ORIGIN, STRUCTURE AND PROPERTIES OF NON-DYEING LINT FIBERS: ANATOMICAL COMPARISON OF MATERNAL TISSUES IN COTTON SEEDS AND MOTES

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Abstract

A comparative anatomical analysis of developing cotton seeds and motes showed remarkable differences in the development of maternal tissues such as non-fiber epidermal cells, phloem, palisade cells, fringe layer, and nucellus as well as in the development of embryos and endosperm (Table 1). The study concludes that there is a correlation between embryo abortion and maternal tissue development.

Introduction

The development of cotton (*Gossypium hirsutum*) seed trichomes ("fibers") begins around the day of anthesis coinciding with pollination, fertilization and the beginning of embryo development. Unsuccessful fertilization or embryo abortion produces undeveloped cotton seeds ("motes;" Pearson, 1949; Joshi et al., 1967). Motes are perceived as the major source of offending fibers and imperfections in textiles. They produce high numbers of immature fibers that interfere with quality requirements. In order to address the possible origin of the problem, developing bolls were examined for mote production, followed by a comparative anatomical analysis of seeds and motes from the same boll.

Material and Methods

Developing cotton (*Gossypium hirsutum* 'Acala SJ2' and 'Acala Maxxa') bolls were collected from greenhouse-grown plants and prepared for microscopy. Seeds and motes were chemically fixed and embedded in Historesin (Jung, Leica Instruments GmbH, Heidelberg). Serial sections were cut at 2 to 3 μm and stained for cytochemistry as described in Weis et al. (1999). All observations were carried out on an Olympus BH-2 microscope (Southern Micro Instruments, Atlanta, GA).

Results

In cotton ovules (Fig. 1A) the two integuments (inner and outer) that later become the seed coats enclosed the nucellus and embryo sac. At the chalaza, the 'mesophyll' of the outer integument consisted of aerenchyma that surrounded the vascular bundles. The outer and the inner integuments were symplastically connected by parenchyma tissue ('plug').

Small motes (Fig. 1B) arrested developmentally at an early stage and were comparable in size to normally developing ovules of 5 to 10 dpa. Several very obvious defects were observed in both integuments and the nucellus. Fiber and non-fiber epidermal cells were not the size of normally developing cells, the integument mesophyll was collapsed, and the aerenchyma was absent. Some anomalous cells occasionally appeared in the region normally occupied by palisade cells.

Medium-sized motes (Fig. 2A) were distinctly different from seeds anatomically (Table 1). In the outer integument, phloem tissue appeared often collapsed, but not consistently so. In the inner integument, cells of the palisade layer were undeveloped or collapsed, except at the micropyle in the vicinity of the aborted embryo (Fig. 2A). In general, mote palisade cells did not develop thick secondary cell walls. The fringe layer (Fig. 2A, fl) was observed undeveloped or collapsed and almost undetectable and/or partially developed only at the micropylar end. Aborted embryos that we observed in motes at 29 dpa (Fig. 2A) and older were at the globular stage and embryo cells were highly vacuolated.

Discussion

Our comparative anatomical analysis of successfully developing cotton seeds and motes showed remarkable differences in the development of maternal tissues such as phloem, palisade cells, fringe layer, and nucellus, as well as in the development of embryos and endosperm (Table 1). Besides the underdeveloped embryos, the most striking feature in motes was the absence of secondary cell walls and its correlation with tissue development.

Secondary cell wall development normally occurs in cells of both the outer epidermis (such as fibers and non-fiber epidermis cells) and inner epidermal layers (palisade cells, and fringe-layer cells). It also occurs in integument mesophyll cells at both ends of the seed. In motes, however, except for the fibers, all other cell types were underdeveloped or collapsed. In cotton ovules, fiber initiation occurs about -3 to –1 dpa followed by elongation at the day of anthesis (Berlin, 1986). Primary fiber wall development is obviously not dependent on fertilization (Nolte et al., 1995; Weis et al., 1999). On the other hand, secondary cell wall formation in fibers and other tissues begins at 14-16 dpa (Meinert and Delmer, 1977; Ryser et al., 1988), well after the globular stage of embryo development (8-10 dpa). Therefore, the arrest of embryo development at the globular stage could affect secondary cell wall synthesis.

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Besides the absence of secondary cell walls, a lack of cell turgor presumably contributed to the observed tissue deformation and damage. The collapse of phloem tissue indicated that translocation of photoassimilates into the ovule/mote was blocked. Osmotic solutes and nutrients which otherwise would have supported cell growth and differentiation might not have been available in all parts of the ovule.

Summary

There is a correlation between embryo abortion and maternal tissue development (see Table 1). However, the analysis did not clarify which generation produces the signals that trigger developmental arrest in the maternal tissues and the embryo.

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Table 1: Anatomical differences of seed and mote tissues

	Seeds	Motes
Outer integument	Fiber and non-fiber epidermal cells with thick secondary wall	Except some fibers, no secondary cell wall thickening of non-fiber epidermal cells
	Aerenchyma at chalaza (Fig. 1A)	Aerenchyma cells at chalaza often (Fig. 1 B) collapsed
	Phloem cells normal	Phloem cells often collapsed
Inner integument	Palisade layer, elongated cells, cell walls thickened (Fig. 2), lignification	Palisade layer underdeveloped, collapsed at chalazal end, partially thickened at micropyle (Fig. 2)
	Parenchyma cell walls at chalazal and micropylar end thickened (Fig. 2)	No cell wall thickenings at either end of the mote (Fig. 2)
	Fringe layer with thick cell wall ingrowths (Fig. 2) on lateral walls, lignification	Fringe layer underdeveloped, collapsed; cell elongation and some thickenings at micropylar end (Fig. 2)
Nucellus	Hypostase (Fig. 1A) cell walls stain for phenols and callose	Hypostase cells sometimes collapsed
	Endosperm cellular	Endosperm appears absent
Embryo	Always fully developed (cotelydons, hypocotyls, radicle)	Absent or aborted (mostly globular stage at 8-12 dpa)

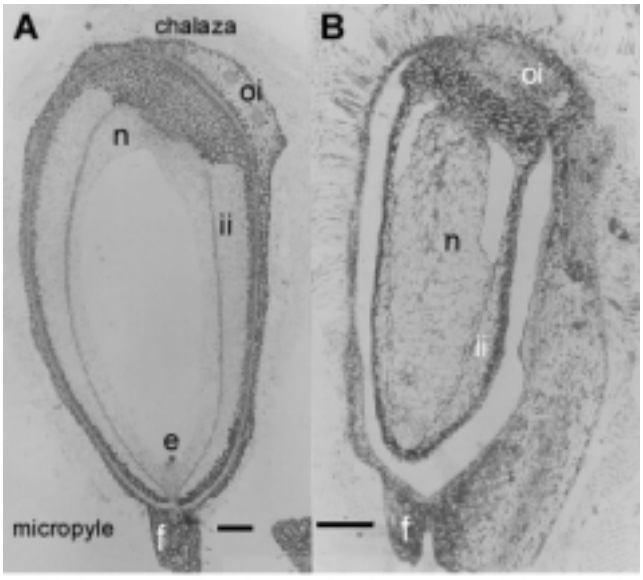

Figure 1. Longitudinal sections of a developing seed at 8 dpa (A) and a small mote at 18 dpa (B) stained with toluidine blue. Bars: 300 μm.

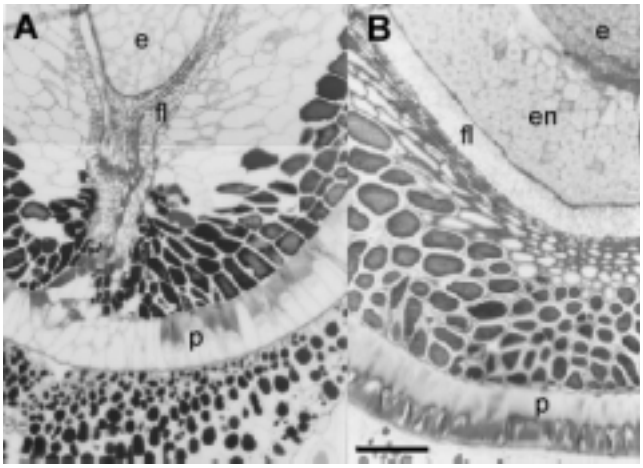

Figure 2. Longitudinal sections of the micropylar end of a medium-size mote at 29 dpa (A) and of a seed at 34 dpa (B) stained with toluidine blue.
Bar: 100 μm (A, B).

Outer integument (oi) and inner integument (ii), funiculus (f), fringe layer (fl), nucellus (n), embryo (e), endosperm (en).