

Epidermal Structure and Stomatal Types in Some Species of Korean Crassulaceae

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韓國產 돌나물과(Crassulaceae) 數種의 表皮構造와 氣孔類型

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ABSTRACT

This study was carried out to investigate the epidermal structure and types of stomata on the upper and lower surfaces of the leaves in six species and one variety belonging to Korean Crassulaceae. The shape of epidermal cells was polygonal, isodiametric, or elongated. The cell wall was thick, sinuous or deeply sinuous. The subsidiary cell wall was thin or mostly arched. The cytolith-containing cells were found in *Orostachys japonicus*. The distribution of stomata was more on the upper surface than on the lower surface in the leaves of *O. japonicus* and *Sedum sarmentosum*. The stomata in the other species were less on the upper surface than on the lower surface, and stomatal size was different in each species. The great majority of stomatal types was the helico-eumesogenous type. This type was subdivided into two, parahelico-eumesogenous type and diahelico-eumesogenous type by us on the basis of the angle of division of guard mother cell and the long axis of the last-formed subsidiary cells. Sometimes allelo-eumesogenous type as well as aniso-eumesogenous type was found. The tetra-eumesogenous type with four mesogenous subsidiary cells was rarely observed. It was observed that the varieties of aniso-eumesogenous type with one to three subsidiary cells and one helix of subsidiary cells were developed by the secondary division of subsidiary cells of aniso-eumesogenous stoma. The compound shape of helico-eumesogenous stomata was found. Five new kinds of stomatal types were observed as follows; the helico-tetra-eumesogenous type, the coallelohelico-eumesogenous type, the cohelico-allelo-eumesogenous type, the duplotetra-eumesogenous type, and the aniso-euperigenous type. These types were reported here in the vascular plants for the first time.

INTRODUCTION

Stomata in dicotyledons were reported firstly to be classified in various types of

stomata by Vesque (1889). He proposed a terminology that was exemplified and firstly observed in the families of Ranunculacéae, Crucifere, Rubiacée, Labiée or Caryophyllée. Metcalfe and Chalk (1950) discussed the difficulties of terminology proposed by Vesque (1889). They developed a second terminology which was widely used for anomocytic (ranunculaceous), anisocytic (cruciferous), paracytic (rubiaceous), diacytic (caryophyllaceous), and actinocytic types of stomata that were newly found and named the above five stomatal types. Pant (1965) and Payne (1979) reclassified the embryophyte on the basis of stomatal ontogeny. Cotthem (1970) reclassified the adult stomata on the basis of their morphological feature with fifteen types. Fryns-Claessens and Cotthem (1973), Dilcher (1974), and Stevens and Martin (1978) discussed and associated the terminology with a morphological feature of adult stomata and ontogenetic stomata.

In Crassulaceae Strasburger (1866) reported the stomatal development in the leaves of *Sedum spurium*. Yarbrough (1934) pointed out that the stomatal ontogeny was proceeded by spiral preparatory divisions forming four to six subsidiary cells. Metcalfe and Chalk (1950) suggested that the stomata in most of Crassulaceae were nearly always surrounded by a girdle of three subsidiary cells. Therefore, they used the terminology of anisocytic for the cruciferous. Inamdar and Patel (1970) reported that the great majority of stomata was the anisocytic type being surrounded by three to six subsidiary cells in *Kalanchoe*. Payne (1970) found helicocytic and allelocytic types in many Crassulaceae and the other several families of dicotyledons. The study on the stomatal types in Korean Crassulaceae has not been known. Therefore the present study was carried out to investigate on the epidermal structure and the stomatal type in Korean Crassulaceae. Some new stomatal types which were found by the authors were reported here.

MATERIALS AND METHODS

The materials of six species and one variety belonging to Crassulaceae were examined. The plants such as *Orostachys japonicus*, *O. malacophyllus*, *Sedum kamschaticum*, *S. aizoon* var. *heterodontum*, *S. alboroseum*, *S. bulbiferum*, and *S. sarmentosum* were collected from the field growing under the natural condition at the area of Chinju and then were normally grown on the sand culture of Hoagland solution in the polyethylene flower pots from April to August, 1982~1983. The epidermal peels of sample were taken from the young and mature fresh leaves by making the paradermal hand section for the observation of stomatal types. They were stained with saffranin, and then mounted in the glycerine water solution. They were observed and microphotographed with the Olympus Universal Research Microscope of Vanox Model AD-1. The terminology used here was followed to Stevens and Martin (1978), and Patel (1978).

RESULTS AND DISCUSSION

Epidermal structure. Although the number of stomata per square millimeter was different in each species, the leaves of all the material plants were observed as an amphistomatic. The leaves were a few or a lack distribution of stomata in vein. The epidermal cells were polygonal, isodiametric, sometimes elongated in vein, and irregularly arranged. Also their cell walls were thick and sinuous or deeply sinuous (Table 1), but subsidiary cell walls were thin (Patel, 1978) and mostly arched (Fig. 20-22, 27, 28, 31-38). A noteworthy difference between two species in *Orostachys* was an occurrence of cytolith in *O. japonicus* (Fig. 38-40) and a compound helico-eumesogenous stomata in *O. malacophyllus* (Fig. 37). The distribution of stomata in the leaves of *O. japonicus* was more on the upper surface than on the lower surface (Table 2). The stomata of *O. japonicus*, *O. malacophyllus*, *S. alboroseum*, *S. bulbiferum*, and *S. sarmentosum* occurred as well-marked groups. The difference among the species of *Sedum* was the occurrence of deeply sinuous-walled epidermis in two species of *S. bulbiferum* and *S. sarmentosum*, but the other species were sinuous. In *S. alboroseum* the first-formed subsidiary cells might become noticeably larger than the other species (Fig. 36). The compound helico-eumesogenous stomata in *S. kamschaticum* and *S. aizoon* var. *heterodontum* existed more than the other species (Table 1).

Types of stomata. The protodermal cell was divided unequally into two cells. One larger cell developed into the epidermal cell, the other smaller cell developed into the stomatal meristemoid (Fig. P 1, 15) like other reports (Esau, 1953, 1965, 1977; Lee and Hong, 1961; Payne, 1970; Fahn, 1974). Sometimes it was divided equally to produce two stomatal meristemoids in the area of vein on the leaves in *S. kamschaticum*, and *S. aizoon* var. *heterodontum* (Fig. P2, 16; Johnson and Riding, 1981). In *S. sarmentosum*, stomatal meristemoid was divided equally into two stomatal meristemoids in the area of vein (Fig. H1, 17).

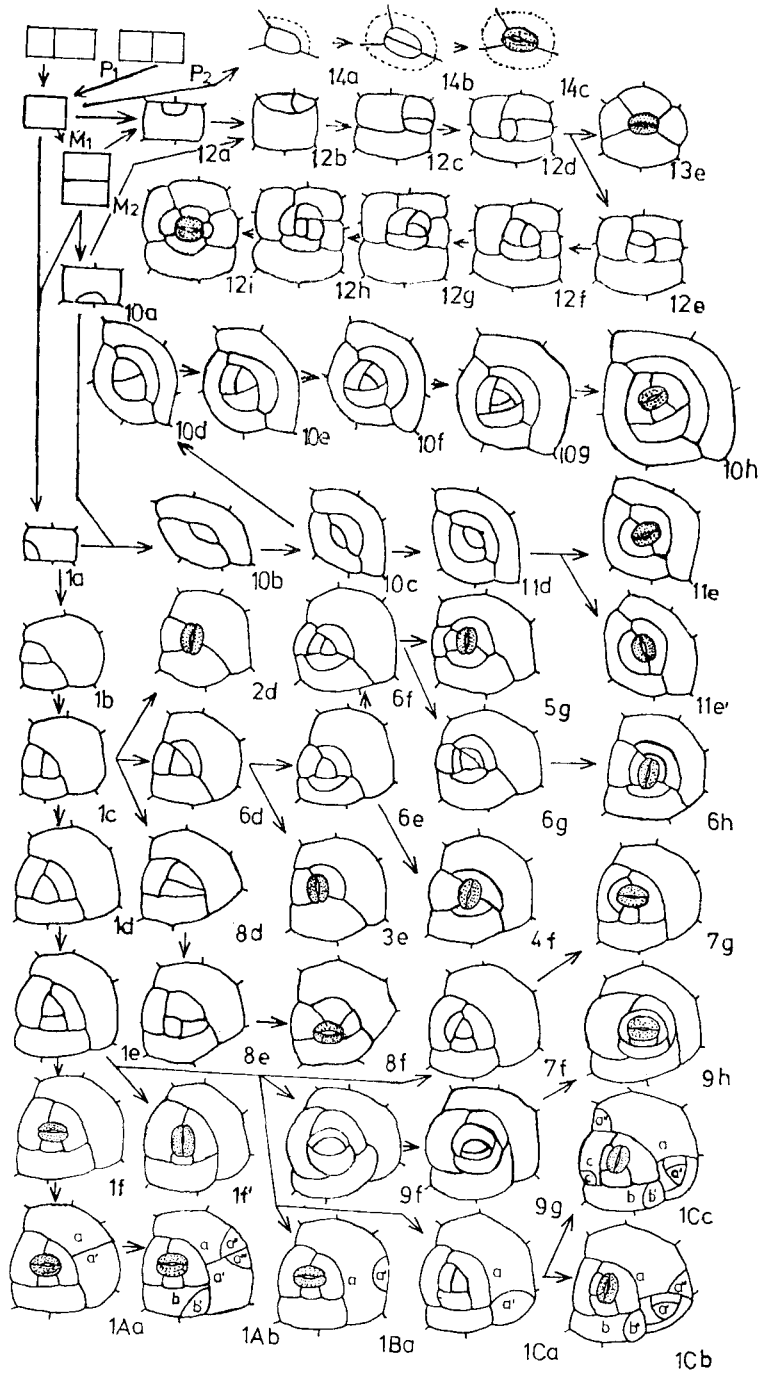
The stomatal meristemoid was tetragonal or pentagonal, and scattered or clustered in random fashion (Fig. 15, 16, 28, 30), and also occurred on both upper and lower surfaces of the leaves. It could be easily distinguished from the adjacent epidermal cells by its small size, densely staining properties, and prominent nucleus (Fig. 15, 16, 34; Inamdar and Patel, 1970). The stomatal meristemoid was divided into various patterns in the shape and in the orientation of the common wall between two daughter cells which were generally unequal in volume (Fig. 1a, 10a, 12a, 16). This common wall in the shape could be cut off so that a small triangular daughter cell might be formed at one corner of stomatal meristemoid (Fig. 1a, 15-17), and divided unequally by a curved wall from a side of stomatal meristemoid (Fig. 10a, 12a, 26). Development of various stomatal types from stomatal meristemoids was discussed as follows.

(1) Helico-eumesogenous and aniso-eumesogenous types. The stomatal meristemoid was

divided into unequal cells. One large cell differentiated as the first subsidiary cell, while the other cell divided again. The new curved wall was placed at an interior angle of about 60° to the preceding one so that a helix of subsidiaries was formed. The guard cells were completely surrounded by three subsidiary cells among four to six cells in the helix (Fig. 1, 15-17, 28, 31-38). At any stage of the development, the last-formed and smallest cell might act as a guard mother cell and produce two guard cells by an ultimate division of the parallel or at right angle to the long axis of the last-formed subsidiary cell. These became parahelico-eumesogenous (Fig. 1f, 28, 31-34, 38) and diahelico-eumesogenous stoma (Fig. 1f', 35, 37). In the case of the ultimate division, after three times division of stomatal meristemoid, an aniso-eumesogenous stoma was produced (Fig. 2, 21). The spiral sequence of division might be either clockwise or anticlockwise direction (Fig. 15, 28; Pant and Kidwai, 1967; Payne, 1970).

Vesque (1889) regarded such stomata as cruciferous on the basis of development. Metcalfe and Chalk (1950) introduced the terminology of anisocytic for the cruciferous type of Vesque (1889) on the basis of the structure and the orientation of mature stomata. According to them, the stomata in Crassulaceae were surrounded by a girdle of three cells. Whatever, Yarbrough (1934) pointed out that the stomatal ontogeny in *Bryophyllum calycinum* was preceded by the spiral preparatory divisions forming four to six subsidiary cells. Korn (1972) reported that stomata in *Sedum stahlii* were anisocytic type possessing usually six subsidiary cells. These cells were formed by the spiral series of cell division, the last of which produced two guard cells. Inamdar and Patel (1970) reclassified them as three subtypes with anisocytic stomata, such as monocyclic surrounded by three, incompletely amphicyclic surrounded by four to five, or completely amphicyclic surrounded by six subsidiary cells. In the present study the parahelico-eumesogenous type could be applied to the report of Yarbrough (1934) and Korn (1972), and to two subtypes of incompletely amphicyclic anisocytic and completely amphicyclic anisocytic type among anisocytic stomata

Fig. 1-14. The developmental pathway of ontogenetic types of stomata in Crassulaceae. Fig. P1, P2. Protodermal cells divided unequally (P1) or equally (P2) into the stomatal meristemoid. Fig. M1, M2. Stomatal meristemoid divided unequally and developed into stomata (M1) or divided equally into two stomatal meristemoids (M2). Fig. 1. Ontogeny of helico-eumesogenous stomata inducing to parahelico-eumesogenous type (1f) and diahelico-eumesogenous type (1f'), and ontogeny of the second (1Aa-a,a'; 1Ba-a,a'; 1Ca-a'), third (1Ab-b,b'; 1Cb-b,b'; 1Cc-b,b'), fourth (1Ab-a,a'''; 1Cb-a,a'''; 1Cc-c,c'), and fifth (1Cc-a,a'') stoma in the subsidiary cells of helico-eumesogenous stoma. Fig. 2-7. Ontogeny of aniso-eumesogenous type (2d) and the varieties of aniso-eumesogenous type with one (3e), two (4f), three (5g) subsidiary cells, a helix of subsidiaries (6h) developed by the secondary division of subsidiary cells of aniso-eumesogenous stoma, and the variety of helico-eumesogenous type (Fig. 7g). Fig. 8. Ontogeny of the compound type of helico-eumesogenous and tetra-eumesogenous type derived from Fig. 1c (8f) stage. Fig. 9. Ontogeny of coallelo-helico-eumesogenous type derived from Fig. 1e stage. Fig. 10, 11. Ontogeny of cohelico-allelo-eumesogenous type (10), and allelo-eumesogenous stomata inducing to diallelo-eumesogenous type (11e) as well as parallelo-eumesogenous type (11e'). Fig. 12. Ontogeny of duplotetra-eumesogenous type. Fig. 13. Ontogeny of tetra-eumesogenous type derived from Fig. 12d stage. Fig. 14. Ontogeny of aniso-euperigenous type.

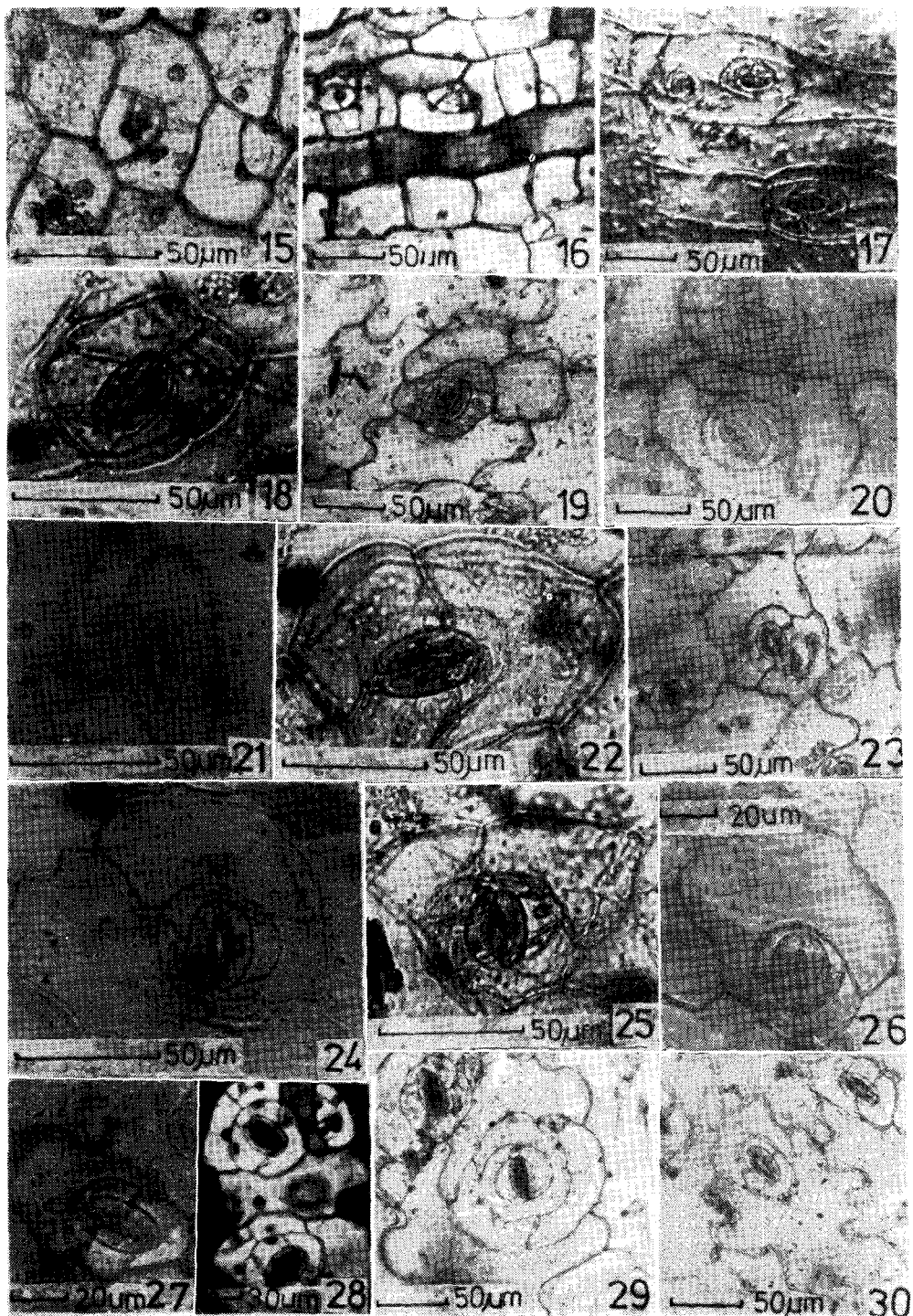


of Inamdar and Patel (1970). Also, the aniso-eumesogenous type could be applied to the monocyclic anisocytic type of Inamdar and Patel (1970).

According to the reports (Bünning, 1952; Korn, 1972; Sachs, 1974; Esau, 1977; Marx and Sachs, 1977), the stomatal meristemoid inhibited all the adjacent cells becoming stomatal meristemoid. This phenomena appeared strongly in *O. japonicus* (Fig. 38). In the other species, the inhibitory influence was decreased with increasing the distance from the developing stoma like other reports (Marx and Sachs, 1977; Jeong, 1983). Three subsidiary cells directly surrounding the developing stoma could act as an inhibitory zone in this study and other reports (Fig. 1Ab, 1Cc, 28, 31-37; Pant and Kidwai, 1967; Jeong, 1983). All the plants except for *O. japonicus* were retaining the meristematic activity for a long time like the reports (Yarbrough, 1934; Paliwal, 1967; Inamdar *et al.*, 1969; Inamdar and Patel, 1970; Payne, 1970; Jeong, 1983). The secondary and tertiary stomatal meristemoid might develop from the other subsidiary cells except for the inhibitory zone directly surrounding the developing helico-eumesogenous stomata, and produce various compound helico-eumesogenous types like the reports (Payne, 1970; Fryns-Claessens and Cotthem, 1973). The secondary division of subsidiary cells began at a center or a corner, sometimes a side of subsidiary cell in the present study (Fig. 1Aa, 1Ab, 1Ba, 1Bb, 1Ca, 1Cb, 1Cc, 28, 32-34).

After three divisions of the stomatal meristemoid, one to three subsidiaries and a helix of subsidiaries developed by the secondary division of subsidiary cells of aniso-eumesogenous stomata were found (Fig. 3-6, 22-24, 27). Also, one subsidiary cell developing by the secondary division of the first-formed cell in three subsidiary cells directly surrounding two guard cells of helico-eumesogenous stoma was found (Fig. 12, 36). This stoma became a variety of helico-eumesogenous type.

Fig. 15-42. Stomatal types and epidermal structure in Crassulaceae. Fig. 15. Early stage in ontogeny of helico-eumesogenous type in *S. aizoon* var. *heterodontum*. Fig. 16. Stomatal meristemoid and developing stomata at vein region of *S. aizoon* var. *heterodontum* (noted the protodermal cell divided equally into two stomatal meristemoids). Fig. 17-25. Stomatal types of *S. sarmentosum*; Fig. 17. Developing stomata from two secondary formed-stomatal meristemoids by the longitudinal division of stomatal meristemoid, Fig. 18. Tetra-eumesogenous type with four mesogenous subsidiary cells, Fig. 19. Duplotetra-eumesogenous type with a helix of eight mesogenous subsidiary cells doubly surrounding the guard cells, Fig. 20. Parallelo-eumesogenous (upper) and parahelico-eumesogenous stoma (lower), Fig. 21. Aniso-eumesogenous type, Fig. 22-24. The varieties of helico-eumesogenous type with two (Fig. 22), three (Fig. 23) subsidiary cells, and a helix of subsidiary cells (Fig. 24) developed by the secondary division of subsidiary cells of aniso-eumesogenous stoma, Fig. 25. Helico-tetra-eumesogenous type, a compound type of helico-eumesogenous and tetra-eumesogenous type. Fig. 26, 30. Diallelo-eumesogenous type in *S. alboroseum* (noted stoma developed by a curved wall from a side of stomatal meristemoid cell like Fig. 26) and *S. bulbiferum* (Fig. 30). Fig. 27, 28. The variety of aniso-eumesogenous type with one subsidiary cell developed by the secondary division of the first-formed subsidiary cell at aniso-eumesogenous stoma (Fig. 27) and the secondary stoma developed at the center of subsidiary cells in helico-eumesogenous stoma in *S. aizoon* var. *heterodontum* (Fig. 28). Fig. 29. Coallelo-helico-eumesogenous type of allelo-eumesogenous in the center of helicoallelo-eumesogenous in *S. bulbiferum* developed.



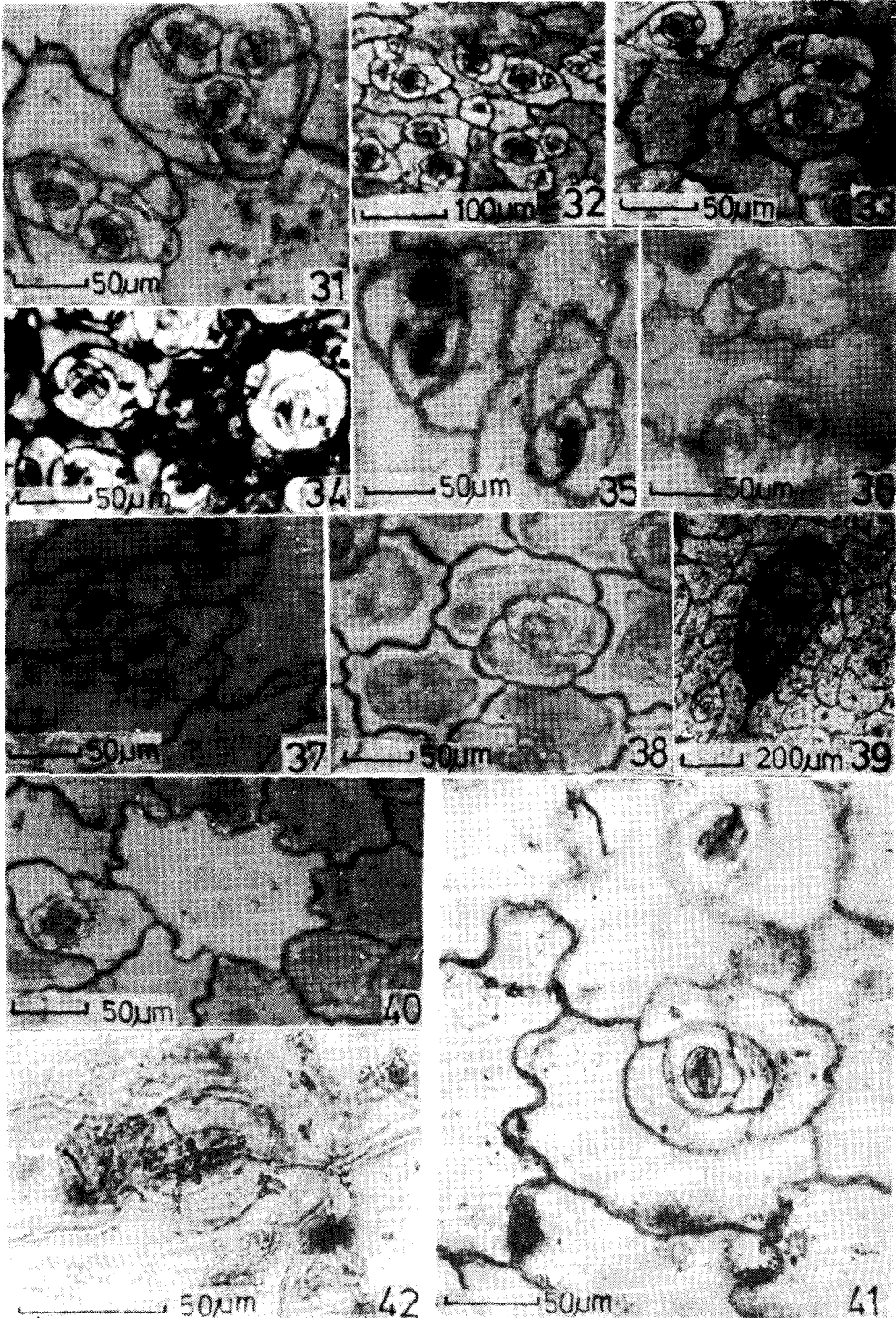
(2) Helico-tetra-eumesogenous type. The stomatal meristemoid was divided into unequal cells. In subsequent division the curved wall was placed at an interior angle of about 60° to the preceding cell. After that, one to three subsidiary cells were produced, and the new curved wall was placed at an interior angle of about 90° to the preceding cell. Finally one helix of five or more mesogenous subsidiary cells including four mesogenous subsidiary cells directly surrounding the guard cells was developed. This stoma became compound type between helico-eumesogenous and tetra-eumesogenous type. It was firstly found in *S. sarmentosum* (Fig. 8, 25).

(3) Coallelo-helico-eumesogenous type. The stomatal meristemoid was developed into an alternating complex of three or more C-shaped mesogenous subsidiary cells of graded sizes of surrounding guard cells in the center of a helix of three or more mesogenous subsidiary cells (Fig. 9, 29). Occurrence of the other type in the center of one stomatal type was reported in Polypodiaceae by Patel *et al.* (1975). This type was firstly found in *S. bulbiferum*. Therefore the authors proposed this as a coallelo-helico-eumesogenous type.

(4) Cohelico-allelo-eumesogenous type. The stomatal meristemoid was developed into one helix of four or more mesogenous subsidiary cells surrounding the guard cells in the center of an alternating complex of three or more C-shaped mesogenous subsidiary cells of graded sizes (Fig. 10). This type was firstly found in *S. bulbiferum* (Fig. 41). Therefore the authors proposed this as a cohelico-allelo-eumesogenous type. The difference between coallelo-helico-eumesogenous type and cohelico-allelo-eumesogenous type occurred that the former was developed into allelo-eumesogenous in the center of helico-eumesogenous stoma, and the latter was developed into helico-eumesogenous in the center of the allelo-eumesogenous stoma.

(5) Allelo-eumesogenous type. The stomatal meristemoid was divided into an alternating complex of three or more C-shaped subsidiary cells of graded size, and the smallest central cell was differentiated into the guard mother cell. The cell could be divided at a right angle to the subsidiary cells and finally formed diallelo-eumesogenous type (Fig. 10e, 26,

Fig. 31. Epidermal structure and a compound helico-eumesogenous stoma in *S. sarmentosum*. Fig. 32, 33. Compound helico-eumesogenous stomata developing at cluster and the epidermal structure of *S. kamtschaticum*. Fig. 34. The secondary stoma developing at one side of the first-formed subsidiary cell in *S. aizoon* var. *heterodontum*. Fig. 35, 37 Parahelico-eumesogenous type and diallelo-eumesogenous type of *S. bulbiferum* (Fig. 35) and *O. malcophyllus* (Fig. 37). Fig. 36. The first-formed subsidiary cell noteworthy larger than the others, and the last-formed subsidiary cell smaller than the others, also the stoma keeping three subsidiary cells developed by the secondary division of subsidiary cells of aniso-eumesogenous stomata, and stoma with one subsidiary cell developed by the secondary division of first-formed subsidiary cells in three subsidiary cells directly surrounding two guard cells of helico-eumesogenous stoma in *S. alboroseum*. Fig. 38-40. Stomatal type of *O. japonicus*; Fig. 38. Epidermal structure without a compound helico-eumesogenous stoma, Fig. 39. The resolute cytolith in lithocyst, Fig. 40. The beneath-formed cytolith on epidermis. Fig. 41. Cohelico-allelo-eumesogenous type of helico-eumesogenous in the center of allelo-eumesogenous type in *S. bulbiferum*. Fig. 42. Aniso-euperigenous type with three perigenous subsidiary cells in *S. sarmentosum*.



30). On the other hand it might take a parallel direction with the subsidiary cells and form parallelo-eumesogenous type (Fig. 11e', 20; Payne, 1970; Fryns-Claessens and Cotthem, 1973). The latter could be applied to incompletely amphicyclic caryophyllaceous and completely amphicyclic caryophyllaceous stomata by Pant and Mehra (1963), and Inamdar (1970).

(6) Duplotetra-eumesogenous and tetra-eumesogenous type. The stomatal meristemoid was divided into two unequal cells by a curved wall at a corner or a side of meristemoid cell. In the subsequent division the new curved walls placed at an interior angle of about 90° to the preceding one so that a spiral of eight mesogenous subsidiary cells developed into an amphicyclic surrounding two guard cells. The difference between this type and the cyclocytic type of Stace (1965) or the cyclo-mesogenous type of Fryns-Claessens and Cotthem (1973) was important that one helix of eight mesogenous subsidiary cells doubly surrounding two guard cells was produced by the spiral division of stomatal meristemoid. This stoma was firstly found in *S. sarmentosum* by us. Therefore we proposed this as a duplotetra-eumesogenous type. If the guard mother cell was generated, the four divisions of stomatal meristemoid in duplotetra-eumesogenous development appeared, and then a tetra-eumesogenous type with four mesogenous subsidiary cells was produced (Fig. 13, 18). This type was observed in *S. sarmentosum*, *S. alboroseum*, and *S. bulbiferum*.

(7) Aniso-eumesogenous type. The meristemoid was cut off from a corner of some large epidermal cells. This cell developed into the guard mother cell which divided into the guard cells. In three adjacent epidermal cells the additional divisions occurred to form three perigenous subsidiary cells which developed into aniso-euperigenous type (Fig. 14, 42). By the difference between this type and aniso-eumesogenous type, this type had three perigenous subsidiary cells in stead of three mesogenous subsidiary cells of aniso-eumesogenous type. This stoma was firstly observed in *S. sarmentosum*.

The ontogenetic pathway and types of stomata were summarized in Fig. 1-14 and Table 1. The great majority of stomatal types was helico-eumesogenous type (Fig. 28, 31-38). This type was observed in all species. Sometimes, aniso-eumesogenous type (Fig. 21) was found in all material plants except for *S. kamschaticum* and *S. aizoon* var. *heterodontum*. Also, allelo-eumesogenous type was found. Tetra-eumesogenous type was rarely found (Fig. 18). Particularly in the present study five types of unrecognized stomata were found as follows; helico-tetra-eumesogenous type (Fig. 25), duplotetra-eumesogenous type (Fig. 19) and aniso-euperigenous type (Fig. 42) in *S. sarmentosum*, and coallelo-helico-eumesogenous type (Fig. 29) and cohelico-allelo-eumesogenous type (Fig. 41) in *S. bulbiferum*. Different types of stomata were observed in the same species (Table 1) like others (Pant and Kidwai, 1967; Payne, 1970) as well as in the same surface of leaf like Jeong (1983). Payne (1970) reported that the helicocytic and allelocytic stomata occurred on the fresh leaves in the plant of arid habits, evergreen species, or weeds of primary site for which stress could be severe. In the present study our results were agreed with the report of

Table 1. Stomatal types in Korean Crassulaceae

Species	Stomatal types	Stomatal number per cluster	Epidermal structure	Number of Fig.
<i>Orostachys japonicus</i>	Helico-eumesogenous, sometimes aniso-eumesogenous	1	Deeply sinuous	P1, M1, 1a-f, 2, P1, M1, M2, 1a-f, 1a-f'
<i>O. malacophyllus</i>	Helico-eumesogenous, sometimes aniso-eumesogenous	1-4	Deeply sinuous	1Ca.
<i>Sedum kamschaticum</i>	Helico-eumesogenous	2-6	Sinuous	P1, P2, M1, M2, 1a-f, 1A-C, 2-4, 7.
<i>S. aizoon</i> var. <i>heterodontum</i>	Helico-eumesogenous	2-6	Sinuous	P1, P2, M1, M2, 1a-f, 1A-C, 2-4, 7.
<i>S. alboroseum</i>	Helico-eumesogenous, sometimes aniso-eumesogenous, allelo-eumesogenous, rarely tetra-eumesogenous	1-2	Sinuous	P1, M1, 1a-f, 1Ca 11-e, 13, 11a-e', 2-4, 7, 8.
<i>S. bulbiferum</i>	Helico-eumesogenous, sometimes aniso-eumesogenous, allelo-eumesogenous, rarely tetra-eumesogenous, coallelo-helico-eumesogenous, cohelico-allelo-eumesogenous	1-3	Deeply sinuous	P1, M1, M2, 1a-f, 1a-f', 1Aa, 1Ca-c, 3, 10h, 11e, 11e' 2-4, 7-9.
<i>S. sarmentosum</i>	Helico-eumesogenous, sometimes aniso-eumesogenous, allelo-eumesogenous, rarely tetra-eumesogenous, duplotetra-eumesogenous, helico-tetra-eumesogenous, anisoperigenous	1-4	Deeply sinuous	P1, M1, M2, 1a-f, 1A-C, 2-8, 11-14.

Table 2. Distribution and size of stomata on the upper and lower surfaces of the leaves in Korean Crassulaceae

Species	Stomatal number/mm ²		Stomatal size, μm			
	Upper	Lower	Upper		Lower	
			Length	Width	Length	Width
<i>Orostachys japonicus</i>	27	18	23.3	15.0	24.3	16.0
<i>O. malacophyllus</i>	17	38	26.7	21.8	37.0	20.8
<i>Sedum kamschaticum</i>	35	59	33.3	22.5	34.0	21.3
<i>S. aizoon</i> var. <i>heterodontum</i>	27	52	47.5	27.8	46.8	26.0
<i>S. alboroseum</i>	21	30	32.5	21.0	33.5	22.5
<i>S. bulbiferum</i>	14	35	38.3	23.0	35.3	21.5
<i>S. sarmentosum</i>	45	39	36.8	22.0	38.3	20.3

Payne (1970).

Distribution and size of stomata. The number of stomata per square millimeter and size of stoma with two guard cells in each species was given in Table 2. The distribution of stomata in the leaves of *O. japonicus* and *S. sarmentosum* were more on the upper surface

than the lower surface. In the other species the number was more on the lower surface than the upper surface. The difference of stomatal number was recognized in each species (Table 2). Yarbrough (1934) noticed that the succulents had relatively fewer stomata than thin-leaved dicotyledons with stomata only on the lower surface in *B. calycium*. Meidner and Mansfield (1968) described that the succulents like Crassulaceae had low stomatal frequency. In these material plants our results were agreed with their reports. The number of stomata per cluster in each species would be obvious from Fig. 15-42 and Table 1 like Payne (1970).

The largest size of stomata was $47.5 \times 27.8 \mu\text{m}$ on the upper surface and $46.8 \times 26.0 \mu\text{m}$ on the lower surface of the leaves in *S. aizoon* var. *heterodontum*. The smallest size was $23.3 \times 15.0 \mu\text{m}$ on the upper surface and $24.3 \times 16.0 \mu\text{m}$ on the lower surface of the leaves in *O. japonicus*. The difference of stomatal size was recognized in each species of Table 2.

摘 要

韓國産 돌나물科(Crassulaceae)에 屬하는 7種을 普州 近郊에서 採集하여 實驗室의 自然條件에서 Hoagland 培養液으로 生長시켰다. 正常으로 生長한 잎의 表皮構造와 氣孔의 類型 및 그 分布를 調査한 結果, 表皮細胞는 多角形 또는 伸長形이 있으며 이들의 細胞壁은 肥厚되었고 波狀形이거나 깊은 波狀形이었다. 副細胞壁은 얇고 大部分이 아치형이었으며 바위솔(*Orostachys japonicus*)의 葉表皮에서는 鍾乳體가 發見되었다. 氣孔의 分布는 7種 모두가 兩面葉이었다. 바위솔과 돌나물(*Sedum sarmentosum*)에서는 葉의 前面에 그 分布가 많았으나 둥근바위솔(*O. malacophyllus*), 기린초(*S. kamschaticum*), 큰기린초(*S. aizoon* var. *heterodontum*), 평의비름(*S. alboroseum*) 및 말뚝비름(*S. bulbiferum*)에서는 裏面에 그 分布가 많았고 各種에 따라 差異가 있었다. 氣孔의 크기는 큰기린초葉의 前面에서 $47.5 \times 27.8 \mu\text{m}$ 이고 裏面에서 $46.8 \times 26.0 \mu\text{m}$ 로서 前面이 더욱 컸으며, 바위솔 葉의 前面에서 $23.3 \times 15.0 \mu\text{m}$ 이고 裏面에서 $24.3 \times 16.0 \mu\text{m}$ 으로 裏面이 더욱 컸다. 氣孔의 主發生 類型은 helico-eumesogenous 型이었고, 이는 孔邊母細胞가 分裂角을 基準으로 마지막으로 形成된 副細胞의 長軸에 對하여 平行으로 分裂된 parahelico-eumesogenous 型과 直角으로 分裂된 diahelico-eumesogenous 型의 두 類型으로 細分될 수 있었다. 이들 類型의 副細胞에서 제 2 차 氣孔이 發生되어 復合 helico-eumesogenous 型이 形成되기도하고 helico-eumesogenous 型의 變異型이 發生되기도 하였다. 各種에서 發見되는 다른 發生類型은 7種中 4種에서 aniso-eumesogenous 型이, 3種에서 allelo-eumesogenous 型이 觀察되었고 tetra-eumesogenous 型이 3種에서 드물게 發見되었다. 지금까지 報告되지 않은 氣孔發生類型의 5種類는 첫째 氣孔母細胞의 螺旋分裂에 依한 8個의 中位形成 副細胞가 두 孔邊細胞를 二重으로 둘러싸고 있는 duplotetra-eumesogenous 型, 둘째는 3個의 周邊形成된 副細胞를 가진 aniso-euperigenous 型, 셋째는 helico-eumesogenous 型으로 分裂하는 途中 母細胞가 tetra-eumesogenous 型으로 分裂하여 두 孔邊細胞를 直接 둘러싸고 있는 4個의 副細胞를 包含하여 5個 以上の 中位形成 副細胞들의 螺旋을 가진 helico-tetra-eumesogenous 型이 돌나물에서, 넷째는 helico-eumesogenous 型으로 分裂하는 途中 母細胞가 allelo-eumesogenous 型으로 分裂하여 螺旋狀分裂한 4個 以上の 中位形成 副細胞들 內에 3個 以上の 中位形成한 C形 副細胞가 漸次 작은 크기로 對生한 coallelo-helico-eumesogenous 型, 다섯째는 allelo-eumesogenous 型으로 分裂하는 途中 母細胞가 helico-eumesogenous 型으로 分裂하여 漸次 작은 크기로 對生한 3個 以上の C形 副細胞들 內에 4個 以上の 螺旋狀分裂한 副細胞들의 螺旋을 갖는 cohelico-allelo-eumesogenous 型이 말뚝비름에서 처음으로 發見되었다.

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