Formation of the Secondary Cell Division Zone in Tomato Pedicels at Different Fruit Growing Stages

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Summary

The abscission zone of the tomato fruit pedicel is initiated by the onset of secondary cell division on the proximal side of pedicels adjacent to the primary abscission zone when the fruit is about 1 cm in diameter. Cells of secondary cell division zone which are flat situated in the inner cortex (central parenchymatous region) of the pedicel. The cells have thinner walls than those of the adjacent cells during the early stage of fruit development to the mature - green stage. At the mature stage, these secondary cell walls thicken and become heavily lignified.

Cells of the primary abscission zone which form at the flower bud stage are smaller and more densely packed than the adjacent cortical cells which are filled with cytoplasm and unlignified. Therefore, the newly formed secondary cell division zone may partly play a role of a protective layer, whereas the primary abscission zone acts as a fruit separation layer.

Key Words: abscission zone, fruit development, lignin, Lycopersicon esculentum, secondary cell division.

Introduction

The abscission zone of tomato flower pedicel which is initiated during the sepal differentiation stage of flower bud development, occur 15 to 20 cell layers deep from the apical surface of the central parenchyma (Tabuchi and Tanaka, 1990a; Tabuchi and Arai, 1998). As the floral stage proceeds to anthesis stage, the abscission zone extends to the epidermal region of the pedicel. During this stage, most of the cells in the abscission zone are characterized by their thin, unlignified walls. Provided the flowers are pollinated and the environmental conditions are favorable for fruit setting, fruit abscission does not occur until the tomato matures.

Tabuchi and Tanaka (1990b) reported the presence of lignified cell zone at the proximal side of the primary abscission zone. These cells which are initiated at the early stage of fruit development were examined histologically and characterized during the formation and development of the tomato fruit pedicels.

Materials and Methods

Seeds of 'Tiny Tim Red' were sown on April, 1989, and seedlings were transplanted to pots (15 cm in diam.) and grown in a greenhouse. Fruit pedicels at five growing stages were collected between July to August, 1989: 1) anthesis and when the fruits were 2) tiny (1 cm in diam.), 3) small (1.5 cm in diam.), 4) mature - green, and mature. Tissue samples of pedicels were fixed in FAA solution (100% ethanol: 30% formaldehyde: 30% acetic acid = 80:10:10, v/v), dehydrated through a tertiary butyl alcohol series, and embedded in paraffin. The embedded tissues were sectioned at 10 μm and stained with 0.1% toluidine blue-O (O'Brien et al., 1964) and photographed. The morphological changes in the different tissues of the primary abscission and secondary cell division zones in the pedicel were observed utilizing more than 20 longitudinal sections per developmental stage. The tissues of the primary abscission zone : epidermis, inner and outer cortex, and vascular bundles and the secondary abscission layer are Fig. 1A. The number of cells per tissue was counted by using a specimen that had the largest number of visible primary and secondary abscission zones.

Results and Discussion

At anthesis, the primary abscission zone was initiated, consisting of 6 to 8 layers with small, flat, cells which cut across the pedicel at the indentation of the epidermis (Fig. 1B). At fruit set, the initiation of secondary abscission zone was ascertained at the proximal side of the primary abscission zone (Fig. 1C, D). We refer to this group of flat cells which forms in the central cortical region (Fig. 1B to J) as the secondary cell division zone in this paper. Cells of the secondary cell division zone were flat in shape, and were forms in the central cortical region (Fig. 1B to J). At the mature - green stage, about 15 to 20 layers of meristematic cells appear (Fig. 1G, H); these have thinner cell walls than the adjacent parenchymatous cells. At the mature stage, their walls...
Fig. 1. (A): Diagram and photomicrographs of the abscission zones of the tomato pedicels.
V: Vascular bundle region. AZ: the primary abscission zone formed at the flower developing stage.
SD: the secondary cell division zone formed at the tiny fruit stage.
(B) - (J): Longitudinal sections of the primary abscission zone and secondary cell division zone in tomato fruit pedicels at different fruit stages.
(B): Anthesis stage. (C) and (D): Tiny fruit stage (1 cm in diam.).
(E) and (F): Small fruit stage (1.5 cm in diam.).
(G) and (H): Mature - green stage. (I) and (J): Matured stage.
(D), (F), (H), (I): Enlargement of (C), (E), (G), (I), respectively. Scale bar = 100 μm.
Fig. 2. Photomicrographs of transverse sections of secondary cell division zone of mature tomato pedicels. Arrows indicate the secondary dividing cells.

(A) and (B): Proximal pedicel between the primary abscission zone and the base of the pedicel.
(C) and (D): Mass of the secondary dividing cells (arrows in (C) and (D)) at the primary abscission zone. Walls of secondary cell division zone ((C) and (D)) are thick and darkly stained compare to the adjacent cells ((A) and (B)).
(B) and (D): Enlargement of (A) and (C), respectively. Scale bar = 100 μm.

Fig. 3. Changes of number of cells in different tissues of the primary abscission zone and secondary cell division zone in pedicel as the fruit develops.
- ○ - ○: Vascular bundle.
- □ - □: Central parenchyma.
- △ - △: Cortex.
- ● - ●: Epidermis.
- ▲ - ▲: Secondary cell division zone.

Cell division in this zone ceased (Fig. 3) as the fruit approached the mature-green stage; the percentage of lignified cells in the secondary cell division zone was small (Fig. 4). The percentage of lignified cells increased 90% between the mature-green and the mature fruit stages. In the primary abscission zone at the different fruit growing stage (Fig. 1B to J), thick lignified cell walls were not observed.

As fruit development proceeded, cells of the central parenchymatous region in the proximal and distal sides of the secondary abscission zone became flatter than did those in the adjacent tissues. In contrast, the cortical cells and those surrounding the vascular bundles in the primary abscission zone were isodiametric. The cells of the central parenchymatous region did not proliferate after anthesis (Fig. 3) but those in the cortical and vascular regions increased from the anthesis to the tiny fruit stage and then ceased.

The distal side of the primary abscission zone became concave as the fruit developed (Fig. 1C, E, G, I) because cell division in the central parenchymatous region
Fig. 4. Percentage of lignified cells per total number of cells in the secondary division zone at different fruit developmental stages.

ceased earlier than it did in the proximal side. Consequently, the cells of the primary abscission zone became pressed distally by the dividing cells on the proximal side.

When cell division in the abscission zone reoccurs, its portion for cell division consists of a few cell layers in either distal or proximal side of the primary abscission zone (Addicott, 1982; Montano and Proebsting, 1988; Sexton and Roberts, 1982; Webster, 1968). The 2 to 3 cell layers of the primary abscission zone, which separates the organ from its mother plant, consist of thin, un lignified cells. Consequently, they have loose combined structures and separate easily (Addicott, 1982). In contrast to the distal side, the proximal side acts as the protective layer. The highly lignified cells prevent the invasion of micro-organisms (Addicott, 1982; Sexton and Roberts, 1982; Webster, 1968) or suberin (Hänsisch ten Cate et al., 1973).

In tomato pedicels, this protective zone is differentiated 4 to 5 cell layers apart from the primary abscission zone on proximal side. The leaves of a juvenile oak trees (Bostrack and Daniels, 1969), needles of Douglas-fir (Montano and Proebsting, 1988), and soybean flowers (Oberholster et al., 1991) possess a similar structure except that in the tomato pedicels, it is limited to the central cortical region.

**Literature Cited**


トマトの果実発育に伴う小果柄の二次細胞分裂帯の形成

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摘 要

トマトの果実発育期における小果柄の離層の発達経過を解剖学的に調べた。その結果、果実の直径が1cmの幼果の段階で、花芽分化時に形成された既存の離層組織（一次分裂組織）の基部側に二次的に分裂した細胞群が認められた。これらの細胞群の形状は小果柄の軸に対して偏平であり、細胞壁も薄く、緑熟期に至るまで分裂し続けた。しかし、完熟期になると分裂を停止して、細胞壁は肥厚してリグニンが集積した。

その一方で、一次離層組織には細胞質が密に詰まっており、完熟期になってもリグニンの集積は認められなかった。以上の結果、花芽分化時に形成された一次離層組織は果実の脱離に関与する分離層としての役割を担い、幼果の段階で形成された二次的な細胞分裂帯が果実が脱離した後に小果柄の組織を保護するための保護層としての役割を担うと考えられた。