Morphogenesis of pericarp in two varieties of *Momordica charantia* L.

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Abstract

The fruits of *Uchchey* and *Karala*, two common Indian varieties of *Momordica charantia* L. have the same length and diameter in initial stages. But with age the rate of lengthwise growth becomes higher in *Karala*, which differs from *Uchchey* by its larger size and much elongated shape. The major cause of their difference in size and shape is the higher cell number of *Karala* in its axial direction from the earliest stages of development, and their rapid transverse division during maturation. Differentiation of xylem bundles of the pericarp starts at the middle and apical parts of the ovary. The courses of differentiation of xylem in the middle, apical and basal bundles are bidirectional, basipetal and acropetal, respectively.

INTRODUCTION

One of the most significant fact in the organic growth is that it is a controlled process which progresses in an orderly fashion for the attainment of the specific shape. The fundamental causes of this integrated development are attributed to "correlation" which may be broadly classified as physiological and genetic (Sinnot 1960). Scientists have reported correlations between cell volume and organ size, of plane and rate of cell multiplication and cell enlargement with the shape and size of organs (Smith, 1950; Maltzahn, 1957; Sinnott, 1939), and phasic relation between cell division and cell enlargement (Mounts, 1932; Erickson and Sax, 1956; Goodwin and Avers, 1956; Maksymowych, 1963). The object of the present study is to discover what type of cellular behaviour (rate or plane of division, or rate or direction of cell enlargement, etc.) are responsible for the ultimate difference of shape and size of the two horticultural varieties *Uchchey* and *Karala* of *Momordica charantia* Linn., used widely as vegetable. The former is small and roundish and the latter large and elongated (Fig. 1).

Fig. 1. *Momordica charantia* L. mature fruits of two varieties 'Karala' (large one) and 'Uchehey' (small one)

MATERIALS AND METHODS

Seeds collected from a local nursery were sown in the experimental garden of the University of Calcutta (India). Flowers and fruits of different size were fixed in formalin-propino-alcohol (Johansen, 1940), and ultimately embedded in paraffin. Serial sections were microtomed at $10\ \mu$ and stained in crystal violet. Areas for spherical and prolate spheroidal cells were calculated with the formulae $4\pi r^2$ (where r =radius) and $4\pi a.b$ (where $a=1/2$ major axis, $b=1/2$ minor axis) respectively. For

studying chromosomes, healthy roots were treated in aesculin (Sharma and Sarkar, 1955), and was finally squashed in the aceto-orcein technique. Figures were drawn with camera lucida.

RESULTS AND CONCLUSIONS

Chromosome morphology

Both the varieties of *M. charantia* have the same number ($2n=22$) and more or less similar appearance of chromosomes. Details of the structure of chromosomes of course differ. The secondary constrictions involve only one pair in *Uchchey* and two pairs in *Karala*. The chromosome types are 2A, 18B, 2C (Fig. 2A) in *Uchchey* and 4A, 14B, 4C (Fig. 2B) in *Karala*.

Fig. 2. Idiograms showing chromosome types (somatic) of '*Uchchey*' (A) and '*Karala*' (B)

Of the three chromosome types, A ($2.5-2 \mu$), has two constrictions forming three unequal segments, one terminal being longest, the other shortest, B ($2.5-1 \mu$), bears a median constriction and C ($1.7-1 \mu$), a submedian one. Thus these two varieties are two chromosomal biotypes.

Relations between dimensions

In initial stages both the varieties have the same length and diameter of the ovary (Fig. 3) Gradually the rate of lengthwise growth is higher in *Karala* than in *Uchchey*. But the increase in diameter of *Uchchey*, upto the 20th day after initiation, is almost equal to or slightly higher than that of *Karala*. Fig. 3 shows these relations between the diameter and length of fruits of the two varieties.

Gross anatomical zones of mature fruits

A cross section of a mature fruit reveals five zones—Zone 1: Epidermis; Zone 2: Subepidermis, spherical or spheroidal parenchymatous cells; Zone 3: The middle

Fig. 3. Graph showing correlation between length and diameter of fruit

region, consisting of large parenchymatous cells, oblate — spheroidal in T. S. with the major axis parallel to surface, intervened by vascular bundles, appearing as a net work in tangential views; Zone 4: Placentae consisting of small isodiametric cells; Zone 5: Innermost layer, consisting of cells smaller than outer epidermal ones.

Correlation between part and whole

A. Cross area of cell and fruit

Figures 4 to 7 represent a relation of the cross area of fruits and area of cells in T. S. of zones 1-4. The increase in area of cells in zone 1 is comparatively higher in *Uchhey* than in *Karala*. In all other zones area of cells in T. S. is larger in *Karala*. Thus it is clear that the relation between cross areas of fruits and the cells differs in different zones. The increase of diameter and cross area of fruits is slightly higher in *Uchhey* than in *Karala* (Fig. 8), though the cells of the former are narrower. Of course, within the varieties there is a correlation between cell area and fruit area in T. S. This type of correlation has been referred as correlation of part and whole as reported between sizes of bean leaf and of entire bean plant (Sinnott, 1921); between sizes of pod and seeds (Sinnott, 1921); between size of buds and the size of shoots (Crane and Finch 1930); between meristematic cells and fruit size in *Cucurbita pepo* (Maltzahn, 1957); and between cell diameter and fruit size in different races of *Cucurbita pepo* and *Lagenaria vulgaris* (Sinnott, 1939). This relation between part and whole seems to be different for the two varieties and the cell diameter of the two varieties is not related much to the difference of fruit diameter of the two.

Mounts (1932) observed that in *Vitis*, cell enlargement begins as mitosis ceases. Erickson and Sax (1956), Goodwin and Avers (1956), and Maksymowych

Figs. 4—7. Graphs showing correlation between cross area of fruits and cross area of cells of Zone 1 (fig. 4), Zone 2 (fig. 5), Zone 3 (fig. 6), and Zone 4 (fig. 7)

U — 'Uchchey'; K — Karala'

(1963), on the other hand, have supported the hypothesis that cells are elongating when cell division is in progress. Graph 4 to 7 show that when the rate of crosswise increase of cell area (particularly of zones 1 and 4) slows down, the cross area of fruits continues to increase. This must be due to cell multiplication which does not stop after a phase of cell enlargement, though there must be a limit of expansion, after which a cell will not divide (Maksymowych, 1963).

Fig. 8A shows that the diameter of fruit upto the 20th day is less in *Karala* than in *Uchchey*, though the cell number (radially) increases more in the former (Fig. 8C). The explanation lies in the cross area of cells (Fig. 8B) which is distinctly less in *Karala*.

Fig. 8. Cross-wise growth of ovary upto the 20th day of initiation.

U — Uchchey; K — Karala

A — increase in diameter; B — increase in mean cell area (cross-wise); C — increase in cell number, radially from epidermis to placenta, at the middle region.

B. Length of fruit and fruit cells

Figure 9A shows that *Karala* fruit elongates more rapidly than *Uchchey*. Figures 9B to 9F show that in the early stages of growth, height of cells of different

Fig. 9. Length-wise increase of ovary up to the 20th day.

U — 'Uchchey'; K — 'Karala'

A — Length of ovary; (A); Mean height of cells in Zone 1 (B), Zone 2 (C), Zone 3 (D), Zone 4 (E), Zone 5 (F)

zones increase with this elongation of fruits. But in *Karala*, in contrast to the greater elongation of fruit, cell elongation of different zones (Figs. 8B-8F) is less.

Relation between cell number and fruit size

Cell size, though correlated with fruit size of individual varieties, can not explain the gulf of difference between the sizes of *Karala* and *Uchchey* fruits. One must seek the explanation in cell multiplication. Though the crosswise increase in number of cells accompany growth of both the varieties and it is more rapid in *Karala* than in *Uchchey* (Fig. 8C), the difference is much conspicuous in the lengthwise increase of cell number (Fig. 10). Radial and longitudinal number of cells in *Karala* is higher from the very early stage, when both the varieties have almost the same length of ovary.

Fig. 10. Length-wise increase of cell number in ovary of 'Uchchey' (U) and 'Karala' (K) upto the 20th day

Cells of *Karala* are shorter than those of *Uchchey* in zone 3 in the early stages. The increase in cell number is very rapid in *Karala* in comparison to *Uchchey*, which explains the longer dimension of the former.

Vascular differentiation

Macerations of the pericarp show the nature of phloem cells and vessels.

Vessels of *Karala* are longer and broader than those of *Uchchey*. Vessel members of the smallest ovaries of both the varieties have loose spiral thickening. They are 112.5 μ long, and 22.9 μ broad in *Karala*, and 108 μ long and 16.6 μ broad in *Uchchey*. In mature fruits, vessel members are large, mean length and breadth being 217.9 μ and 30.5 μ in *Karala*, and 194.1 μ and 14.5 μ in *Uchchey*. Thickening bands are highly condensed and almost indistinguishable. Long and narrow sieve tubes are visible in the smallest fruits. Sieve tubes newly differentiated in 10 to 12 days old fruits are much longer in *Karala* (57.1 μ) than in *Uchchey* (37.0 μ). In well developed fruits of *Karala* and *Uchchey* their mean lengths are 71.4 and 41.8 μ respectively.

Tracheary elements are first formed at the middle portions, at the peduncle and at the neck region of the cortex of the inferior ovary (Fig. 11). By progressive acropetal growth of the basal bundles, basipetal growth of the neck bundles and bidirectional growth of the middle bundles, continuity is established. The vascular bundles

Fig. 11. Growth of vascular bundles in the two varieties

A and B — differentiation of tracheary elements at the middle part and at neck in the stages 1 and 2; C and D — rows of elongated provascular cells differentiating into vascular interconnections in stages 2 and 7

gradually anastomose and from a reticulum 16 days after fertilization. These interconnections begin to develop within four to five days after initiation, when certain contiguous cells of the ground tissue divide in a particular direction to produce rows of elongated cells (Fig. 11) which gradually differentiate into the vascular bundles, as in early stages of *Luffa* fruit (Sinnott and Bloch, 1943). Many undifferentiated or partly differentiated such elongated cells noticed after 16 days of fertilization, are multinucleate (Fig. 11). List (1963) has reported such multinucleate early vessel members and their mother cells in *Zea mays*, *Arisaema triphyllum*, *Marsilea quadrifolia*, *Acorus calamus*, *Pellandra virginica*, etc.

Thus in the development of the ovary of *Uchchey* and *Karala*, the two cytologically distinct Indian varieties of *M. charantia*, though the enlargement of cells in the longitudinal and radial dimensions has a role on the difference in their shape and size, the major causes of the difference are the number of cells in the axial direction from the very early stages of development and the rate of their transverse division during maturation. The differentiation of tracheary elements in both the varieties follows a common course of bidirectional progress from the middle part of the ovary, basipetal growth from the neck and acropetal growth from the base, simultaneously interconnecting by formation of vascular elements by unidirectional division of certain adjacent cells and lengthwise expansion of the derivatives.

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Morfogeneza owocni dwóch odmian Momordica charantia L.

Streszczenie

Owoce dwóch odmian *Momordica charantia* L. 'Uchchey' i 'Karala' różnią się znacznie kształtem i wymiarami, choć ich zawiązki są bardzo podobne. Odmiana 'Karala' ma znacznie większe i dłuższe owoce. Główną przyczyną różnic w kształcie i wielkości jest większa liczba komórek wzdłuż osi podłużnej od samego początku rozwoju oraz szybkie tempo ich poprzecznych podziałów w okresie dojrzewania owoców.

Opisano także różnice w rozwoju wiązek naczyniowych w obu badanych odmianach.