Structural Changes in the Abscission Zones of Pedicels at Different Ripening Stages of Tomato

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Summary

Structural changes in abscission zones on tomato pedicels were anatomically and histochemically investigated. One week after the onset of the fully ripe stage of fruit development, cells of the xylem parenchymatous region in the primary abscission zone which formed at the flower bud stage elongated longitudinally more than those of the adjacent cells. Ten days later, the elongated cells formed in the primary abscission zone, but their walls hydrolyzed in two weeks, leaving large intercellular cavities. Fruit abscission then occurred. Simultaneously, cells became lignified in the secondary cell division zone, on the proximal side of the abscission zone. No further development occurred until the fruit abscised. These results indicate that the primary abscission zone acts as the separation layer, whereas the lignified secondary cells act as the protective layer.

Key Words: abscission zone, cell elongation, fruit ripe stage, Lycopersicon esculentum, target cells.

Introduction

In the tomato flower pedicel, cells of the abscission zone are initiated during the sepal differentiation stage of a flower (Tabuchi, 1999). As fruit development proceeds, the secondary cell division zone is formed at the proximal side of the primary abscission zone (Tabuchi and Arai, 2000). Cell walls of the secondary cell division zone increase in thickness and become heavily lignified at full ripe stage. These results indicate that the primary abscission zone may act as a separation layer and the secondary abscission zone plays a role of the protective layer. However, the functions of these two abscission zones are unclear, we observed the structural changes in the primary and secondary abscission zones, anatomically and histochemically, on the tomato pedicels.

Materials and Methods

Tomato (Lycopersicon esculentum Mill. cv. ‘Tiny Tim Red’) plants were used for the experiments. Fruit pedicels at four mature stages were collected from the plants grown in a greenhouse: 1) full ripe stage, 2) one week after the onset of the full ripe stage, 3) 10 days after the onset of the full ripe stage, and 4) two weeks after the onset of the full ripe stage. Collected fruit pedicels were fixed in FAA solution (100% ethanol: 30% formaldehyde: 30% acetic acid=80:10:10, v/v), dehydrated through a graded tertiary butyl alcohol series, and embedded in paraffin. The embedded tissues were cut to longitudinal 10 μm thick sections with a microtome. The sections were stained with 0.1% toluidine blue-O as described in O’Brien et al. (1964) and Tabuchi (1998, 1999). Toluidine blue-O stains cell wall components such as pectin materials, cellulose, and lignin (O’Brien et al., 1964). The abscission zone of a fruit pedicel is divided into four histological regions: the central parenchymatous pith, vascular tissue (xylem and phloem), cortex, and the epidermis (Tabuchi and Arai, 2000). The morphological and histochemical changes of the primary and secondary abscission zones in the pedicels were observed more than 20 longitudinal sections at four ripening stages of fruit.

Results and Discussion

At full ripe stage (Fig. 1A), the cells between the primary (AZ) and secondary (SD) abscission zone are flattened in a tomato pedicel. One week later (Fig. 1B), the xylary cells in the primary abscission zone elongated longitudinally more than did those of the adjacent tissue. Ten days later, these elongated cells gradually expand toward the pith and cortex region in the primary abscission zone (Fig. 1C). Then, the elongated cells extend laterally in regions of the primary abscission zone (Fig. 1D) which consists of a single or two cell layers. The cell walls of these layers are thinner than those of the adjacent cells. Two weeks later, the cell walls of the elongated cells disintegrate, forming intercellular cavi-
ties (Fig. 1E). These cavities which develop only in the primary abscission zone enlarge. Finally, the fruit separates from the pedicel at this juncture (Fig. 1F).

The photomicrograph reveals that the cell walls of the primary abscission zone at full ripe stage stained darkly (positive) by toluidine blue-O (Fig. 1A), whereas the ripeing stage proceeded, the elongated cell walls of the primary abscission zone absorbed less stain (negative) (Fig.1 B–E). The low affinity of elongated cell walls for the stain after the onset of the full ripe stage of tomato fruit indicates that cell wall components, such as pectin and cellulose, degrade rapidly.

The degradation of cell wall components in the abscission zone accompanied by histochemical changes in bean petiole have been described (Rasmussen and Bukovac, 1969; Webster, 1968, 1975b), sweet cherry fruit (Stösser et al., 1969a), sour cherry fruit (Stösser et al., 1969a,b), and Cucumis fruit (Webster, 1975a). The breakdown of pectin and cellulose in the abscission zone is attributed to pectin metylesterase, polygalacturonase, and cellulases.

In tomato fruit pedicels, cell division was observed in the primary abscission zone during the floral bud developing stage, but no cell division was observed at the ripe stage of fruit. The female flower buds of Ecballium (Wong and Osborne, 1978), leaves of Impatiens sultani (Sexton and Redshaw, 1981), and processing tomato fruit with jointless pedicel (Tabuchi et al., 1999) underwent similar changes. In female flower buds of Ecballium, cell enlargement of the abscission zone is induced by exposure to ethylene; These enlarged cells at the ovary–pedicel junction have a large nuclei (8C DNA, nuclei more than 7.3 μm in diameter) compared to the nonenlarging neighbor cells (4C DNA, nuclei less than 4.8 μm in diameter) (Wong and Osborne, 1978). They proposed that the enlarged cells differentiated as target cells for ethylene. Subsequently, Osborne (1984, 1989) added that the ethylene responsive target cells in the abscission zone are enlarged by sufficiently high levels of the hormone. In pedicels, elongated cells in the primary abscission zone which may act as a target cell of ethylene, evolved from the ripe fruit, may secrete cell wall degrading enzymes, such as polygalacturonase or cellulase. Consequently, cell walls may become thin and allow elongation to occur in the primary abscission zone.

However, the lignified secondary cell division zone is found only in the proximal side of the primary abscission zone as the fruit ripens. Stösser et al. (1969b), Iwashori and van Steveninck (1976) reported the formation of secondary abscission zones in sour cherry and lemon fruits, respectively. However, these cell layers formed without cell division and lignification, which indicate that the formation of the secondary abscission zone induces leaf and fruit abscission. In tomato pedicels, secondary divided lignified cells occur only in the proximal side of the pedicel, even after the fruit abscission occurs; thus, we conclude that the primary abscission zone acts as a separation layer of fruit, and lignified secondary divided cells or periderm, acts as the protec-
tive layer against the invasion of micro-organisms.

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Literature Cited


