Organization of root apical meristems in some angiosperms

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Abstract. The root apical organization in three angiosperm plants belonging to different families and growth habits was studied at three developmental stages (embryonal, seedling and older roots). Iberis amara Linn. and Euphorbia pulcherrima Klotzsch showed a 'closed' type of organization with discrete initials for the cortex, columella and stele. Mangifera indica Linn. roots with an 'open' type of organization, had common initials for the stele and columella and a cup-shaped initiating zone for the cortex. In all the three species the epidermis and peripheral part of the rootcap arise from a common complex of initials. The samples from well established plants in Euphorbia and Mangifera also contained dormant and metacutinized roots. The growing (older) roots in Mangifera showed a small quiescent centre at the root pole.

Key words: Angiosperms; Closed type; Euphorbia pulcherrima Klotzsch; Iberis amara Linn.; Mangifera indica Linn.; Metacutinization; Open type; Quiescent centre; Root apical organization.

Introduction

Literature reveals only a few attempts at suggesting classification and evolutionary trends in root apical organization. Erickson (1878), Popham (1952) and Guttenberg (1960) have classified and Haberlandt (1914), Voronin (1956), Pillai (1966) and Bhambie and Rao (1973) suggested some evolutionary trends in the root apical structures. It has been proposed to investigate the ontogeny, structure and classification of root apical meristems in plants of different habits and families. A few aspects of these have been reported in some Mimosoideae (Sharma and Sharma, 1988) and Polyalthia longifolia (Sharma and Sharma, 1988). The present study deals with the ontogeny, structure and classification of root apical meristems in Candytuft, Poinsettia and Mango.

Materials and Methods

The seeds of Iberis amara Linn. (Candytuft), Euphorbia pulcherrima willd. ex Klotzsch (Poinsettia) and Mangifera indica Linn. (Mango) were soaked in water overnight and embryos from these were dissected out to collect the radical apex. Soaked seeds were also germinated in petriplates lined with moist blotting paper and in Iberis were transferred to earthenware pots after one week. During the first week after seed wetting when the radicle measured 5.0

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to 10.0 mm the root apices were harvested. Root apices from well established plants from the field in *Euphorbia* and *Mangifera* and from the earthenware pots in *Iberis* were also collected. About 15 samples of each material were fixed in FAA, dehydrated through TBA series and embedded in paraffin. Serial longitudinal sections cut at 4-5 μm were stained with safranin-light green combination (Johansen, 1940) and PAS-reaction (Jensen, 1962). Width of the root body and rootcap was measured at the columella head. Sectional surface area were obtained (Sass, 1964; Sharma and Sharma, 1988) and multiplied with the total number of quiescent cells and expressed in μm². To calculate nuclear area the formula πr² has been used and expressed in μm².

**Results**

In all the three species the embryonal, seedling and older roots showed a similar type of organization. Samples from well established plants of *Euphorbia* and *Mangifera* also contained dormant roots along with active ones. The tips of dormant roots appeared brown while those of growing roots are white or lightly coloured.

The structural organization in the root apices falls under two types viz., the 'closed' type in *Iberis* and *Euphorbia* and the 'open' type in *Mangifera*. The diameter of the root body and peripheral part of the rootcap etc. are given in Table 1. There is a gradual decrease in width of the root body from embryonal to seedling and older root apices in all the species.

**The type I (*Iberis* and *Euphorbia*)**

The cortical, columella and central cylinder initials are arranged in the form of 3 or 4 superimposed tiers at the root pole (Figs. 11, 12). The initials for epidermis and peripheral part of the rootcap are present at the periphery of the root, proximal to the root pole as the rootcap-epidermis complex.

The cortical initials in *Iberis* are arranged in a tier between the columella initials and central cylinder initials and are 2-4 (in L. S.) cells wide (Figs. 1, 11). The cells are densely stained and their peripheral derivatives show Korper divisions followed by differentiation into cortex proximally (Figs. 1, 2, 5). In *Euphorbia* the cortical initials are two layered (Figs. 2, 5, 12).

The central cylinder initials are represented by a tier of 5-7 cells (in L. S.) proximal to the cortical initials (Figs. 1, 2). The proximal

<table>
<thead>
<tr>
<th>Organism</th>
<th>Stage</th>
<th>Diameter</th>
<th>Width of peripheral region (one side in L.S.) (μm)</th>
<th>Area of quiescent centre (μm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Euphorbia pulcherrima</em></td>
<td>Radicular apex</td>
<td>292.0</td>
<td>96.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Seedling root</td>
<td>280.0</td>
<td>95.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Well established (older) root</td>
<td>272.0</td>
<td>90.0</td>
<td>—</td>
</tr>
<tr>
<td><em>Iberis amara</em></td>
<td>Radicular apex</td>
<td>240.0</td>
<td>73.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Seedling root</td>
<td>232.0</td>
<td>71.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Older root</td>
<td>200.0</td>
<td>70.0</td>
<td>—</td>
</tr>
<tr>
<td><em>Mangifera indica</em></td>
<td>Radicular apex</td>
<td>1200.0</td>
<td>480.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Seedling root</td>
<td>972.0</td>
<td>360.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Older root</td>
<td>700.0</td>
<td>250.0</td>
<td>180.0</td>
</tr>
</tbody>
</table>
Figs. 1-6. Median longitudinal sections of the root apex at different developmental stages.

Figs. 1, 3. *Iberis* radicular apex Fig. 1 ×200, Fig. 3 ×250.
Figs. 2, 4. *Euphorbia* radicular apex ×250.
Fig. 5. *Euphorbia* older root apex ×250.
Fig. 6. *Euphorbia* dormant root showing metacutinized layers ×200.
(Figs. 3, 4, 6—Apices stained with PAS reagent)
derivatives of these widen by Korper divisions and differentiate into the central cylinder.

The initials for columella are immediately distal to the cortical initials and about 5-6 cells wide in *Iberis* and 3-5 cells wide in *Euphorbia*. These cells are densely stained and divide by regular anticlinal and occasional periclinal divisions to form 7-9 vertical columella files (Fig. 1).

The cells in the rootcap-epidermis complex are denser stained than all the other initials. These divide by anticlinal divisions proximally and Kappe divisions distally. The proximal derivatives differentiate into the epidermis and the distal derivatives into the peripheral part of the rootcap (Figs. 1-5).

**The type II (Mangifera)**

The root apices have a common group of initials for the stele and columella and a hollow cup-shaped initiating zone for the cortex. The epidermis and peripheral part of the root-cap arise from a common complex of initials. On the basis of cell complexes observed the apex can be broadly divided into six zones viz., Zone 1 (the central group of initials), Zone 2 (the stele), Zone 3 (the columella), Zone 4 (the initiating zone for the cortex), Zone 5 (the cortex) and Zone 6 (the rootcap-epidermis complex) (Figs. 7, 8, 13).

The Zone 1 is flat to concave and present at the head of columella. The distal derivatives of this zone give rise to the columella and proximal ones to the stele. In older roots, the centrally located cells in this zone are lighter stained than the peripheral ones (Fig. 7) and n/c ratio (nuclear to cell area ratio) shows a higher value in the latter than the former region (Fig. 10). There is a gradual increase in the n/c ratio of the peripheral region as the root grows (from embryonal to seedling and older roots).

The central cylinder in the radicular and
The type I in *Iberis* and *Euphorbia* showed discrete initials for the stele, cortex and columella and the type II in *Mangifera* had common initials for the stele and columella and a cup-shaped initiating zone for the cortex. Both the types reported here resemble the 'closed' and 'open' types respectively according to the classification of Guttenberg (1960). The 'open' type of organization reported by Sharma and Sharma (1988) in three tree species of Mimosoideae resembles that in *Mangifera* except for the rootcap-epidermis complex present in the latter.

Guttenberg (1955), Byrne and Heimsch (1970) and Armstrong and Heimsch (1976) reported some ontogenetic changes in the root apical organization. In the present study as also the previous reports (Sharma and Sharma, 1988), the apical organization remains unchanged during ontogeny. Armstrong and Heimsch (1976) reported reduction in cortical initials from two-layered to single-layered during ontogeny in three species of compositae but the two-layered cortical initials is a constant feature in *Euphorbia*.

Haberlandt (1914) suggested an evolutionary trend in the organization of root apical meristems and considered the apical meristems with common group of initials as advanced over the stratified apical meristems. Voronin
Figs. 11-13. Diagramatic representation of the two types of root apical organization.

Fig. 11. Type I in *Iberis*.
Fig. 12. Type I in *Euphorbia*.
Fig. 13. Type II in *Mangifera*.

(1, 2, 3, 4, 5, 6=Different zones of the apex; C=Cortex; CC=Central cylinder; CCI=Central cylinder initials; CI=Cortical initials; CO=Columella; COI=Columella initials; E=Epidermis; KA=Kappe divisions; KO=Körper divisions; M=Metacutis; R=Peripheral part of the rootcap; REC=Rootcap-epidermis complex).

(1956), Pillai (1966) and Sharma and Sharma (1988) considered the type of apical meristems with common initials as phylogenetically primitive. The present study significantly showed the 'open' type in the tree species and 'closed' type in the herbaceous and shrub species. This is in accord with the previous reports (Sharma and Sharma (1988) in some Mimosoideae and Sharma and Sharma (1988) in *Polyalthia longifolia*). The data support Voronin and others.

Clowes (1954) advanced the concept of quiescent centre in roots of *Zea*. The older roots of *Mangifera* showed a lightly stained hemispherical group of cells at the root pole. Clowes suggested that the cells located on the surface of the hemisphere are the initials and that the cells within the centre itself divide seldom, if at all. The n/c ratios in the two regions support this. But the presence of quiescent centre is not a constant structural feature as it is not seen in all the roots of *Mangifera* and any root of the other two species.

In dormant roots the meristem is isolated from the outside by layers of darkly stained cells with lignified and suberized walls. The formation of such layers was referred to as "metacutisierung" by Plaut (1910) and metacutization by Wilcox (1954). The development of metacutis can be compared to the type I reported by Sharma and Sharma (1988) in *Polyalthia longifolia*.

**Literature Cited**


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曼生之植物的根尖分生組織

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研究三種屬於不同科的生長習慣的被子植物在三個不同發育階段（胚芽、苗和老根）的根尖分生組織。Iberis amara Linn. 和 Euphorbia pulcherrima Klotzsch 為閉式組織，皮層、輸柱及中柱各具有不同的原始細胞。Mangifera indica Linn. 之根為閉式組織，中柱及輸柱具有共同原始細胞，皮層有維管的原始帶。此三物種之表皮和根冠周圍細胞皆發生自共同原始細胞複合體。取樣 Euphorbia 和 Mangifera 之良好植株有休眠和後角化的根。Mangifera 的生長（老）根之根尖出現一小靜止中心。