

Chapter 1

ANATOMY AND MORPHOLOGY OF THE COTTON SEED AND SEEDLING

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INTRODUCTION

The structures of the seed of the cotton plant (*Gossypium* sp.) have been described in great detail by Brown (1927), Baranov and Maltzev (1937), Leahy (1948), Tharp (1965), Mauney (1968), and Oosterhuis and Jerstadt (1999). The definitive structures of the seed and seedling which influence the development of the subsequent crop are: 1) vascular connections, 2) seed coat and chalazal pore connections, 3) cotyledons, 4) hypocotyl and radicle axis, and 5) apex. This review will concentrate upon these five elements of the seed anatomy and morphology.

VASCULAR CONNECTIONS OF THE SEED

During development the seed is connected to the vascular system of the plant through the attachment of the funiculus to the placenta of the boll (Figure 1K). There are vascular strands consisting primarily of phloem in the raphe (Fig 1, J) of the seed extending to the chalazal pore on the distal portion of the developing seed. The vascular strands end at the pore. Thus, all hydration and nutrition for the developing embryo must enter the embryo sac through the spongy (unvascularized) tissue of the chalazal pore. This arrangement enables the plant to bathe the developing embryo in endosperm with very high osmotic potential (Mauney, 1961; Trolinger, et al., 1993) while the canopy operates at familiar, and fluctuating, water potential (Van Iersel et al., 1994, Van Iersel et al., 1995; Van Iersel and Oosterhuis, 1996)

SEED COAT AND CHALAZAL PORE STRUCTURE

Seed dormancy is evolutionarily and culturally necessary for cotton which has a long period of exposure to weather before harvest. The embryos must remain dormant while the bolls are subjected to moisture from dew and rainfall for up to more than 60 days after the first bolls crack. This dormancy may be due to ABA as a biochemical inhibitor (Kloth and Turley, 2010) or due to physical prevention of moisture uptake. It is probable that each of these mechanisms plays a role in preserving germinability in mature seed before harvest.

It has been demonstrated (Simpson, 1935; Christiansen and Moore, 1959) that water for germination of the dormant seed must enter through the chalazal pore. The palisade layer of the mature dry seed is heavily lignified and impermeable to water. (Figure 1G) The seal at the funiculus is also impenetrable until broken by moisture entering through the chalaza. The chalazal seal is a heavily lignified plug of tissue. In "hard" seed cultivars and species this plug may persist for months or years. Placing the seed in hot (80 C) for a short period (1 minute), ethanol,

or ethyl ether disrupts this seal, allowing water to enter and germination to begin (Christiansen and Moore, 1959). In "soft" seed cultivars the normal storage period from harvest to planting is sufficient to break the dormancy tendencies and allow immediate imbibition.

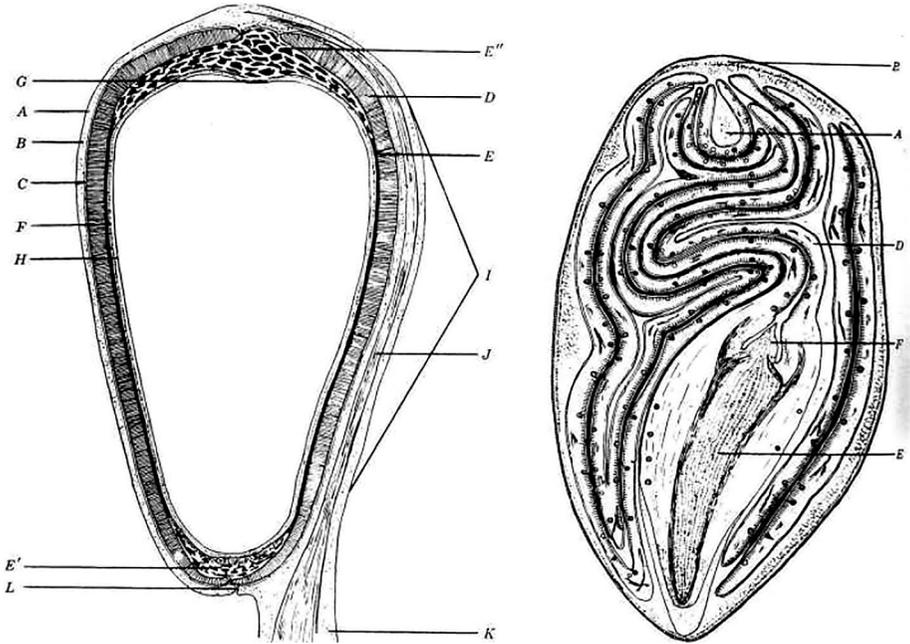


Figure 1. Structure of mature cotton seed. Seed coat (on left): A, outer epidermis; B, outer pigment layer; C, colorless layer; D, palisade layer; E, inner pigment layer; E', inner pigment layer differentiated at micropyle; E'' inner pigment layer differentiated as a chalazal cap; F, fringe cells; G, specialized cells at base of chalazal cap; H, membrane cells; I, raphe; J, vascular bundle; K, funiculus; L, micropyle. Embryo (on right) A, endosperm; B, nucellus; D, cotyledon; E, hypocotyl and radicle; F, epicotyl. From Leahy, 1948, as presented by Tharp, 1960.

COTYLEDONS

Two massive cotyledons occupy the majority of the volume and weight of cotton seed. They begin development as protuberances on the globular embryo at about 9 (Hector, 1936) to 12 (Quintanelha et al., 1962) days after pollination (DAP) to form what is known as the heart stage embryo. From that point the cotyledons expand in a sigmoid growth curve (Figure 2) to fill the embryo sac at about 20 DAP. The morphology of these cotyledons is identical to the primary leaves of the plant. There are resin glands (Fig. 3) which contain gossypol. However, whereas aerial leaves contain starch grains as the principle storage product, cotyledons contain oil and protein bodies in the cytoplasm as storage energy (Reeves and Valle, 1932). Because the cotyledons are the primary source of photosynthate for the seedling, any damage to them through weather and sand abrasion or insect attack (thrips feeding) can produce a severe delay in seedling growth.

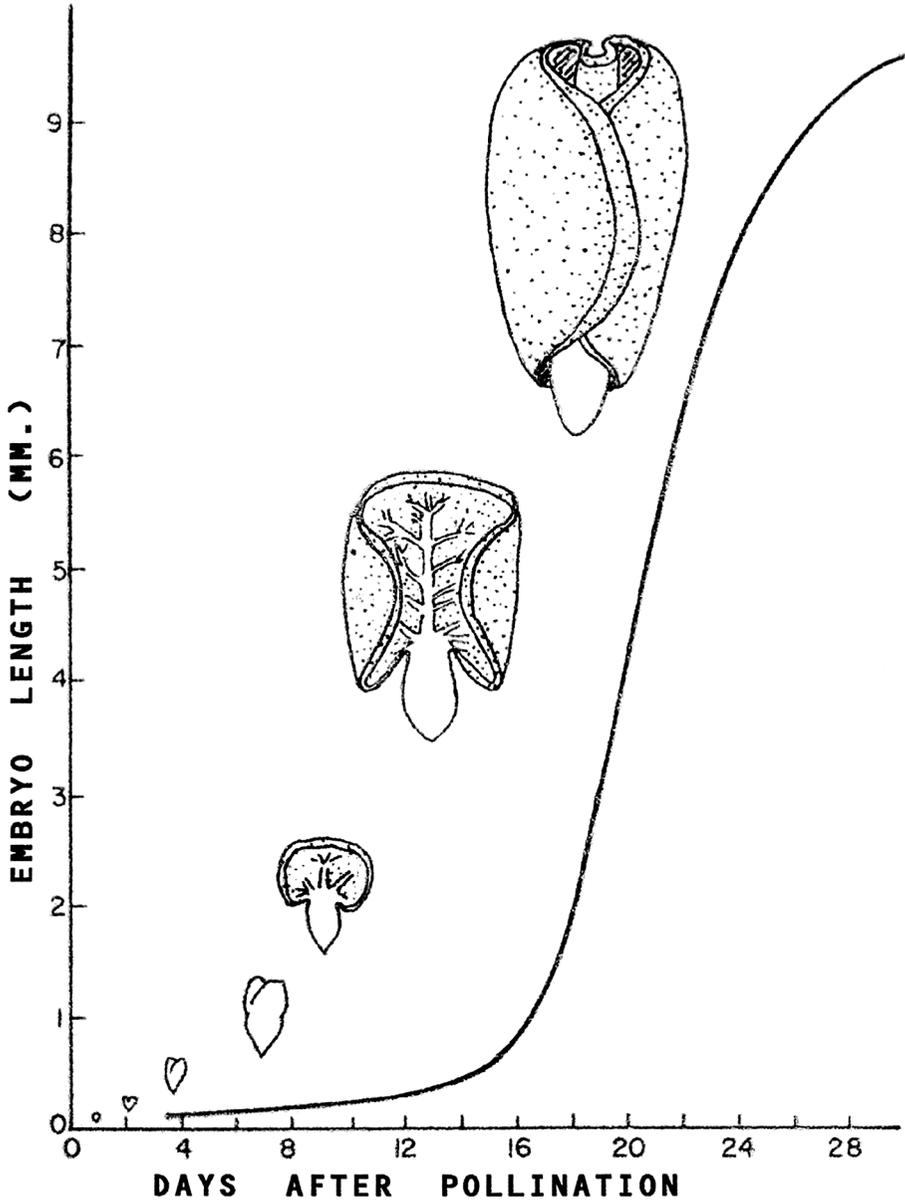


Figure 2. Growth of the cotton embryo. Sigmoid curve is a plot of embryo length with time as measured as days from pollination (DAP). Illustration shows degree of differentiation at various stage of growth in length. From Mauney 2012.

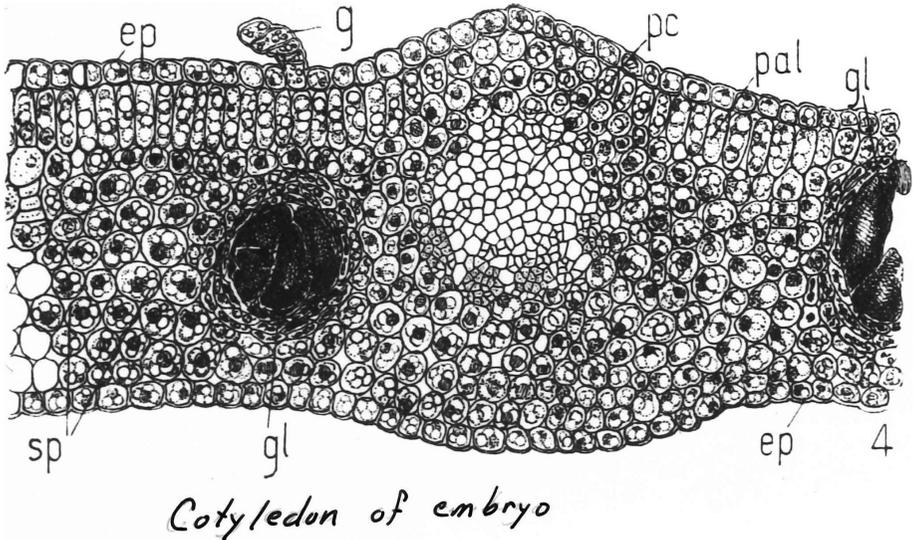


Figure 3. Cross section of the embryonic cotyledon showing resin glands (gl). From Baranov and Maltzev, 1937

HYPOCOTYL AND RADICLE AXIS

The hypocotyl of the cotton seed is a well-developed stem between the cotyledons and the radicle. The transition from hypocotyl and radicle (stem and root) can be seen in Figure 4 at section 5 and 6 where the tetrarch arrangement of the typical root vascular system (McMichael, 1986) changes to the circular stele of the typical aerial stem of the vegetative cotton plant. That these structures are differentiated in the seed means that the elongation of the hypocotyl and radicle into stem and root at germination can be rapid, limited by only imbibition of water.

Upon germination, water entering the chalazal pore travels to the radicle which rapidly elongates and breaks through the micropyle of the seedcoat and becomes the seedling root. Water entering the root hydrates the hypocotyl, which elongates pushing the cotyledons through the soil (Figure 5). Because of the drag of the cotyledons the hypocotyl forms a “hook” as it penetrates the soil. This hook is the first tissue to emerge from the soil. After emergence the hypocotyl straightens (Fig 5) allowing the cotyledons to function as photosynthetic leaves. Under ideal conditions of moisture and temperature the seedling can begin adding dry weight by 4 to 5 days after imbibition (Mauney, unpublished).

The most active tissue of the germinating cotton seed is the radicle. It can penetrate into the soil 15 to 20 cm. by the time the cotyledons unfurl (Tharp, 1960). Secondary roots form from lateral meristems located at each of the tetrach vascular bundles in the root (Figure 6). Thus, secondary roots are observed in rows down each quadrant of the tap root.

The vigorous expansion of the root system during the seedling phase results in the highest root/shoot ratio of any stage in the plant development (Taylor and Klepper, 1974; Mauney, et al., 1994). The high R/S ratio enables rapid expansion of the leaf area when the true leaves begin expansion.

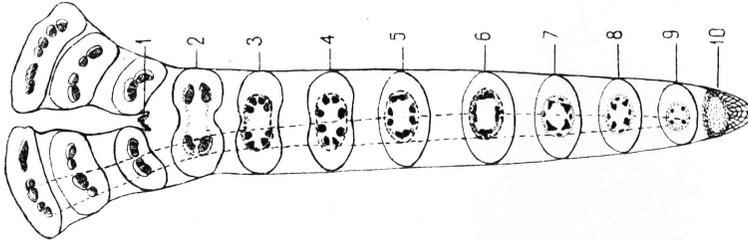


Figure 4. Drawing of the embryonic axis showing the vascular development, 1, epicotyl 2 to 5, hypocotyl; 6 to 10, radicle. From Baranov and Maltzev 1937.

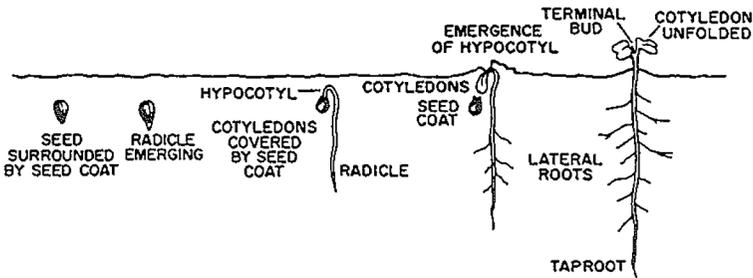


Figure 5. Drawing of stages of seedling establishment from seed to cotyledon unfolding. From Oosterhuis, 1991.

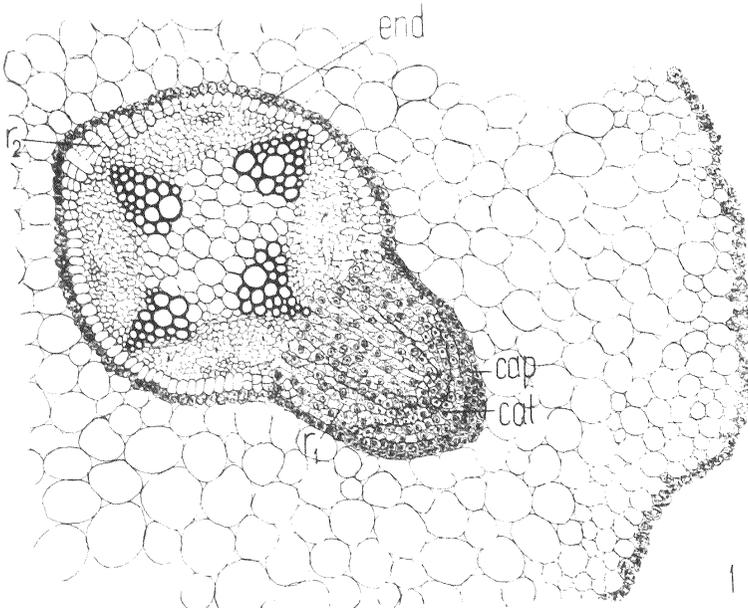


Figure 6. Drawing of the epicotyl of the embryonic axis with a single true leaf primordium and the apical meristematic dome. From Baranov and Maltzev, 1937

APEX

The length of the seedling phase of cotton production derives from the fact that that embryo has no plumule as seen in legumes and grasses. A cotton seed (embryo) contains only a poorly developed epicotyl (apex) consisting of a single leaf primordium and a meristematic dome (Figure 7). Using carbohydrates from the photosynthetic activity of the cotyledons and water from the rapidly expanding root system the epicotyl develops the tissues of the first primary leaf during the first week of seedling establishment.

The first and second leaves are not lobed. Climax leaf lobing occurs at about the sixth true leaf. Axillary branch buds are found at the base of the expanded cotyledons and all true leaves. Axillary buds are not present in the seed. At the time The second true leaf is unfurled about five to seven additional true leaf primordia have been organized into the plumule of the plant. At that time the axillary meristems are sensitive to floral induction which is influenced by plant vigor and environmental conditions (Mauney, 1966).

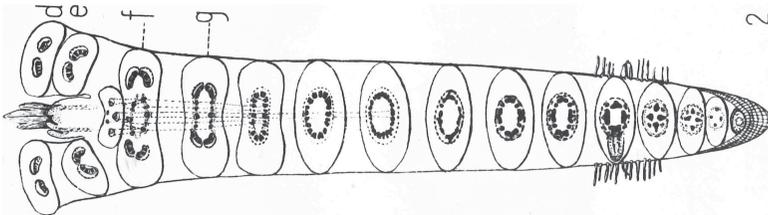


Figure 7. Drawing of the vascular development in the seedling axis. Note secondary root development and root hairs at transition zone to radicle.. From Baranov and Maltzev 1937.

SUMMARY

The structures of the cotton seed determine much of the developmental timing of the juvenile and mature plant. The well-developed seed radicle allows rapid establishment of a tap root to support the seedling. The cotyledons contain energy for seedling expansion and become photosynthetic immediately. The fact that the seed has no plumule delays seedling display of true leaves until the apical meristem can develop leaf primordia. Thus, the seedling stage is a long and vulnerable stage in the development of the crop.

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