This report concerns increased understanding of the parameters of induction and early development of abscission in the 'Stanley' plum. It may also serve as a reference for abscission in other stone fruits, for abscission studies. Zucconi and Bukovac (13) stressed the importance of sampling considerations in relation to peach fruit abscission.

Leaf abscission in Phaseolus consists of 4 sequential stages which culminate in separation and are distinct in the laminar abscission region (11). These include 1) pith wall breakdown, which may not be related to abscission, 2) cell division, 3) cellular differentiation, and 4) cortical and vascular cell breakdown. Also cell divisions progress with time from outer toward inner cortical layers and, as cortical cells divide, some vascular cells do also (11).

Large quantities of starch were observed in the separation layer of mature orange fruits, but not in immature fruits; thus starch accumulation was not necessary for abscission (12).

Separation may result from dissolution of one or more layers of cells or cell parts. Three types of dissolution have been observed (1): the middle lamella between 2 layers of cells dissolves, the primary cell walls remaining intact; both middle lamella and primary cell walls between the 2 layers dissolve leaving, at most, thin cellulosic walls over the protoplasm; or entire cells of one or more layers dissolve. This study was designed to characterize and elaborate the sequence of structural changes related to abscission of the spur/pedicel in young-persisting fruits and 'drop' fruit of plum.

Materials and Methods

Young fruits were collected sequentially at various stages of development prior to and during abscission of first and second drops and 'June drop'. The persisting fruits were separated from those that were beginning to drop by absence of chlorophyll and cessation of growth in 'drop' fruit. Plant material was preserved in FAA, dehydrated through a

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Spur/Pedicel Abscession in Plum (Prunus domestica L. cv. Stanley) Morphology and Anatomy of Persisting and Drop Fruits

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Abstract. Parameters of spur/pedicel abscission in the plum (Prunus domestica L. cv. Stanley) have been recorded throughout induction and development during the early stages of fruit growth. This study of abscission includes both young-persisting and 'drop' fruits, each having diverse abscission potentials. Gross morphology revealed irregularity of pattern and stain intensity in abscission development occurring between the spur and fruit pedicle. Anatomical study indicated an effect upon cells (as far as 20-50 in number away from the immediate abscission zone) in response to safranin and fast green stains.

This report concerns increased understanding of the parameters of induction and early development of abscission in the 'Stanley' plum. It may also serve as a reference for abscission in other stone fruits, for correlation with growth, and for consideration of effective timing for the use of chemicals in fruit control. The developmental stages of floral-tube and style abscission in plum (Prunus domestica L.) have been characterized (8). Also, anatomical changes in abscission of reproductive structures have been summarized for Prunus persica, P. cerasus, P. avium and P. armeniaca (3, 4, 5, 6). These studies have been summarized in 'Shedding of Plant Parts' (9). Continued studies of the senescence phenomena of abscission that result in separation of the fruit pedicel from the spur were made to delineate further knowledge of this process in other parts of the plant. Rapidity of development of fruits of this species provides excellent material for abscission studies. Zucker and Bukovac (13) stressed the importance of sampling considerations in relation to peach fruit abscission. However, no studies on spur/pedicel abscission in plum have been reported.

The development of the laminar abscission zone of primary leaves of Phaseolus vulgaris L. was correlated with increasing frequency of tyloses and other plugging materials in the xylem, coupled with dissolution of callose from abscission zone sieve tubes (7). In cotton, the relationship between tyloses formation and abscission was not causal (2). Rather, tyloses development appeared to be a secondary phenomenon related to loss of membrane permeability and reduction of pressure in the vessels, with greater turgidity and metabolic activity of adjacent parenchyma. The work of Scott et al. and Bornman point out the existing variations between species.

Development of localized cellular senescence can play a major role in abscission (7). Tyloses formation in vascular elements may induce water stress in tissues distal to the separation zone. In addition, clearing of sieve-tube callose may facilitate mobilization from distal to proximal tissues. Both types of changes may hasten cellular senescence in the zone of separation.

Leaf abscission in Phaseolus consists of 4 sequential stages which culminate in separation and are distinct in the laminar abscission region (11). These include 1) pith wall breakdown, which may not be related to abscission, 2) cell division, 3) cellular differentiation, and 4) cortical and vascular cell breakdown. Also cell divisions progress with time from outer toward inner cortical layers and, as cortical cells divide, some vascular cells do also (11).

Large quantities of starch were observed in the separation layer of mature orange fruits, but not in immature fruits; thus starch accumulation was not necessary for abscission (12).

Separation may result from dissolution of one or more layers of cells or cell parts. Three types of dissolution have been observed (1): the middle lamella between 2 layers of cells dissolves, the primary cell walls remaining intact; both middle lamella and primary cell walls between the 2 layers dissolve leaving, at most, thin cellulosic walls over the protoplasm; or entire cells of one or more layers dissolve. This study was designed to characterize and elaborate the sequence of structural changes related to abscission of the spur/pedicel in young-persisting fruits and 'drop' fruit of plum.

Materials and Methods

Young fruits were collected sequentially at various stages of development prior to and during abscission of first and second drops and 'June drop'. The persisting fruits were separated from those that were beginning to drop by absence of chlorophyll and cessation of growth in 'drop' fruit. Plant material was preserved in FAA, dehydrated through a

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were large and lacked affinity for safranin. This is the beginning point of abscission development occurred between the spur and fruit/pedicel (Fig. 1-4). Stages of development would be beyond Stage VI (8), in which the floral-cup base had abscised. The fruit pedicels were intact and the stage of growth recorded would be between the second drop and “June drop”.

Fig. 1A shows development between the spur and pedicel of a persisting fruit. The central portion of the stem had intact vascular tissue and showed no evidence of abscission, although cortical cells were large and lacked affinity for safranin. This is the beginning point of abscission in a non-persistent fruit. Seven days later, the abscission pattern was evident over a wide area through the outer cortex on both sides of the fruit pedicel in a non-persistent fruit (Fig. 1B and C). Abscission-related changes affected approximately 20-50 cells in longitudinal width and extended into the phloem and xylem. The pith remained intact. A spur/pedicel of the size illustrated in Fig. 2,C might persist into the ‘June drop’ or third wave of abscission. In all cases, the point of abscission is initiated in the region contiguous to scar tissue (phellem, phelloderm and phellogen) from the base of previously abscised bud scales on the fruit spur. Fruit of the first drop ceased to grow as indicated by the small size and weak spur/pedicel development (Fig. 2 and 3A,B and C). Poorly developed vascular strands had been cut off by extensive development of the abscission layer from the outer cortex, with cellular changes occurring over a large area proximal and distal to the break. Breakage started in cortical cells contiguous to, and consequently cutting across, the vascular system. The affected area extended beyond cortical tissues into the phloem, xylem and pith (Fig. 2B and C). Progressive development of a second layer of abscission tissue had been initiated, farther down the pedicel toward the fruit (lower arrow), but this fruit would drop as a result of cellular activity in the initial abscission zone (Fig. 2C, upper arrow).

Growth variations in cells adjacent to the abscission layer were evident over a large area (Fig. 3A,B, and C). Constriction on the distal side of the abscission area was evident (Fig. 3A), with cortical cells becoming meristematic. Cells of the abscission zone continued to the base of the previous abscission of bud scales and floral abscission, resulting in phelloderm being produced in abundance throughout this area. The condition of this stage of development suggested that previous abscission injury might relate to abscission in later stages of development. Also, vascular branching proximal to the abscission break was evident (Fig. 3A and B, arrows). Breaks extending from the outer cortex into the vascular tissues and pith are illustrated (Fig. 3C, upper arrow). Abscission of the ‘June drop’ showed irregular development of the abscission layer through the basal portion of the fruit (Fig. 4A,B and C). Development was contiguous to that of previously formed tissues in abscission of the floral-cup base. It traversed the pedicel and severed vascular bundles thus separating the fruit and pedicel. Vascular bundles were necrotic and lignified contiguous to the fruit (Fig. 4C). This involved a more limited number of cells near the separation layer (Fig. 4A and B); but, in Fig. 4C there appeared to be a distal layer of cells that preceded the formation of a second layer over a large area of the fruit. Intense uptake of safranin staining throughout cortical tissues was apparent (Fig. 4A). Enlargement of this area is shown in Fig. 4C. Cells were nucleated and meristematic in relation to the separation layer. The first abscission development in the proximal end of the fruit is shown in Fig. 4B and C. Similar development was reported in sour cherry (Prunus cerasus L.) during fruit maturation, in the transition zone between the fruit and pedicel, consisting of 5-8 rows of cells (10).

Vascular bundle branching (Fig. 4B, arrows) was apparent in relation to the formation of the separation layer and was well-defined in relation to clusters of lignified and necrotic cells.

**Results**

**Gross morphology.** Irregular patterns and extent of abscission development occurred between the spur and fruit/pedicel (Fig. 1-4). Stages of development would be beyond Stage VI (8), in which the floral-cup base had abscised. The fruit pedicels were intact and the stage of growth recorded would be between the second drop and “June drop”.

**Morphology and anatomy of outer cortex, phloem and xylem.** Spur/pedicel abscission development of persisting fruit (that may develop into second drop fruit) is shown in the mid-pedicle of the pedicel, Fig. 5. Abscission was initiated in cells of the outer epidermis at a juncture marked by an indentation. The outer cortex cells had become meristematic with suberization and lignification occurring in cells contiguous to the epidermis. Lignification progressed toward the distal end where a well-defined phellogen layer had developed after abscission of bud scales. Abscission development had traversed (only 60%) the spur/pedicel union (Fig. 5A,B and C). The distal portion of the pith adjacent to the abscission layer did not stain with safranin. This was also the case in floral-cup abscission of stone fruits (3, 4, 5, 6, 8). Vascular tissue on the spur was still functional and stained readily with fast green. This viability would account for the persistence of this fruit.

Swirling of xylem and phloem was evident adjacent to the separation layer. Cortical and phloem cells of the fruit pedicel were lignified and retained safranin in the region of pedicel-fruit attachment. Periclinal and anticlinal divisions were apparent where the phloem tissues were traversed by development of the separation cavity (Fig. 5B).

Radial enlargement in the meristematic area of the abscission region involved only a few cell layers. This development progressed from the outer cortex through the vascular bundles into the pith. Tissue changes in the pith involved a layer of cells separating spur from pedicel with affinity for safranin, indicating lignification. These areas were located distal to the separation cavity. Cell walls in the pith gradually thickened. Areas throughout the vascular tissue (Fig. 5B) show little abscission-related development (only 3 cells in the separation layer). This indicates recent initiation of meristematic activity.

Characteristics of the cortical cell parenchyma of ‘drop’ fruit originated in the outer cortex and was contiguous with previous abscission sites of fallen bud scales or flowers (Fig. 6B, arrows). The cells covered a large area proximally and distally and did not stain positively with safranin or fast green.

Continued aberrations in tissue growth, resulting from the abscission process, at the point of fallen bud scales or flowers are illustrated, Fig. 7. Periclinal (P) and anticlinal (A) divisions were apparent in cortical cells adjacent to the phloem. Disorganization of phloem and xylem was apparent (Fig. 7), with cell divisions occurring to such extent that metabolites could have difficulty being translocated across the separation layer. Webster (11) found, prior to leaf abscission, increasing number of tyloses commonly materialize in the vascular elements at the abscission zone, and in Phaseolus, tanniferous compounds may appear in sieve elements as was characterized in the ‘Stanley’ plum.

A decrease in pedicel size was noted where abscission occurred between the spur and pedicel in this study of the plum. Separation of vascular strands involved only a few rows of cells; however, at the outer cortex, collenchymatous tissue had formed over a longer time as a result of the break in tissues. This had been completely separated as a result of cell divisions, while vascular tissues remained intact. A line of demarcation was evident, with only a few cells involved on the proximal and distal sides of the spur/pedicel.

Abscission of the xylem area. The abscission zone had a minimum of strengthening tissue progressing through the xylem as compared with the contiguous area (Fig. 8A-D). Xylem elements (XE) (indicated by arrows) were surrounded by lignified, thick-walled cells. This was characteristic of the abscission area, especially distal to the spur/pedicel (Fig. 8A-D). Meristematic activity, as evidenced by nucleated cells, was evident in tissues adjacent to the xylem, indicating several different stages of development have occurred within a limited time throughout the abscission area. Weakened periclinal and anticlinal cell walls adjacent to xylem elements facilitated separation of these tissues. The abscission process had developed across the cambium into the phloem (Fig. 8C, right). The proximal side of the abscission zone (Fig. 8D) showed xylem interspersed with parenchyma, progressing irregularly.
Fig. 1. Longitudinal sections showing gross morphological differences. A, spur/pedicel of persisting fruit; B, C, non-persisting fruit 7 days later. Note tissue changes in outer cortex (arrows). A, ×32; B and C, ×25.
Fig. 2. Longitudinal sections of non-persistent fruit showing abscission development traversing poorly developed vascular strands. Note that the abscission area always originates near the point of previous wound injury associated with abscission of bud scales and other floral organs (arrows). In 2,C, the extent of cell activity is indicated by arrows. A and B, x 16; C, x 12.
Fig. 3. Longitudinal sections showing growth variations occurring over a wide area between the fruit spur and pedicel of nonpersisting fruit. A) constriction of growth in abscission area; B and C) tissue changes that resulted in breaking and forming of swirling patterns of vascular tissue. A and B, ×20; C, ×32.
Fig. 4. Longitudinal sections showing fruit/pedicel abscission (arrows) in relation to previous abscission of the floral-cup base: A, irregular pattern in abscission development; B, swirling of vascular elements (VE, arrows); and C, large area of affected tissue in the outer cortex (OC, arrows). A, ×25; B and C, ×100.
Fig. 5. Abscission development between the spur/pedicel of a persisting fruit that will possibly abscise at a later date: A, tissue development crossing the vascular tissue (VT) and into the pith (Pi). B, enlargement of this VT area with cell wall thickening apparent on both sides of the abscission zone (P, proximal; D, distal), and small cells with walls intact in the immediate abscission area. C, arrow shows pith cells (enlarged from Pi in Fig. 5.A) that are void of cytoplasmic contents in relation to thick, suberized cell walls. A, x25; B, x100; C, x250.
Fig. 6. Spur/pedicel abscission starting in the outer cortex of drop fruit pedicel (A) and continued development 3 days later (B). A, ×160; B ×62.

Fig. 7. Spur/pedicel abscission originating in the outer cortex and traversing the phloem (PH) and into the xylem (X). Note extreme disorientation of the conducting tissues. Note periclinal (P) and anticlinal (A) divisions. ×100.
Fig. 8. Abscission development through the xylem and phloem tissues of non-persisting fruit. A, xylem tissue (XE) adjacent to pith; B, tissue adjacent to A showing phloem (PH) development; C, xylem adjacent to phloem (left) and abscission progressing into outer cortex; and D, line of abscission (arrows), showing irregularity and tissue development in relation to that on the proximal (P) side. Top figures – proximal side of abscission zone; bottom – distal side. A, B and C, ×400; D, ×160.
Abscission, progressing from the extreme right, was contiguous to the primary phloem fibers adjacent to the outer cortex of the pedicel (Fig. 9.A). Contents of cells on both sides of the abscission layer in the outer cortex stained with safranin, indicating cell wall thickening. However, stain affinity was lacking for safranin in the area where phloem and xylem tissues were evident and then traversed across the pedicel into the pith. Xylem and phloem fibers have thick walls and appear senescent some distance away from the abscission zone by increased uptake of safranin. Cell division was evident in the phloem companion cells proximal to the zone. These cells were distorted by parenchyma tissue interspersed between the protophloem cells. Small islands of cells arranged in a circular pattern developed 20–30 cells.

Fig. 9. Abscission development in a non-persisting fruit traversing phloem tissue in 3 different locations of a spur/pedicel: A, meta-phloem (MP) with nucleated parenchyma (NP) in the abscission region, and protophloem fibers (PF) adjacent to nucleated cambial tissues (CT); B, phloem (P), left, adjacent to cambial tissue (CT) (right); note division occurring along the abscission line with an abundance of nucleated cells; C, abscission in phloem region showing nucleated phloem parenchyma (PP) adjacent to phloem fibers (PF). Proximal side of the pedicel from abscission zone is located at top of each figure. A, ×1,000; B and C, ×1600.
closer to the proximal side, resulting in a distinct forking pattern and disorientation of the functioning phloem. This development might hinder normal translocation (Fig. 3A and B).

Wall thickening of some cells, with an abundance of nucleated cells, was evident (Fig. 9B). Adjacent cells were thin walled; they eventually collapsed. Lack of safranin stain affinity on the proximal side of the juncture indicated lack of lignification and more parenchymatous tissue development. Cell wall thickening and lignification were apparent on the distal side.

Cell division and wall thickening occurred in cells adjacent to the protophloem fibers (PF) (Fig. 9C). Although no breakage of fibers was evident, division was apparent in adjacent parenchyma cells. Cell separation by anticlinal means (indicated by arrows) was evident and resultants may separate along the newly formed wall. Although separation was not evident, strands stained readily with safranin some distance away from the abscission zone, indicating that the abscission effect was taking place in these tissues.

Spur/pedicel abscission in non-persisting fruits was irregular in growth and extent as compared to persisting fruits. This abnormal development extended 20-50 cells proximally and distally as indicated by affinity to stain. Extensive vascular branching occurred on the proximal side of the abscission and, in some cases, this area extended into 2 definite zones.

**Literature Cited**


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**Antitranspirant Effects on Fruit Growth of ‘Manzanillo’ Olive**

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**Abstract.** An antitranspirant (AT) applied 2–3 weeks before harvest accelerated olive (*Olea europaea L.*, cv. Manzanillo) fruit growth and led to larger fruit at harvest. The fruit-enlarging effect was detected within 1 day of application. A simulated rain also increased fruit size, but much of the gain in size was lost as soon as the “rain” was terminated. Daytime fruit shrinkage was reduced significantly with the AT. At harvest, fruit moisture was higher in AT-treated fruits, and after harvest the water lost from fruits was lower. When AT was substituted for the last pre-harvest irrigation, fruit size was increased.

The climate is usually dry and warm before and during the olive harvest in California. Growers have observed that if rain occurs during this period it increases olive size and dollar returns. Hence, such precipitation is referred to as “million-dollar rain.” The increase in fruit size is attributed entirely to the rain, not to increased soil moisture. It is presumed that: 1) the fruit absorbs rainwater; and/or 2) the high ambient humidity during such weather retards water loss. If the latter is the cause, an antitranspirant (AT) would be expected to increase fruit size (1–8). We compared the effect of an antitranspirant (6) and of artificial rain on olive fruit growth near harvest. The antitranspirant effect was studied also on trees with the last pre-harvest irrigation omitted.

**Materials and Methods**

The 20-year-old olive trees used in this experiment were growing in the Wolfskill Experimental Orchards at Winters. Two irrigations were applied during the summer. An additional irrigation (last pre-harvest irrigation) of about 13 cm was given on September 24 to most of the orchard but withheld from 1 area. Soil moisture changes in the irrigated and unirrigated sections were determined gravimetrically by soil sampling at 30-cm intervals to a depth of 120 cm. Samples were taken periodically in the irrigated and unirrigated areas at 2 locations each.

Since crop loads were variable, the trees were rated into 3 crop categories: good, moderate, and light. For each treatment, 1 tree was selected at random from each category, making 3 replicate trees per treatment.

For fruit growth measurements 20 fruits were selected randomly at about 1.5 m height around each tree and tagged. An ink spot was placed on the check of the fruit so that the diameter could be measured at the same point each time with a caliper. Measurements were made at 1 to 4 day intervals between 0800 and 0900 hr. On most dates a second measurement was made at about 1600 hr to determine fruit shrinkage between morning and late afternoon.

The first antitranspirant spray (early) was applied on October 6. The antitranspirant (AT) spray used was a wax-latex experimental product (CS-6432) of the Chevron Chemical Company, applied at 1.5% a.i. in water (v/v) with a hand gun under 400 lb pressure from an orchard sprayer. Thorough coverage was obtained by wetting

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