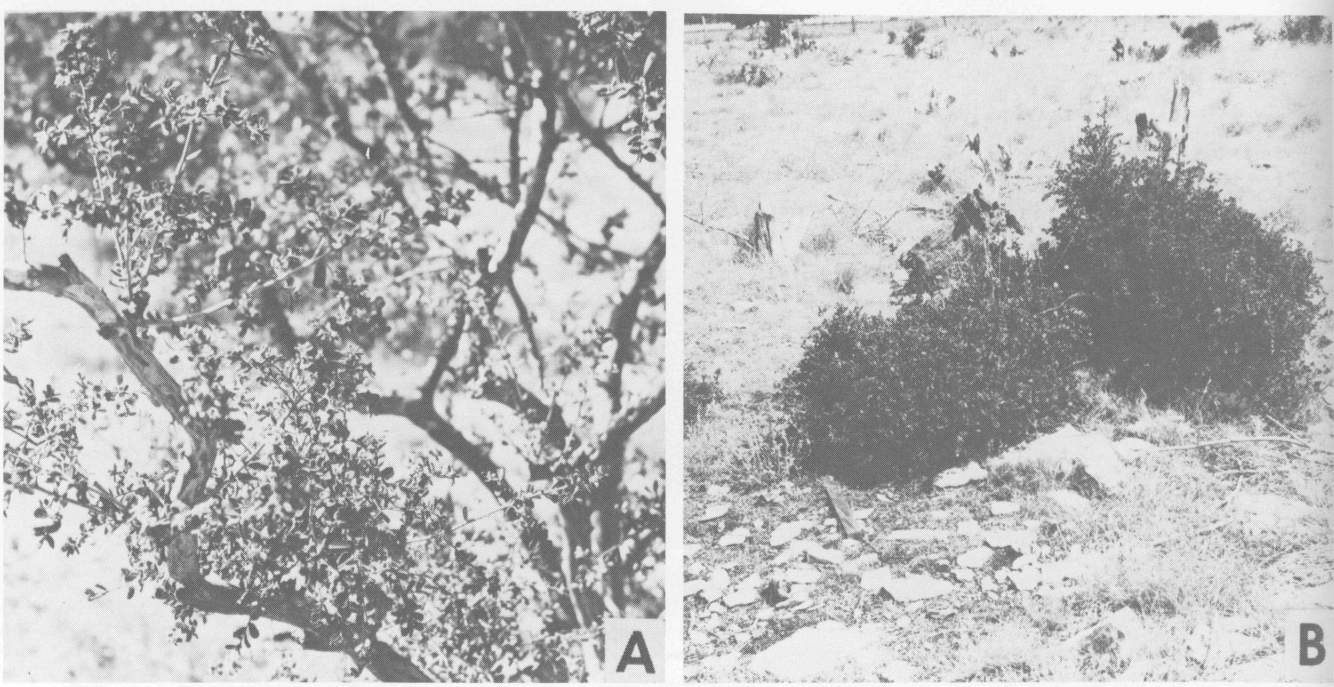


Figure 25. Resprouting of cut Texas persimmon plants at Georgetown, Texas. A. Production of new stems in July 1971 after branches had been cut off October 1970. B. Sprouting on August 1970 from stems cut off March 1969. At left, new stems from roots. The two large groups of stems in center have sprouted from cut-off stem bases.

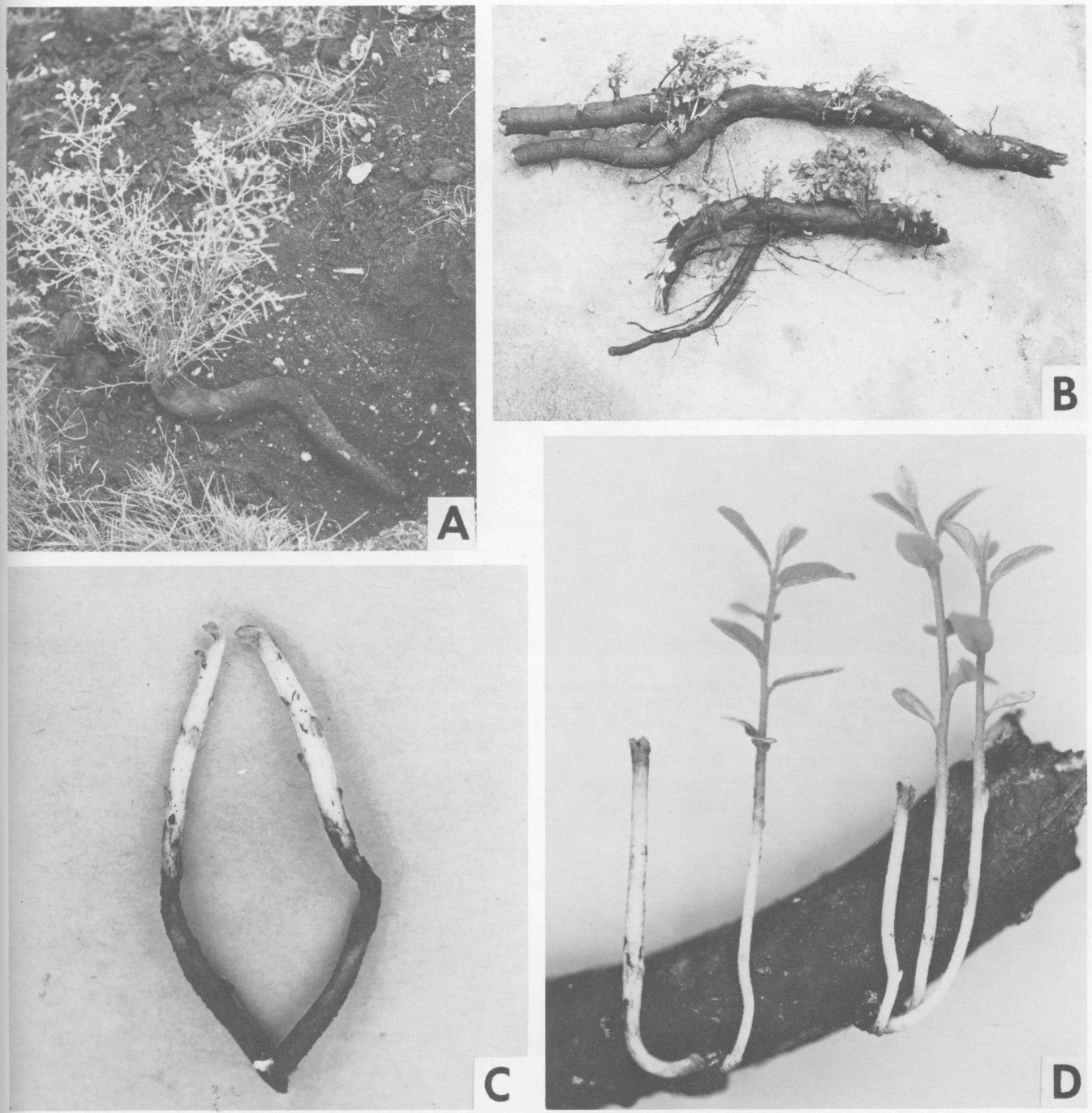
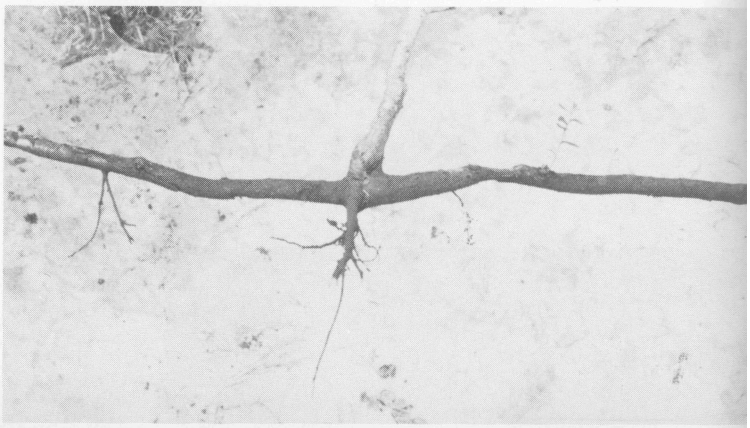


Figure 26. Sprouting pattern of Texas persimmon roots. A. A steep-angling root at Georgetown, Texas, which had been cut off about 9 months earlier. B. Roots collected April 24, 1973, which had been cut off with a bulldozer at Llano, Texas about 6 months earlier. C. Sprouts in the underground stage from a 4-inch-long root section planted in soil in the greenhouse October 13, 1972, and photographed April 13, 1973 (1.8X). D. Sprouts on a 4-inch-long root section planted in soil in the greenhouse December 28, 1972, and photographed April 13, 1973, showing the transition from the underground to the above-ground stage (1X).



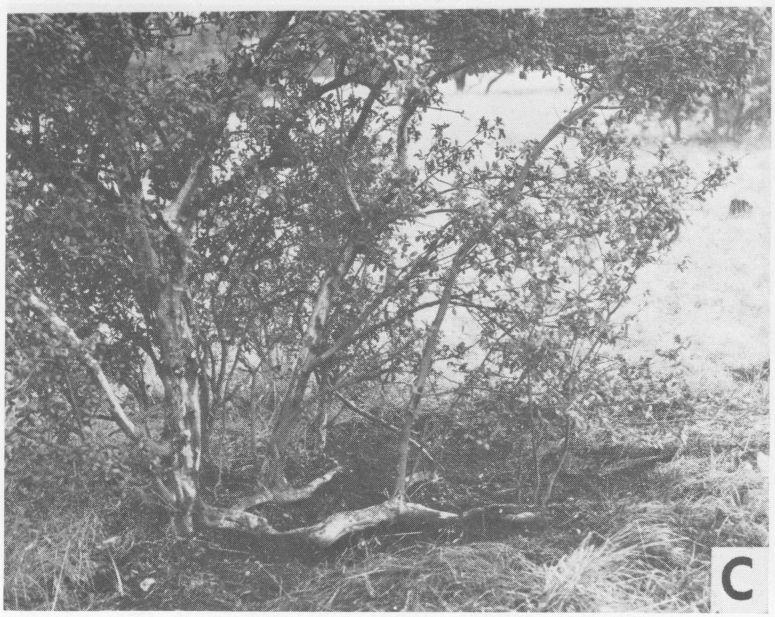


Figure 27. Root sprouting of Texas persimmon on natural stands. A. Root 1 inch in diameter at Sonora, Texas, October 1970. B. Root 1 inch in diameter at Georgetown, Texas, May 1970. C. A 7-foot-tall plant at Georgetown, September 1970. D. A 26-foot-tall plant at Uvalde, Texas, September 1972.

Figure 28. Sprouting of 1.5-year-old Texas persimmon plants in the greenhouse cut off in January and photographed August 1972. Cutting treatments (left to right) are 1 inch below, 1 inch above, 1 inch above, 4 inches above, and 4 inches above ground, respectively.

LEAF MORPHOLOGY AND ANATOMY

Location and Number of Production

On a new stem, one leaf is produced at each node. Most new stems are initiated from about March 25 to April 10 at Georgetown, and elongation is complete by mid-May. Subsequently, a few new stems may be produced after abundant rains, particularly in September and October. The leaves expand to full length within 3 weeks after emergence. At first they are light green and later turn dark green.

Figures 16A, 16B, 16C and 16D show leaves on new stems. On May 5, 1973, 42 new stems of various sizes were collected at Llano and sorted into six groups according to number of nodes. The largest leaves had developed in the middle of the stem (Table 10). Those toward both ends were smaller. The size differential was less marked on the stems with the fewest number of nodes than on those with more nodes. The leaves were roughly half as wide as long.

Other than on new stems, leaves are produced primarily on the next two older stem increments. Very few leaves are produced on older stems. These leaves appear to arise in a whorled arrangement from a series of buds on telescoped stems. Most frequently, three to five leaves are produced on these foreshortened stems.

Table 10. Length of Texas persimmon leaves collected at Llano, Texas, May 5, 1973

Node position beginning from the tip[1]	Number of nodes on stem[2]					
	5 to 7	8 to 10	11 to 12	13 to 14	15 to 17	19 to 21
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	17	14	10	8	10	4
2	18	18	15	10	14	8
3	19	19	18	13	17	10
4	17	22	22	17	20	14
5	12	22	23	18	20	17
6		21	25	16	20	20
7		16	27	19	23	21
8		13	24	21	24	24
9			19	23	25	24
10			16	19	24	25
11			11	14	23	26
12				11	21	28
13				8	20	24
14					14	27
15					11	25
16						22
17						16
18						14
19						10
	(8)	(9)	(10)	(6)	(7)	(2)

[1]Measurements were begun at the first easily measured leaf about 0.25 inch behind the apical meristem.

[2]The number of stems measured in each group is in parentheses at the bottom of the table. Where two numbers of nodes were combined, the oldest node of the one with the most nodes was omitted. Where three numbers of nodes were combined, the node at either end of the one with the most nodes was omitted, while the oldest node of the middle one was omitted.

Morphology

The blade arises on a petiole about 2 millimeters long, which is usually covered with long, unicellular trichomes (Figure 29A). The leaf is simple and oblanceolate in shape (Figure 29B). The margin is entire, the base acute and the tip obtuse. The size and shape vary widely from plant to plant. Mature leaves vary from less than 1 centimeter to about 4 centimeters in length; most are 2 to 3 centimeters long and about twice as long as wide at the widest point. Either the blade is flat, or each lateral half rises slightly from the midrib outward to the margin. The margins frequently curl downward. Leaf veination is net-like.

The upper surface is glabrous (smooth), but usually it has a few trichomes (Figures 29B and 30A). The lower surface has more trichomes, but the number may vary from almost none (Figures 29C and 30B), some (Figure 30C) to many (Figures 29D and 30D).

Stomata occur only on the lower surface, as shown for the upper surface (Figure 30A) and the lower surface (Figures 30B and 30C), respectively. The guard cells have no adjoining subsidiary cells. Table 11 shows the stomatal numbers on the lower surfaces of the leaves. These numbers were derived by viewing five leaves from five plants for each source tested in Table 11. Stomatal numbers at the leaf tip, middle and base in the lamina region were about the same (250 to 271 per square millimeter). Stoma concentrations on the greenhouse plants and on field plants with leaves 14 to 16 millimeters long were similar (219 to 230 per square millimeter). Large leaves from plants at Georgetown had more stomata (329 per square millimeter).

Anatomy

The petiole is generally about 2 millimeters long. A petiole transection from a leaf collected in May 1969 is shown in Figure 31A. A cuticle covers all external surfaces. Several single-cell elongated trichomes are present. The vascular system lies in a bundle in the center of the petiole and is surrounded by cells

Table 11. Concentration of stomata on Texas persimmon plants from the greenhouse and from the field at Georgetown, Texas

Source of leaves and collection dates	Leaf length	Region of the leaf lower surface			
		Tip	Middle	Base	Mean
	(mm)	(No./ mm^2)	(No./ mm^2)	(No./ mm^2)	(No. mm^2)
Greenhouse plant	16	216	234	206	219
Field plant					
March 23 to April 22	14	194	241	255	230
June 8 to July 26	26	339	339	310	329
Mean		250	271	257	

that appear to be parenchyma. The xylem and phloem are both crescent-shaped, about seven cells deep and separated by a cambium.

A series of leaf transections were made through the midrib of leaves collected periodically during the growing season; these are shown in Figures 31B through 31D. On April 22, most of the leaf cells have fully enlarged (Figure 31B). The palisade parenchyma are one to two cells deep, and the spongy parenchyma are compact. Most of the cells in the vascular bundle of the midrib have differentiated. However, the abaxial fibers and the xylem vessels have lignified only slightly. By May 11 (Figure 31C), most of the xylem and bundle fibers have more fully lignified. On July 8 (Figure 31D), the leaf has fully developed. with the xylem, phloem and fibers forming successive crescent-shaped layers. The xylem and bundle fibers have fully lignified, and the spongy parenchyma have more intercellular air spaces than previously. No further changes occurred during the year.

Figures 31E and 31F show the transectional structure of a leaf vein and margin as they appeared on leaves collected May 11, 1970. The vein has a structure similar to, but smaller than, that of the midrib. It also has a secretory cell and a prominent trichome. The margin curls downward (Figure 31F) and has a large crystal in the palisade and upper spongy parenchyma. The leaf midrib and blade transections of greenhouse plants are similar to those produced in the field. However, the greenhouse leaf generally has less cuticle on the blade and slightly fewer tiers of xylem cells, phloem cells and bundle fibers in the midrib.

Figure 32 shows a series of tangential sections in the lamina, taken progressively from the upper to lower leaf surface. Figure 32A is the upper epidermis, showing the shape of the irregularly shaped ground epidermal cells. Also, it shows the epidermal cell arrangement around the base of the trichomes. The trichomes have been cut off at the surface. Figure 32B is a view in the palisade parenchyma. A large crystal occurs at the upper left, and a secretory cell is at the lower left. A vein is shown at the lower right. Figure 32C is the spongy parenchyma area, with several crystals, secretory cells and veins. Figure 32D shows stomata in the lower epidermis.

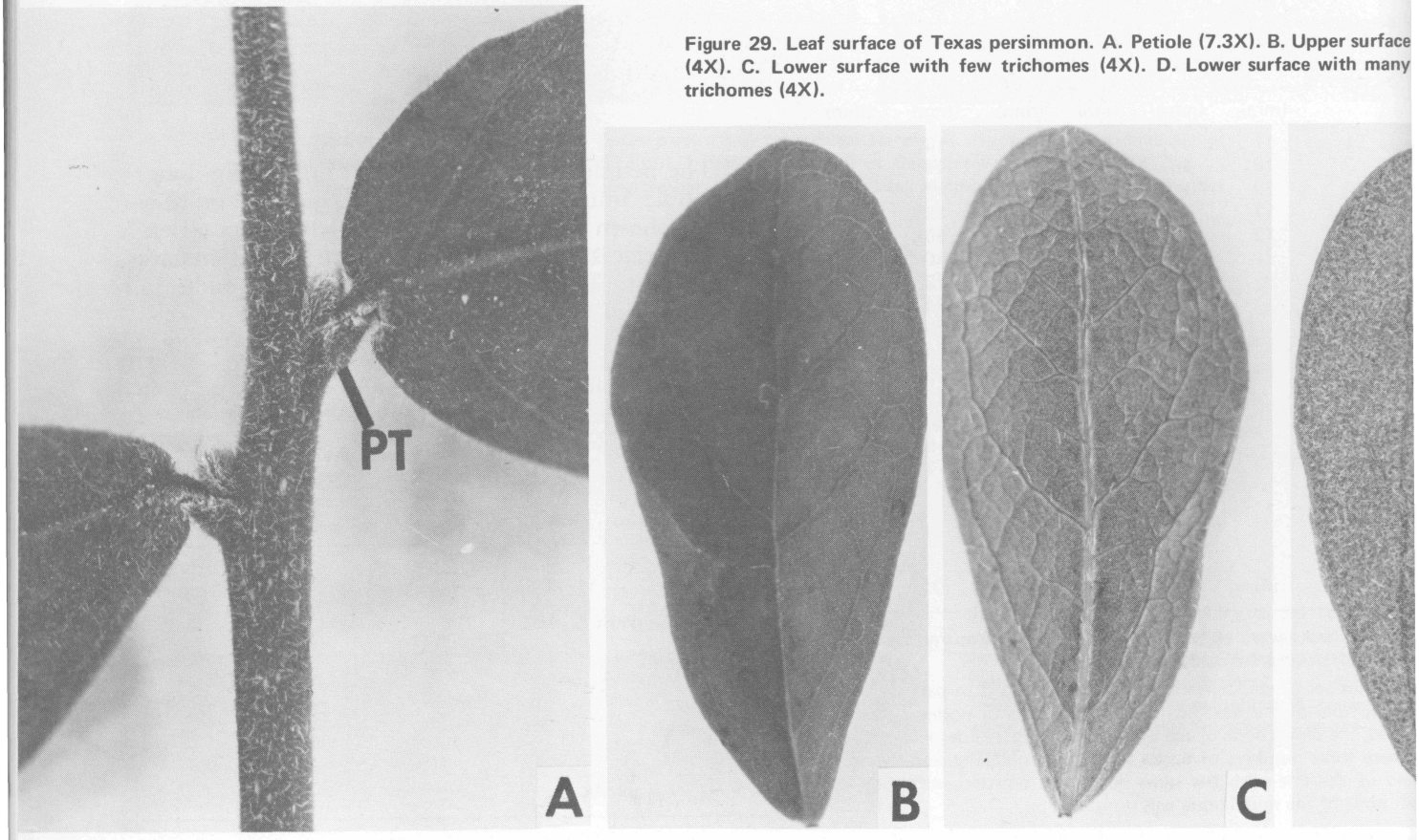
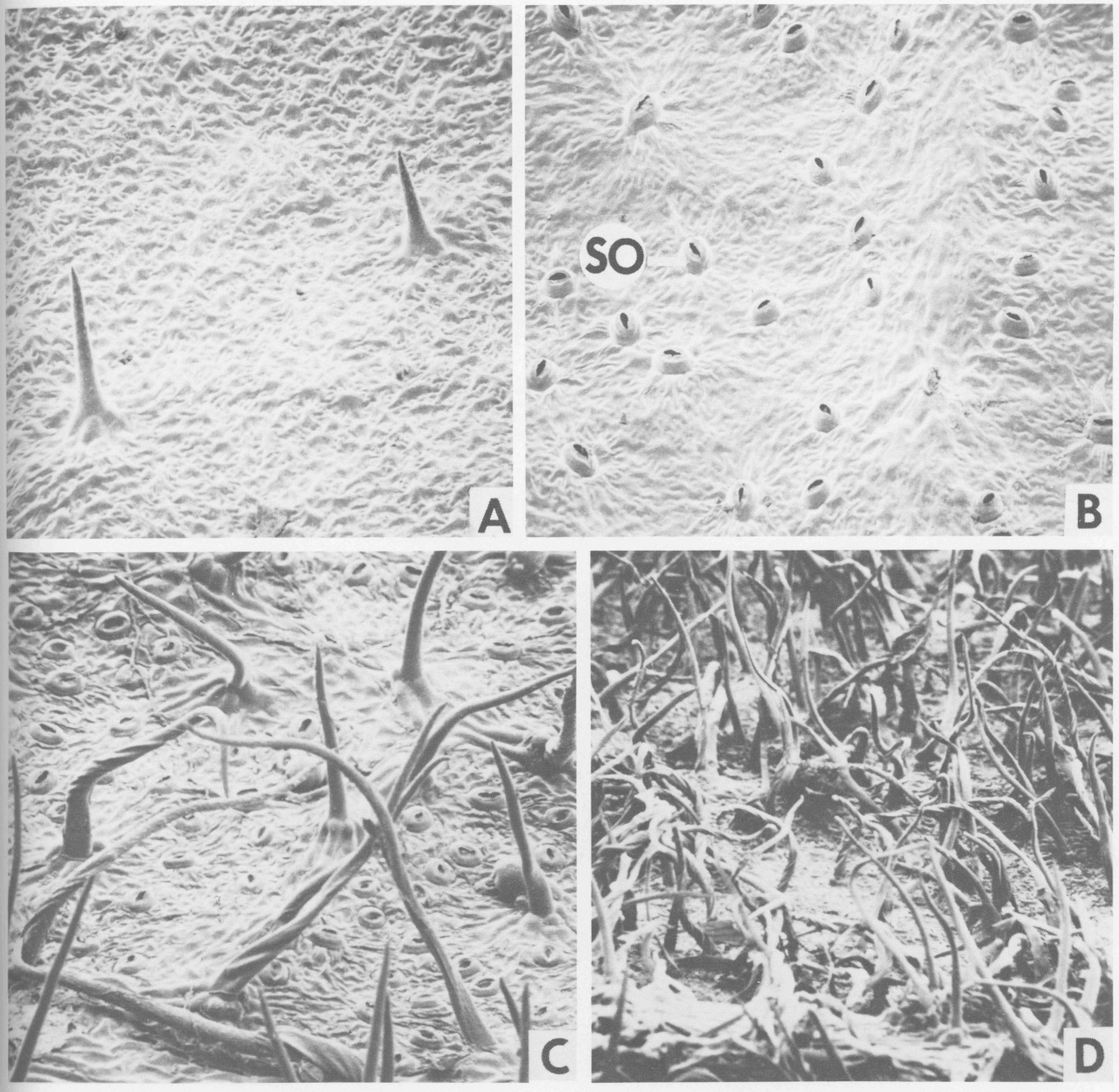
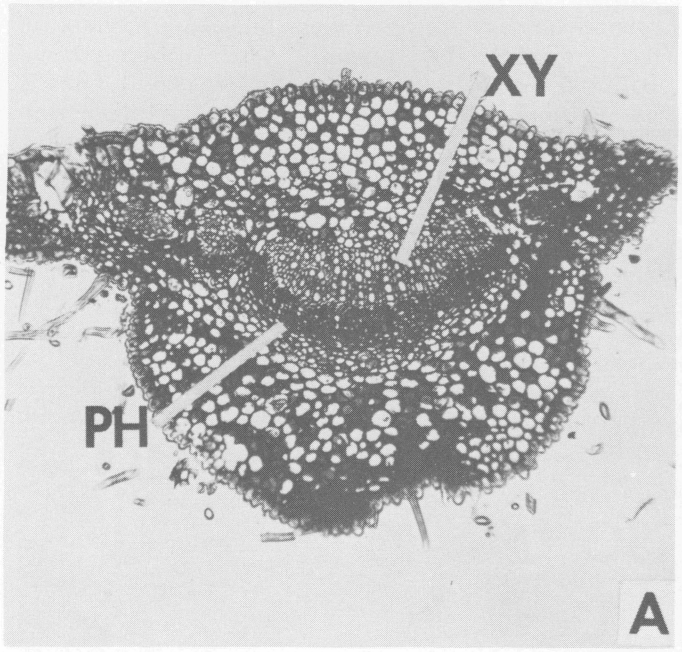


Figure 29. Leaf surface of Texas persimmon. A. Petiole (7.3X). B. Upper surface (4X). C. Lower surface with few trichomes (4X). D. Lower surface with many trichomes (4X).

Figure 30. Leaf surface of Texas persimmon (photographs courtesy of Shirlee Meola). A. Upper lamina surface (220X). B. Lower lamina surface with no trichomes (220X). C. Lower lamina surface with a medium concentration of trichomes (220X). D. Lower lamina surface with a dense concentration of trichomes (100X).

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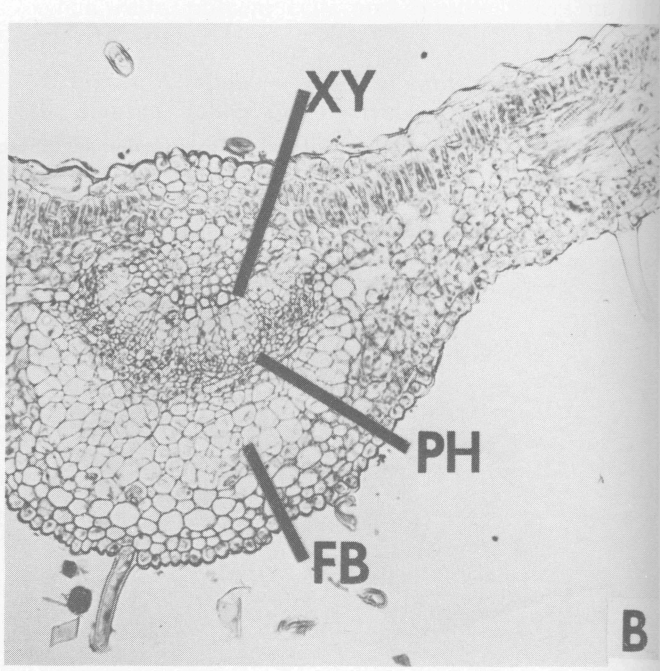
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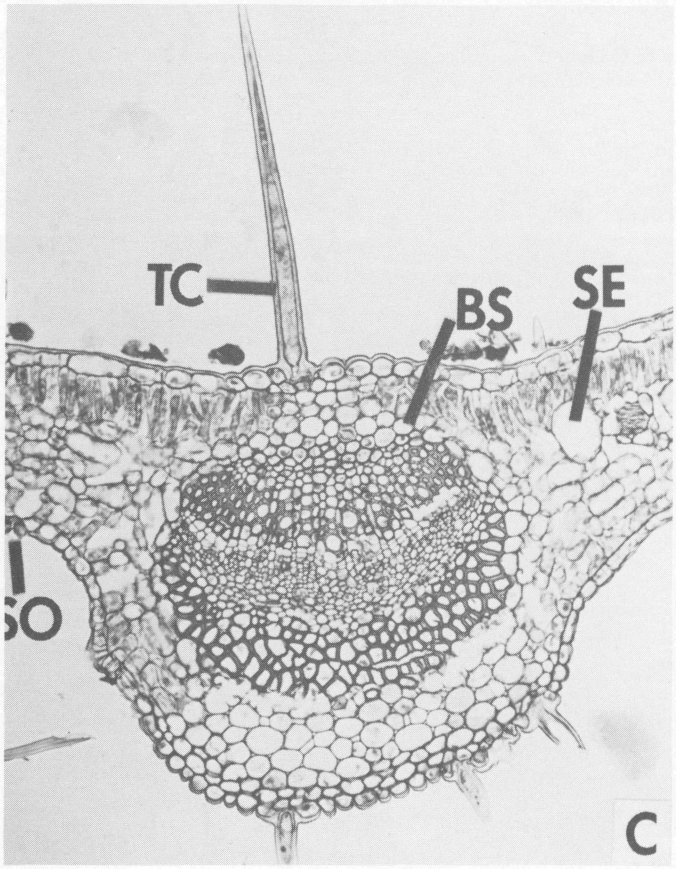
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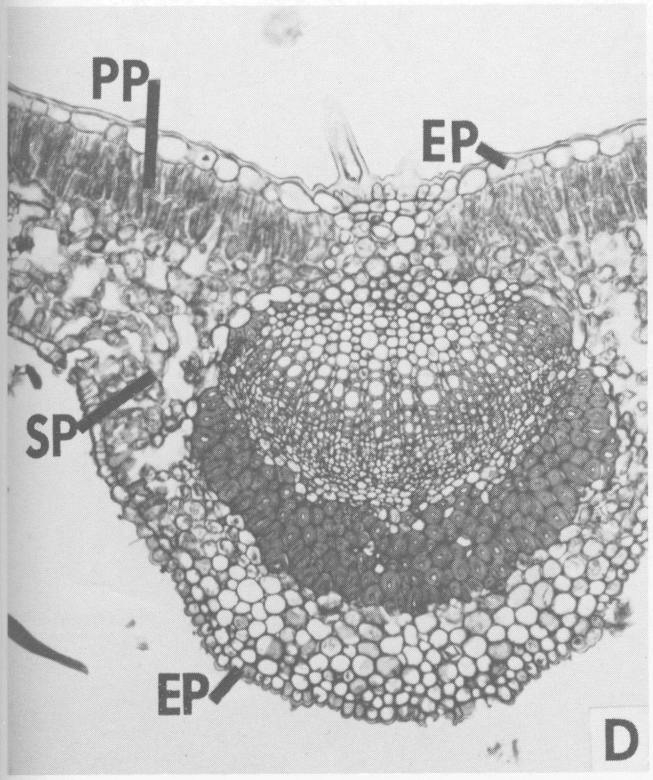
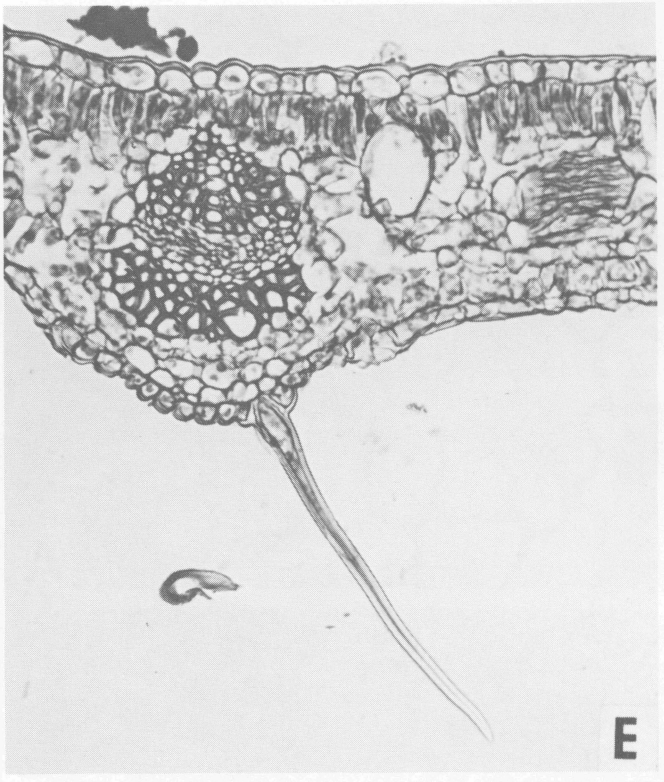




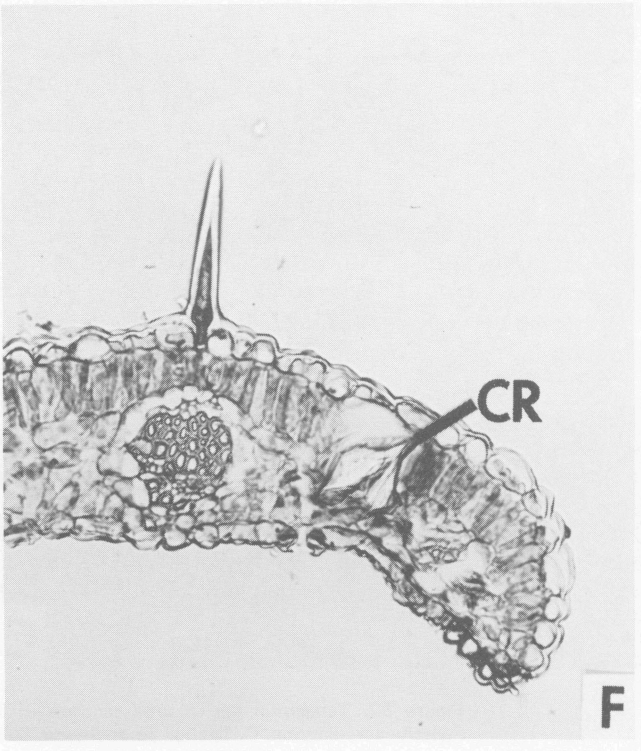


Figure 31. Leaf transections of Texas persimmon. A. Petiole, May 5, 1969 (82X). B. Midrib, April 22, 1970 (170X). C. Midrib, May 11, 1970 (170X). D. Midrib, July 8, 1970 (170X). E. Vein, May 11, 1970 (243X). F. Margin, May 11, 1970 (243X).

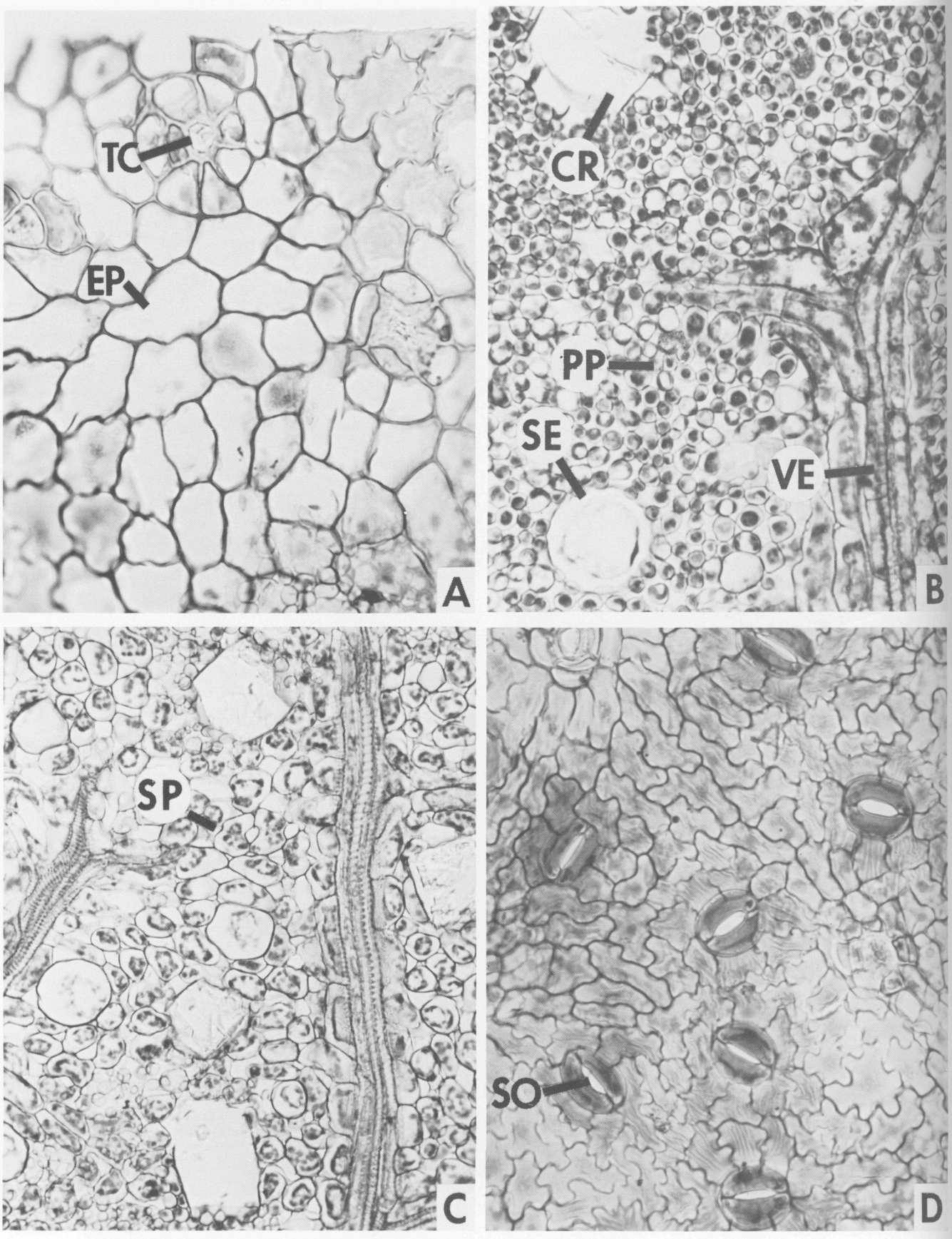


Figure 32. Tangential leaf lamina sections of Texas persimmon (All 455X). A. Upper surface. B. Palisade parenchyma. C. Spongy parenchyma. D. Lower epidermis.

ROOT MORPHOLOGY AND ANATOMY

Morphology

The morphology and anatomy of the Texas persimmon seedling root has been discussed in the seedling section. This section concerns roots from older plants.

Several mature Texas persimmon plants were dug up with a bulldozer near Llano on July 1, 1971. Most of this area was rocky, with shallow soil. Figure 33A shows two interlocking plants with several large horizontal roots. Each seems to have had a large taproot, which was broken off during the excavation operation. Figure 33B shows a plant with several large shallow roots. Figure 33C shows a plant with a long, large horizontal root. Apparently, where the soils are deep, the Texas persimmon plant produces a deep taproot. However, on shallow sites, where Texas persimmon frequently grows, it produces many shallow roots that grow along the top of the underground rock layers until they can find rock-free areas to penetrate deeper soil layers.

Figure 33D shows short sections of several roots up to 2.25 inches in diameter which were dug at Georgetown on September 1, 1970. The root surface has furrows running parallel to the long axis of the root. The root is always black or dark brown, unless exposed to the light, where it may be gray like the stem. No dark prominent heartwood is present unless the root is injured.

Anatomy

Typical Texas persimmon root transections are shown in Figure 34. Figure 34A shows a root 0.5 centimeter in diameter, collected on March 24, 1970, before new radial growth had started. The root was covered with a series of semicircular layers of phellem. This was underlain by about five tiers of sclereids. The translocating phloem was about six cells deep. No cambial cell division was occurring at the time of collection. The xylem parenchyma were filled with starch, which serves as a reserve food supply. Figure 34B shows a root 2 centimeters in diameter, collected June 8, 1970, during an enlargement stage. The cambium was producing new xylem. The outer new xylem cells were not lignified. Figure 34C shows a root 2 centimeters in diameter, August 27, 1970, after radial growth had been completed. The translocating phloem was clear and 13 to 15 cells deep. The older phloem outside no longer had intact sieve elements, because they had been crushed during expansion growth.

The growth-ring formation in Texas persimmon roots, as in roots of most arid and semiarid land species, is erratic. Growth rings seem to form any time abundant moisture is available during a warm period. Consequently, incomplete and thin growth rings are common on most Texas persimmon roots.

Typical tissue widths of five size classes of Texas persimmon roots from Georgetown are presented in Table 12. The periderm and sclereid layer thicknesses were between 0.12 and 0.25 millimeters and 0.12 to 0.17 millimeters, respectively, but showed no consistent size trends over the different size classes. The phloem was considered to be the areas between the sclereids and the cambium. The overall phloem was thicker in roots 31 to 80 millimeters in diameter than in roots 3 to 27 millimeters in diameter. The average xylem growth-ring thickness increased only slightly in progressively larger roots (0.78 to 0.90 millimeters).

Table 12. Texas persimmon root tissue thicknesses of samples collected in 1969 and 1970 at Georgetown, Texas

Root diameter	Periderm thickness	Sclereid layer thickness	Phloem thickness	Xylem growth-ring thickness
(mm)	(mm)	(mm)	(mm)	(mm)
3 to 14	0.25	0.13	0.29	0.78
15 to 20	.20	.17	.28	.79
21 to 27	.12	.12	.34	.83
31 to 39	.21	.12	.47	.90
40 to 80	.15	.17	.61	.88

Typical tangential sections of roots of Texas persimmon are presented in Figure 35. Figure 35A shows irregularly shaped phellem cells near the surface of the root. The layer with variously shaped sclereids is presented in Figure 35B. The outer phloem is comprised largely of parenchyma with remnants of now non-translocating sieve elements (Figure 35C). Figure 35D shows translocating phloem, cambium and outer xylem. Two peripheral xylem vessels lie at the extreme left. Two rows of fusiform initials and some ray cambial initials of the cambium lie between the xylem vessels. The ray cells have large conspicuous nucleii. A number of fusiform cells occur from the center to the right side, which are not fully differentiated. A sieve tube member of the phloem occurs at the lower right. None of the cells contain starch granules. Figure 35E shows the inner xylem with vessels, fibers and parenchyma. Starch granules occur abundantly in the parenchyma.

Figure 36 shows radial sections of a Texas persimmon root. Figure 36A shows the phellem, phellogen, phelloderm, sclereid and outer phloem tiers. Figure 36B shows the sclereid tier, rays, non-translocating phloem, translocating phloem and cambium. Figure 36C shows the xylem with several rays. Crystals occur in the phloem and xylem parenchyma.

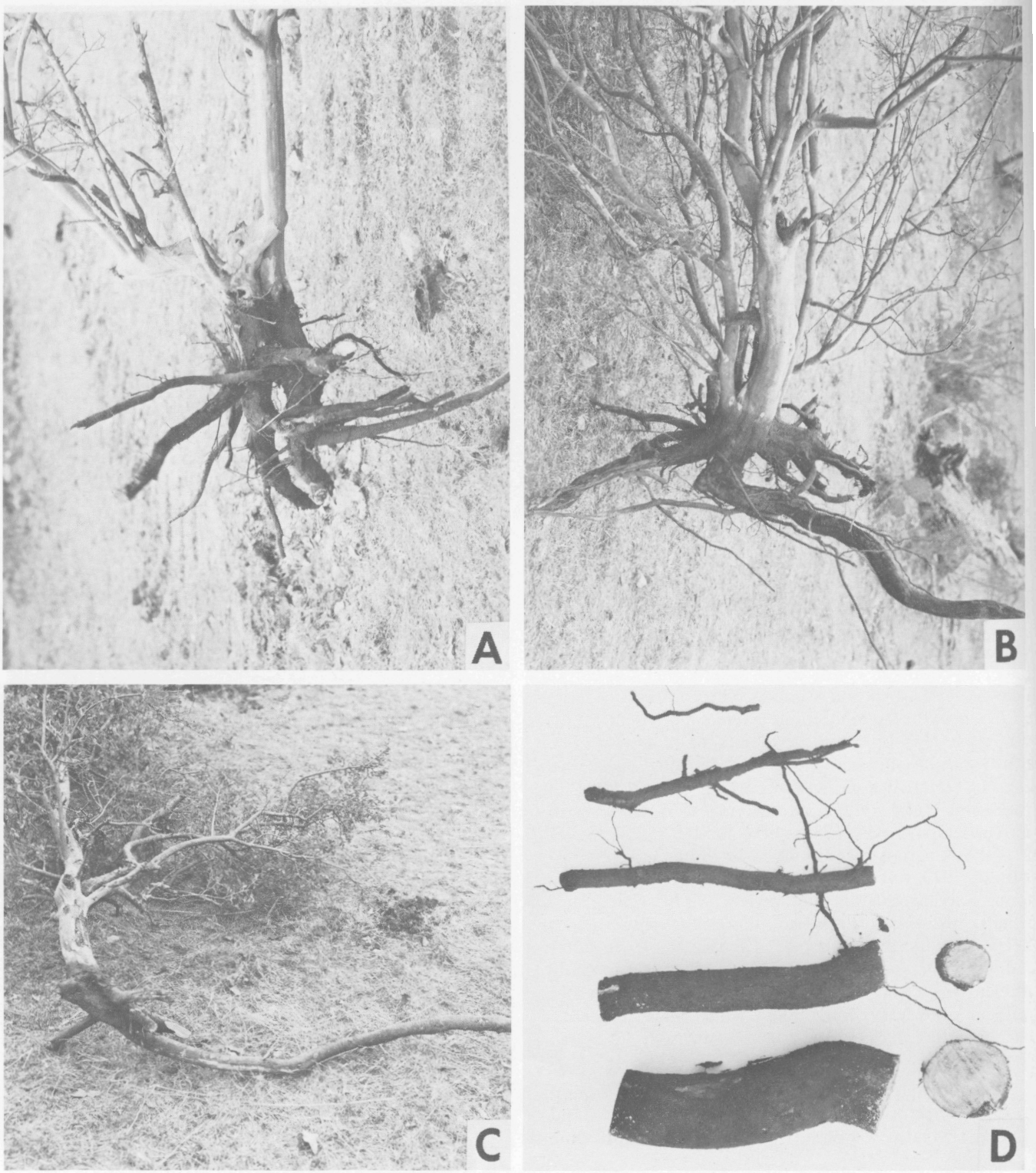
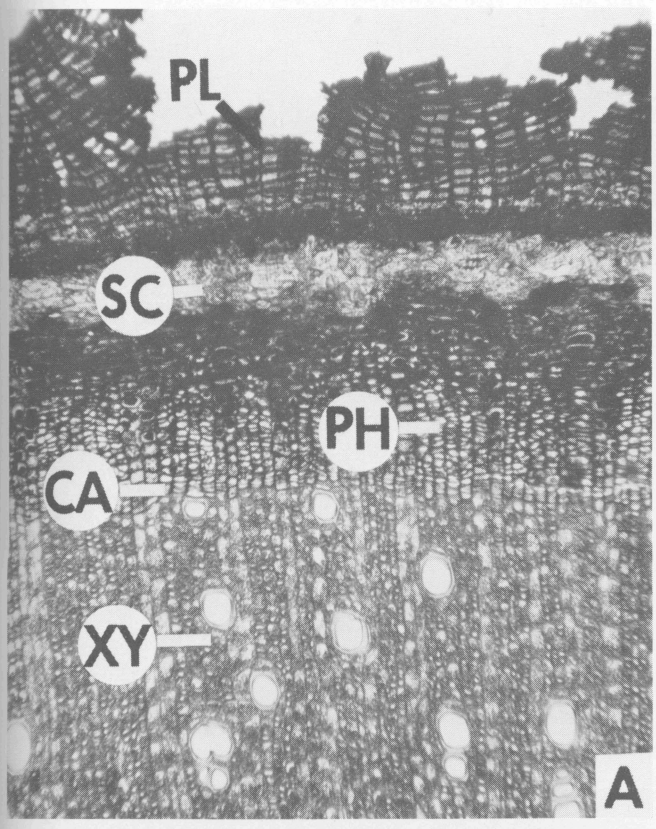
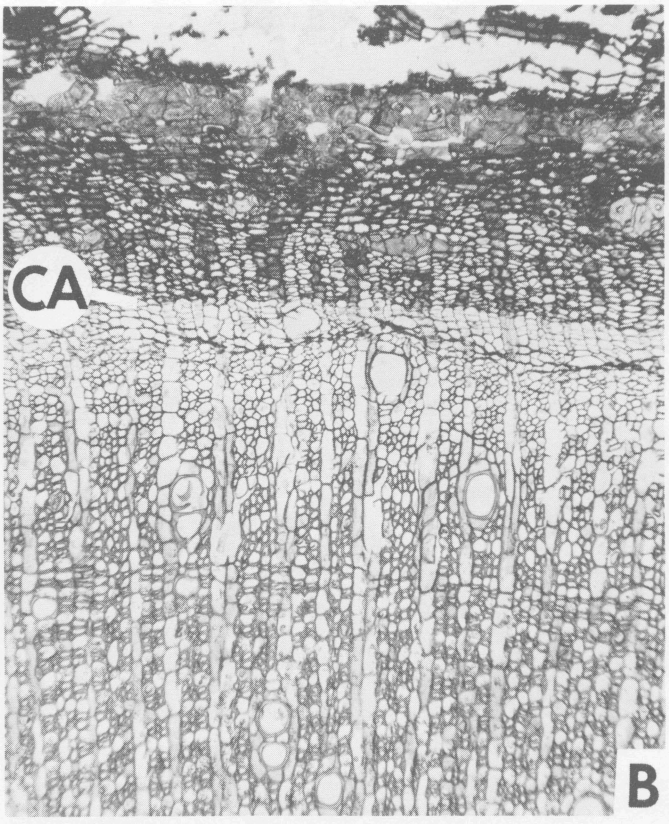


Figure 33. Main root systems of Texas persimmon at Llano, Texas, July 1971. A. Two interconnected plants with broken tap roots. B. A plant with an extensive lateral-root system. C. A plant that gained support and sustenance largely from one shallow lateral root. D. Short pieces of five roots up to 2.25 inches in diameter.





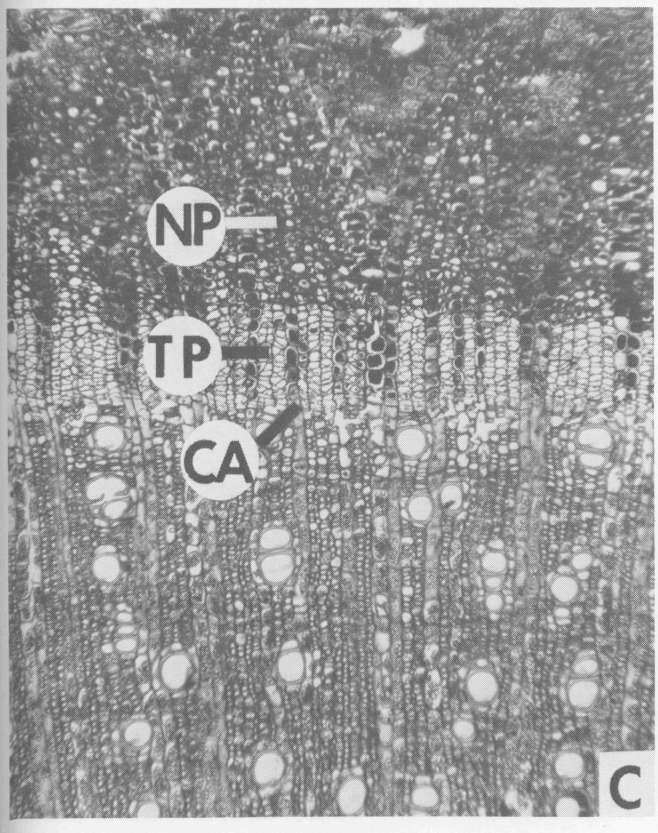
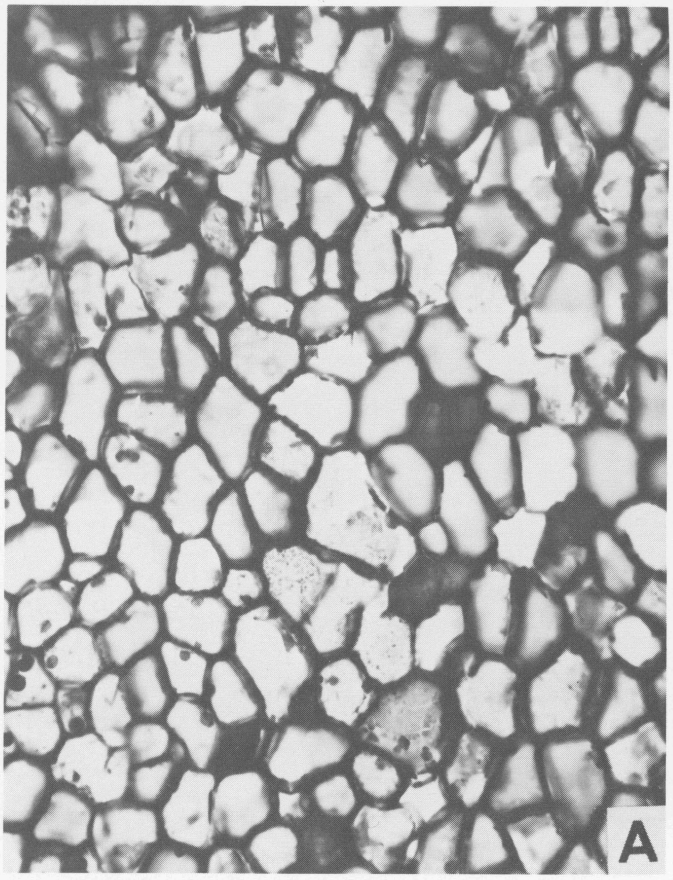
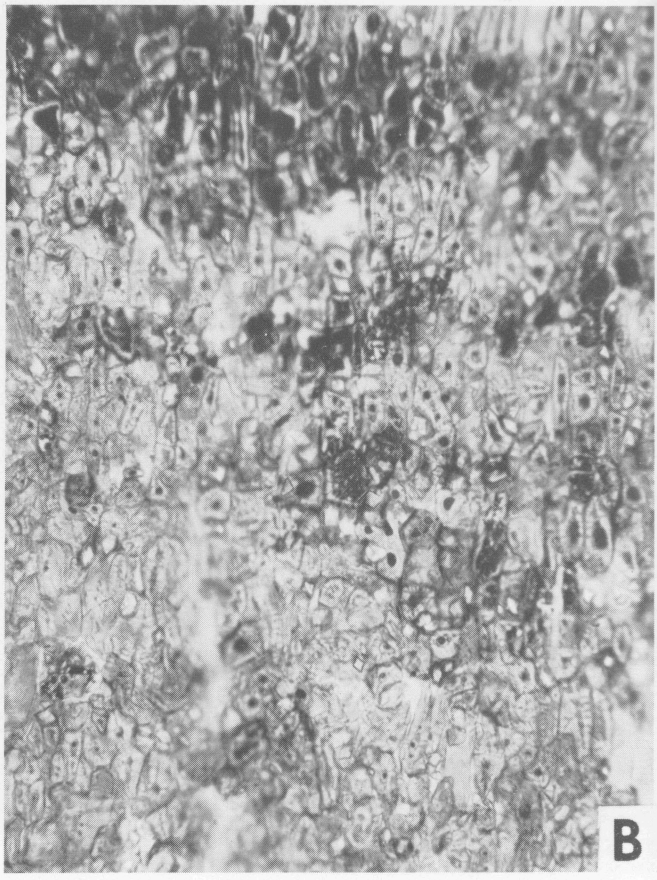


Figure 34. Transections of Texas persimmon roots 0.5 to 2 centimeters in diameter (All 82X). A. April 21, 1969. B. June 8, 1970. C. August 27, 1970.





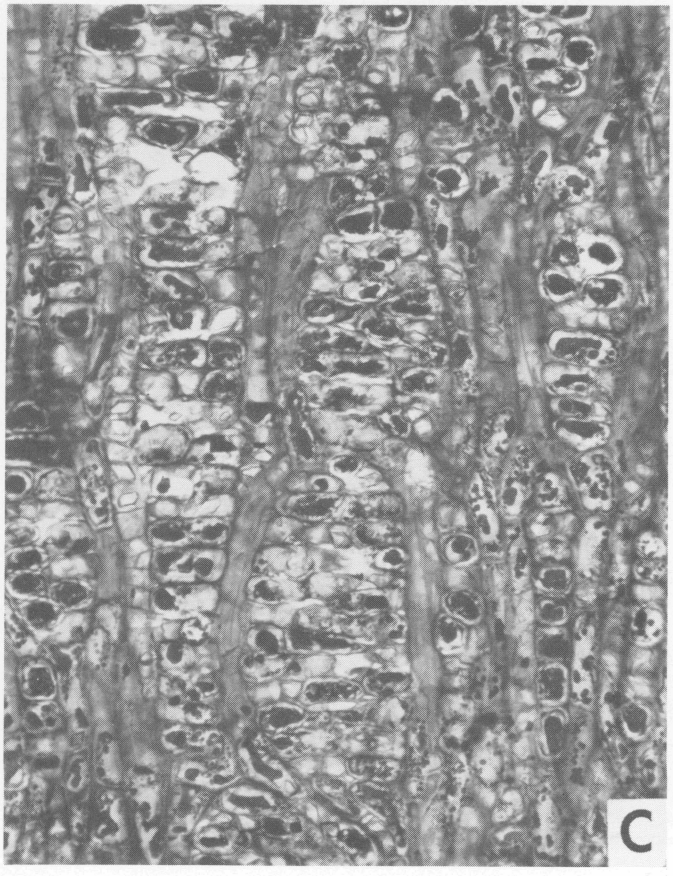
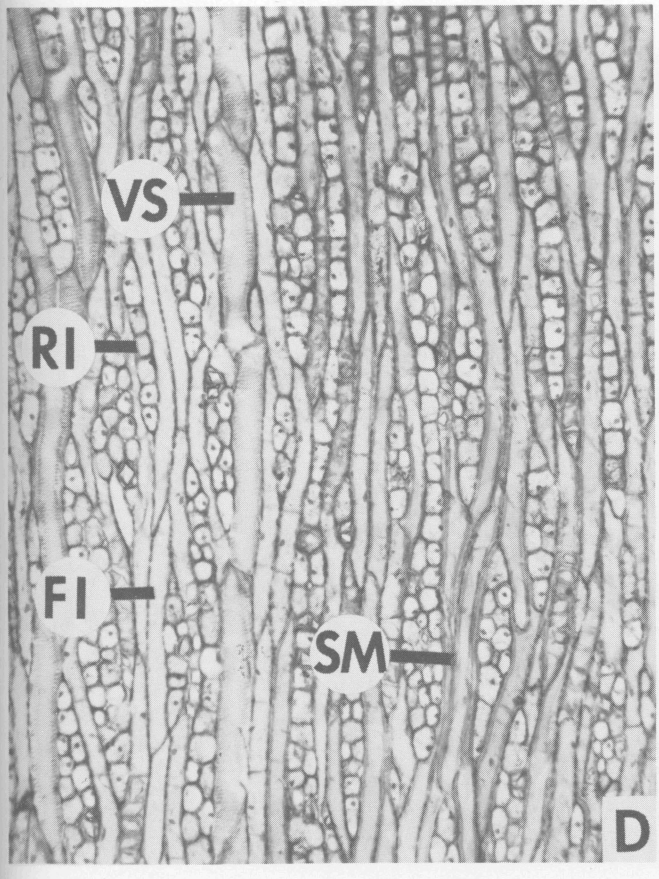


Figure 35. Tangential root sections of Texas persimmon (All 170X). A. Periderm. B. Sclereids. C. Outer phloem. D. Translocating phloem, cambium and outer xylem. E. Inner xylem.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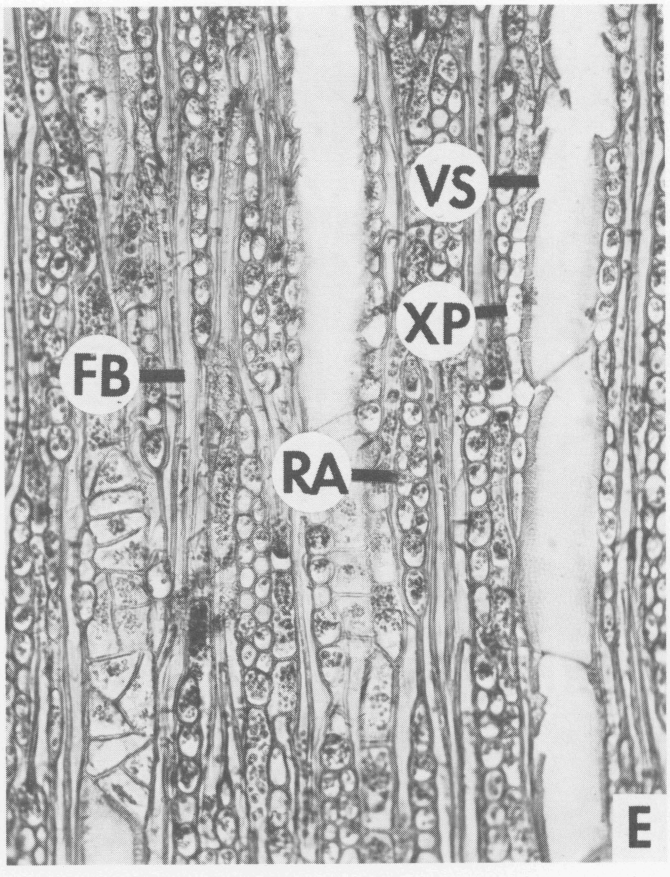
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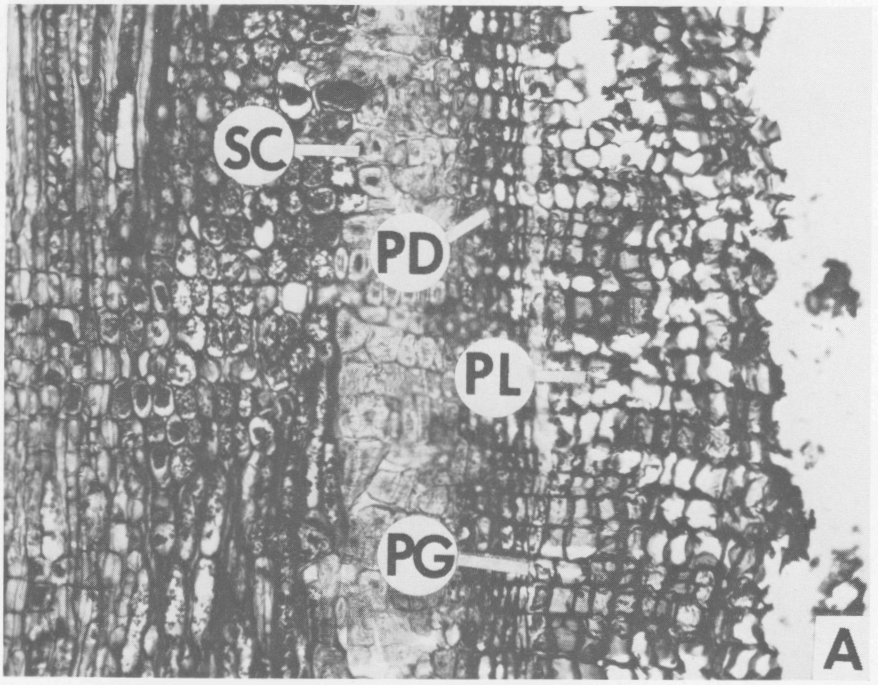

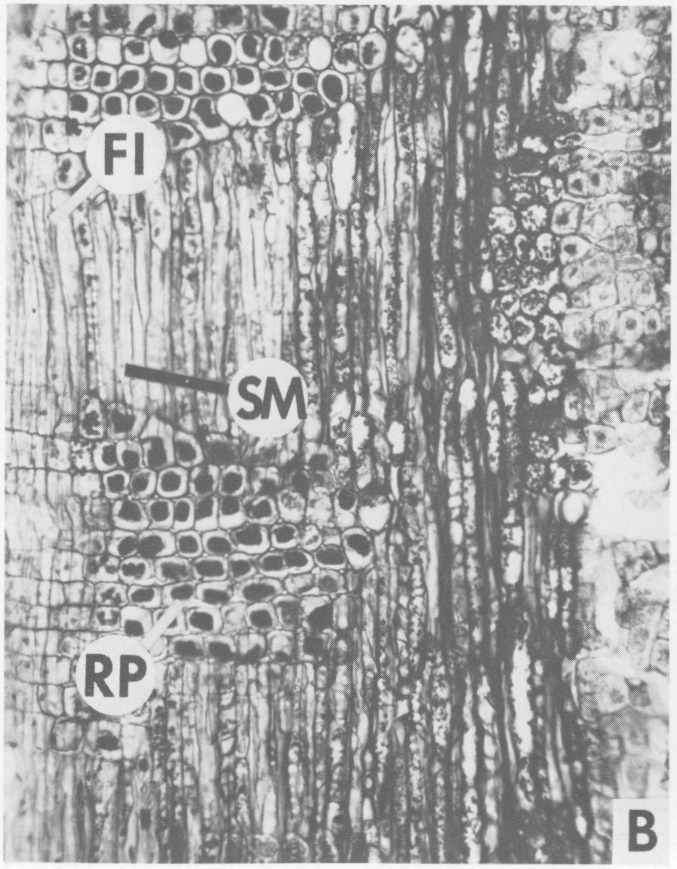

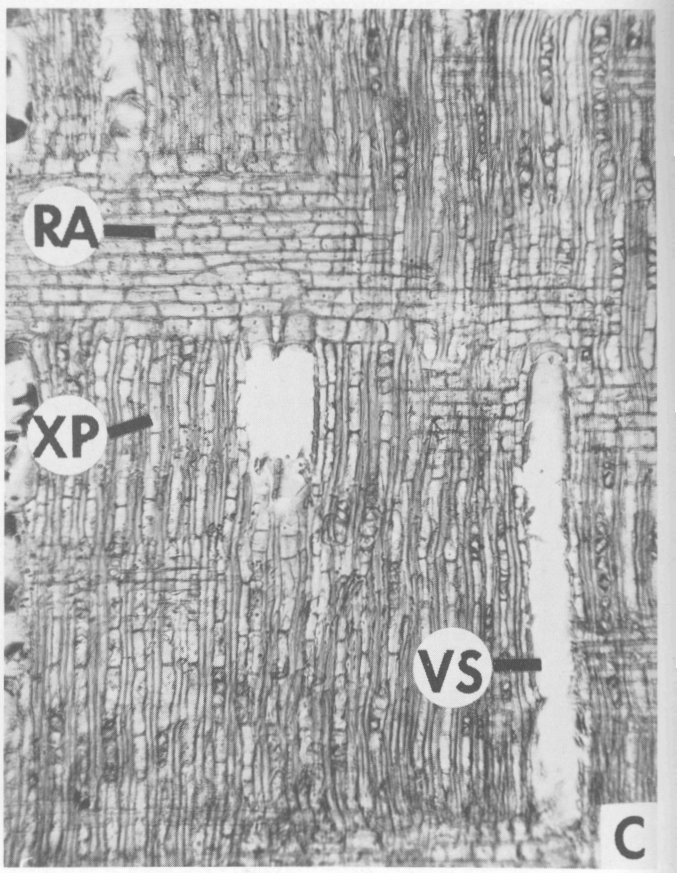

Figure 36. Radial root sections of Texas persimmon, November 1, 1970. A. Periderm, sclereids and outer phloem (170X). B. Cambium, phloem and sclereids (170X). C. Xylem (82X).

SEEDLING RESPONSE TO HERBICIDES

Texas persimmon plants were grown from seed for about 10 months, when they were 10 to 18 inches tall. The experiments were conducted from July 16, 1970, to March 29, 1971, and from March 1 to June 25, 1973. Tebuthiuron and karbutilate were sprayed only in the second experiment.

Tebuthiuron was by far the most effective chemical for defoliating and killing Texas persimmon (Table 13). Picloram was about equal to tebuthiuron for defoliating Texas persimmon. Only tebuthiuron killed a significant number of plants compared to plant deaths in the untreated pots.

As of 1975 the new herbicide tebuthiuron has been applied to Texas persimmon in the field, but the results have not been evaluated.

DISCUSSION

Texas persimmon is a difficult plant to work with. It grows slowly and erratically. A low percentage of seed germinate from fresh, intact fruit. Even washed seed germinate erratically and emerge over a several-week period when planted in a soil mixture in the greenhouse. None of the physical or chemical treatments tried increased percentage germination or caused uniform seedling development. A temperature of 80° F with adequate soil moisture seemed most favorable for producing new elongation growth.

In the field few new plants are produced as seedlings each year. Apparently Spanish goats, Rambouillet sheep and whitetail deer digest and destroy seeds they feed on. Cattle and at least some nonruminant animals, such as the raccoon, scatter seeds in their feces, and some of these seeds may subsequently germinate. Apparently, the slow rate of development hinders the establishment of many seedlings in the field. Most seedlings probably desiccate before they can become established. Once established, however, the plants are very persistent.

Table 13. Greenhouse Texas persimmon seedling response to herbicide sprays applied at 1 pound per acre[1]

Chemical	Defoliation	Dead plants
	(%)	(%)
1. Amitrole	13 e	0 b
2. Atrazine	15 e	0 b
3. Bromacil	25 de	10 b
4. Cacodylic acid	28 de	18 b
5. Dicamba	32 cde	10 b
6. 2,4-D	54 bc	35 b
7. Dichlorprop	36 cde	20 b
8. 2,4-DB	36 cde	22 b
9. Fenac	21 de	9 b
10. Karbutilate	28 de	12 b
11. MCPA	36 cde	22 b
12. Mecoprop	23 de	11 b
13. MCPB	32 cde	12 b
14. Picloram	81 a	37 b
15. Picloram + 2,4,5-T (1:1)	33 cde	14 b
16. Silvex	37 bcde	16 b
17. Tebuthiuron	100 a	100 a
18. 2,4,5-T	44 bcd	23 b
19. Untreated	14 e	0 b

[1]Values followed by the same letter are not significantly different according to Duncan's multiple range test.

Texas persimmon may occur either as single-stemmed or as multistemmed individual plants or as mottes – most are multistemmed. These plants seldom are the most numerous component of the woody vegetation in natural stands. However, Texas persimmon may become dominant after other species have been controlled.

Most control measures remove only some or all of the above-ground portions of the stem. When the upper stems are cut off, normally about four new stems are produced just below the cut. When cut off at the soil line, the plant may produce as many as 20 vigorous stems at the base of the stem and on the root. When cut off at the upper root, the remaining roots can produce few to many new shoots. These shoots produce leaves much reduced in size on underground nodes; aboveground leaves are normal.

Surfaces of Texas persimmon vary widely. New stems are generally highly pubescent, while still having an epidermis. Subsequently, the stem exterior is slightly furrowed until 1 to 2 centimeters in diameter as a result of multiple shallow phellogen formation during radial enlargement. Ultimately, however, the stem usually becomes somewhat smooth, because the phellogens form large, continuous layers that kill extensive areas of the outer periderm and phloem, which strip off in sheets in late summer and fall. Leaves may have few to many trichomes ,particularly on the under surface.

Herbicides have generally not been effective for controlling Texas persimmon. Hoffman (5) has found that 16 pounds of 2,4,5-T ester in enough diesel oil to make 100 gallons of solution, applied to the point of runoff on the cut-off stumps, will kill a large percentage of plants in the field in July and August. Broadcast applications of herbicides generally kill few if any Texas persimmon plants, unless the rate of herbicide is so high that desirable forage plants are unduly injured. In unpublished results, this researcher found that picloram as the potassium salt in granules killed individual Texas persimmon plants at Marble Falls when applied at 4 to 6 pounds per acre in the fall. In this greenhouse study, picloram and the new herbicide tebuthiuron seem to be the most effective for controlling Texas persimmon. However, tebuthiuron probably will kill grass and broadleaf species if applied as a broadcast treatment.

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GLOSSARY[6]

Apical meristem — A group of dividing cells at the tip of root or shoot that produce the precursors of the primary tissues of root or shoot.

Bark — All tissues outside the cambium in woody plants.

Bud primordium — The bud in its earliest stage of development (differentiation).

Bundle sheath — A layer or layers of cells, usually parenchyma, enclosing a vascular bundle.

Bud trace — The cylinder of lignified parenchyma in the xylem extending from the origin out to the base of the present bud in the stem.

Cambium — A persistent layer of dividing cells which gives rise to the radial enlargement of the secondary xylem and secondary phloem.

Companion cell — A specialized parenchyma cell in the phloem associated with a sieve-tube member.

Cortex — The primary ground-tissue region between the vascular system and the epidermis.

Cotyledon — One of the first two leaves of the embryo as found in the seed.

Cuticle — A layer of waxy material, cutin, on the outer wall of epidermal cells.

Endocarp — The inner layer of the fruit wall developed from the ovary wall.

Endosperm — The nutritive and protective tissue formed within the embryo sac of the seed.

Epidermis — The outer layer of cells primary in origin.

Exocarp — The outer layer of the fruit wall developed from the ovary wall.

Fiber — An elongated tapering cell with a more or less thick secondary wall usually containing lignin.

Fusiform initial — An elongated cell with wedge-shaped ends in the cambium that gives rise to the elongated cells in the radially enlarging (secondary) xylem and phloem.

Hypocotyl — The portion of an embryo or seedling below the cotyledons and above the primary root.

Inch — A measure of length equal to 2.54 centimeters or 25.4 millimeters.

Lamina — The blade or expanded part of a leaf.

Leaf — The thin expanded organ borne laterally on the stem including the blade, or lamina, and petiole.

Leaf primordium — The leaf in the earliest stage of development (differentiation).

Mesocarp — The middle layer of the fruit wall developed from the ovary wall.

Midrib — The central or main vein of a leaf.

Non-translocating phloem — The outer region of the phloem containing parenchyma and fibers that does not participate in the movement of foods.

Palisade parenchyma — Elongated, thin-walled cells in the leaf arranged perpendicular to the surface under the upper epidermis.

Parenchyma — Living cells of primary or secondary origin varying widely in shape, wall thickness and size usually concerned with photosynthesis, storage or excretion of various materials, wound healing and origin of adventitious structures.

Periderm — Secondary protective tissues including the phellen and phelloderm derived from the phellogen which replaces the epidermis in stems and roots.

Petiole — The supporting foot-stalk of a leaf.

Phellem — Non-living cells in the periderm formed to the outside by the phellogen.

[6]Some of the definitions apply specifically to Texas persimmon.

Phelloderm — A tissue of thin-walled cells in the periderm formed to the inside by the phellogen.

Phellogen — The cork cambium or dividing layer of cells which forms the outer protective tissue (periderm) of stems and roots consisting of phellem to the outside and phelloderm to the inside.

Phloem — The principal food-conducting tissue of the plant which is composed of companion cells, sieve tube members, parenchyma and fibers.

Pith — The primary ground tissue in the center of a stem or root comprised of parenchyma.

Ray — A panel of tissue formed by the cambium and extending radially in the secondary xylem and secondary phloem of the stem and root.

Ray initial — A rectangular cell in the cambium that gives rise to ray cells of the xylem and phloem.

Root — The descending axis of the plant without nodes or internodes developing underground and absorbing moisture and nutrients from the soil.

Sclereid — A lignified, thick-walled cell with many pits varied in shape but typically not much elongated.

Secretory cell — A living cell specialized with regard to secretion of one or more usually organic substances.

Seed — The ripened ovule consisting of the embryo and its proper coats.

Sieve tube member — An elongated cell in a sieve tube of the translocating phloem.

Spongy parenchyma — Leaf parenchyma with intercellular spaces lying between the palisade parenchyma and the lower epidermis.

Stem — The ascending axis of the plant developing above ground with nodes, internodes and leaves.

Stoma (pl. stomata) — A minute opening between two guard cells in the epidermis which allows gaseous interchange between the atmosphere and the internal cells of the leaf.

Translocating phloem — The inner region of the secondary phloem containing sieve tube members and companion cells that translocate the food materials in the plant.

Trichome — An outgrowth of the epidermis, variable in shape, size and function usually referring to hairs.

Vascular bundle — A strand-like part of the vascular system composed of xylem and phloem in the stem and leaf.

Vein — A strand of vascular and supporting tissue in the leaf.

Xylem — The principal water and mineral conducting tissue in the plant. The secondary xylem (wood) is also important for support and food storage. It is comprised of vessel members, parenchyma and fibers.

Xylem vessel — A tube-like series of elongated vessel members with the common walls having open ends.

PHOTOGRAPH SYMBOL IDENTIFICATION LIST

Letters	Identification
AM	Apical meristem
BP	Bud primordium
BS	Bundle sheath
BT	Bud trace
CA	Cambium
CC	Companion cell
CO	Cortex
CR	Crystal
CT	Cotyledon
EN	Endocarp
EP	Epidermis
ES	Endosperm
EX	Exocarp
FB	Fiber
FI	Fusiform initial
HP	Hypocotyl
LF	Leaf
LP	Leaf primordium
ME	Mesocarp
NP	Non-translocating phloem
PD	Phelloderm
PG	Phellogen
PH	Phloem

Letters	Identification
PI	Pith
PL	Phellem
PP	Palisade parenchyma
PT	Petiole
RA	Ray
RC	Root cap
RI	Ray initial
RP	Ray parenchyma
RT	Root
SC	Sclereid
SD	Seed
SE	Secretory cell
SG	Starch granule
SM	Sieve tube member
SO	Stoma
SP	Spongy parenchyma
ST	Stem
TC	Trichome
TP	Translocating phloem
VB	Vascular bundle
VE	Vein
VS	Xylem vessel
XP	Xylem parenchyma
XY	Xylem

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