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Field Studies of the Brown Alga *Pelvetia siliquosa* with Implications for Taxonomy and Distribution

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Field observations of *Pelvetia siliquosa* plants were given at monthly intervals on the western coast of Korea with implications for taxonomy and distribution. Plant length and wet weight were closely related to the occurrence of receptacles, all of which had a peak in August. The fusiform receptacles known as a discrimental character of the species were found at a low frequency throughout the year. The other morphometric features showed a wide range of variation even within a single population.

Key Words: distribution, morphological variation, *Pelvetia siliquosa*, taxonomy

INTRODUCTION

The genus *Pelvetia* is typified by *P. canaliculata* (Linne) Decaisne et Thuret from European waters and is characterized by the most distinguishing feature having two eggs in a single oogonium (Decaisne and Thuret 1845). Four species have been reported to be members of the genus (Tseng and Chang 1953); *P. babingtonii* (Harvey) De Toni from Japan, *P. canaliculata* from Europe, *P. fastigiata* (J. Agardh) De Toni from the northeast Pacific, *P. siliquosa* Tseng et Chang from China and Korea.

P. siliquosa is characterized by small height, fusiform receptacle, and longitudinally divided eggs, and occurs in shore on the Yellow Sea. *P. siliquosa* shares many features with *P. babingtonii*, while differs from it in large thallus, rod to club-shaped receptacle, and vesicles (Tseng and Chang 1953). Yoshida and Silva (1992), however, reported that this taxonomic features depended on habitats and seasons of growth at least in *P. babingtonii*.

P. siliquosa is also very similar with *P. fastigiata*, but Tseng and Chang (1953) pointed out that *P. siliquosa* plants were much smaller, with thin segment and broad angle of branches, than *P. babingtonii* and *P. fastigiata* plants and also produced intercalary receptacles with broad pedicel and abrupt apex.

In order to approach taxonomic problems included in *Pelvetia siliquosa*, the Korean plants in different months and locations were examined in this study. A biogeographical consideration was also given.

MATERIALS AND METHODS

Field observations were given in Taean (36°43′ N, 12°07′ E) on the western coast of Korea during May, 1992 and May, 1993. This site was selected because of the great abundance of the *Pelvetia siliquosa* plants and the habitat on the flat rock in the upper intertidal.

At each visit, sixty or more plants were at random sampled by using five quadrats (30×30 cm^2) within the upper intertidal zone (Ward 1974). Each specimen was observed for reproduction, length and wet weight. Comparative studies of plants in Geojedo (128°35″ E, 34°47″ N), Jindo (126°15″ E, 34°36″ N) and Dolsando (127°47″ E, 34°36″ N) on the southern coast, and in Wido (126°18′ E, 35°37′ N) on the western coast were carried out in April and July, 1993.

Morphological features used for delimiting species or genus were statistically investigated and the results were analyzed descriptive statistics.

Herbarium specimen of Marine Biological Laboratory of Academia Sinica Tsingtao (AST), China were also available.

Dedicated to Prof. In Kyu Lee by the first author, celebrating his sixtieth birthday.

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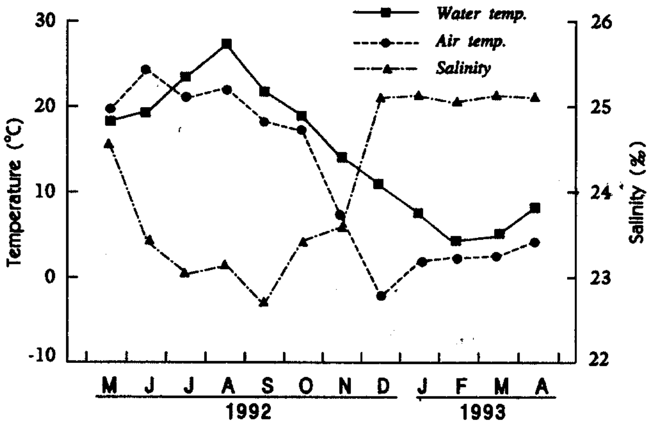

Fig. 1. Monthly variation of environmental factors in Taean.

RESULTS

Growth and reproduction: Maximum temperature of surface seawater in Taean was 26°C in August, whereas the minimum 4°C in January. This variation differed from that of air temperatures, which ranged from −1°C in December to 23°C in June. Salinities showed the maximum value of 25‰ during December and April and the minimum of 22‰ in September (Fig. 1).

In the study area, *P. siliquosa* plants occurred at a coverage of 10-50% throughout the year and showed the various morphologies (Fig. 2). Width of branch became wide in biannual plants and forms of receptacles were different in different ages of growth. The mean wet weight of each individual showed a maximum of 2.69 g in August whereas a minimum of 0.31 g in February and March.

Reproduction was positively related to wet weight (r > 0.89) (Fig. 3). Reproductive receptacles also occurred throughout the year. The maximum reproduction was shown in August whereas the minimum in March. Wet weight and reproduction were positively related to temperature of surface seawater (r > 0.98, r > 0.91), but negatively to salinity (r < −0.91, r < −0.77).

The reproductive percentage of local plants was 95% in July from Geojedo, while 20% in April from Wido.

Morphologies in different months: Plant length was a

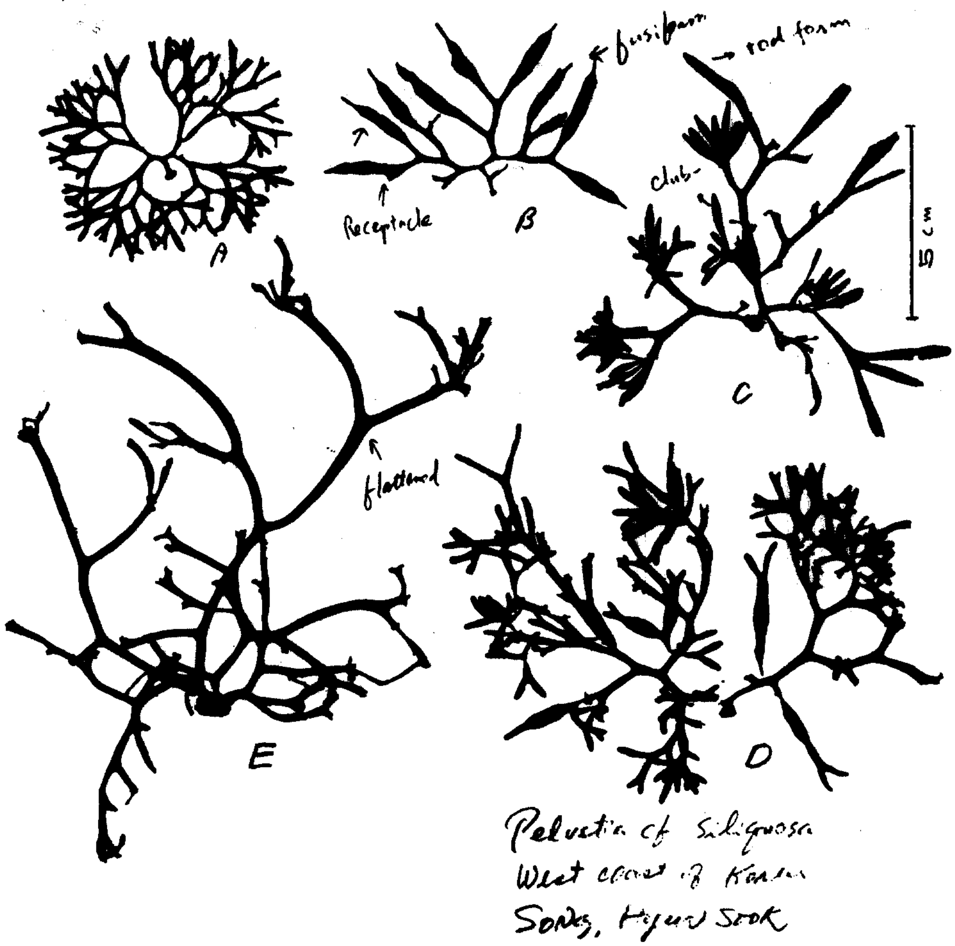

Fig. 2. Various habits of Korean *Pelvetia siliquosa* plants. A and E; Plants from Oeyondo in January, 1993. B; Plant from Geojedo in April, 1993. C; Plant from Taean in November 1992. D; Plant from Taean in June 1992.

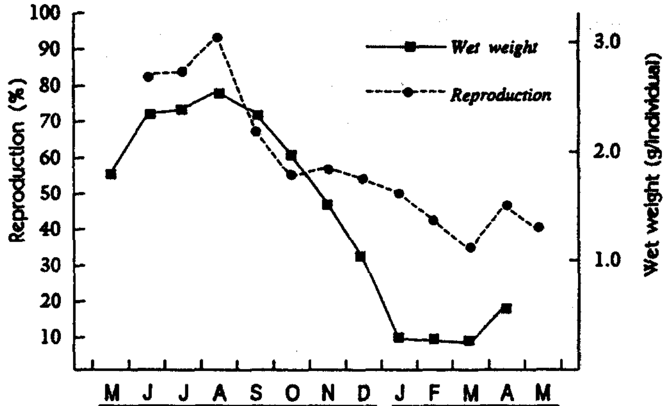

Fig. 3. Mean wet weight and reproduction of *P. siliquosa* plants in different months in Taean.

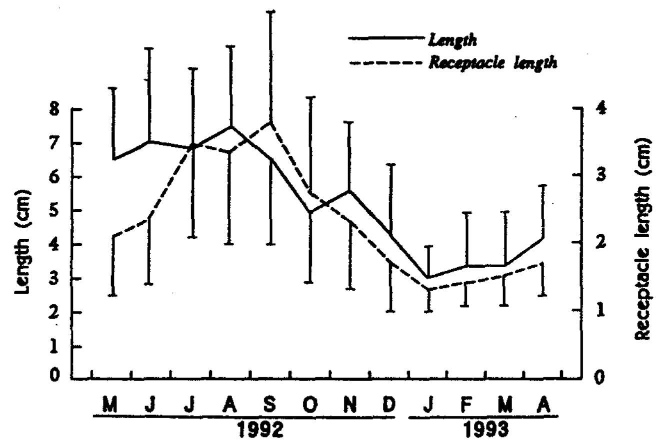

Fig. 4. Mean length of plants and receptacles of *P. siliquosa* plants in different months in Taean (with vertical bars of standard deviation).

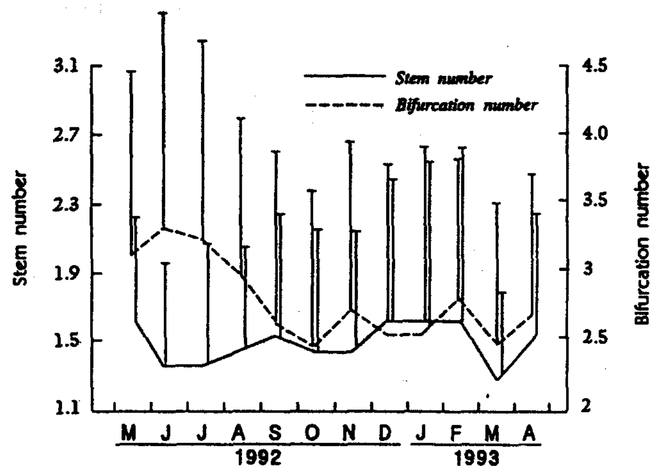

Fig. 5. Mean number of stem and branching bifurcation of *P. siliquosa* plants in different months in Taean (with vertical bars of standard deviation).

mean of 4.9±1.6 cm, with a maximum of 18.4 cm in August (Fig. 4). Rhizoid diameter was a mean of 0.5±0.1 cm (n = 1,393) and showed a maximum in May and June. The number of stems on a single rhizoid ranged 1 - 6 and showed the maximum during December and February (Fig. 5). The diameter of stem increased to 0.9 cm in August, with a mean of 0.3±0.1 cm and the thickness ranged between 0.1-0.2 cm. Branches were dichotomously produced and the number increased with plant length. The upper angle of branches was a mean of 71.9±7.0 whereas the lower angle 67.1±5.2.

In cross section (Fig. 6), stem was divided into cortical and medulla layer. Cortical layer was composed of inner filamentous and surface round cells. Medullar layer was composed of cylindrical and filamentous cells. Cylindrical cells were a mean of 18.8±2.7 x 25.1±3.3 μm while filamentous ones a mean of 7.8±1.2 x 37.5±3.3 μm. Filamentous cells in the cortical layer became much short and thick. Epidermal cells were bead-like and had many plastids.

Receptacles were diverse in shape (Fig. 7). Rod to club forms of receptacles were more often observed in every collection. The fusiforms occurred at low frequency throughout the year (Fig. 8), and showed the negative correlation to the rods and the clubs, respectively ($r < -0.93, r < -0.95$).

Conceptacles were hermaphroditic. In a single conceptacle, a mean number of oogonium was 18.6±3.7 and the size 62.6±10.0 x 108.6±14.1 μm. One to four egg cells were produced in a single oogonium and, when divided, the division was longitudinal, oblique to transversal (Fig. 9).

Morphologies in different locations: There were no differences in mean plant length among local populations (Table 1). Geojedo plants in April were the largest with 4.4±1.3 cm. The number of dichotomous branches showed the opposite tendency to the angle of dichotomous branches.

Rod forms of receptacles increased on the young plants, while club forms on the olds. The receptacle length seemed long in plants from Jindo, Dolsando and Geojedo, but there were no significant differences from Taean plants.

Type material: The type specimen of *Pelvetia siliquosa*, which is given herbarium no. AST 51-942 in AST, China, was collected from Mashan, Shantung Peninsula, China (Fig. 10). The plant was 12 cm long with a discoid rhizoid and terete fronds. It had 19 receptacles, of which 13 ones were fusiforms while 6 rod to club forms.

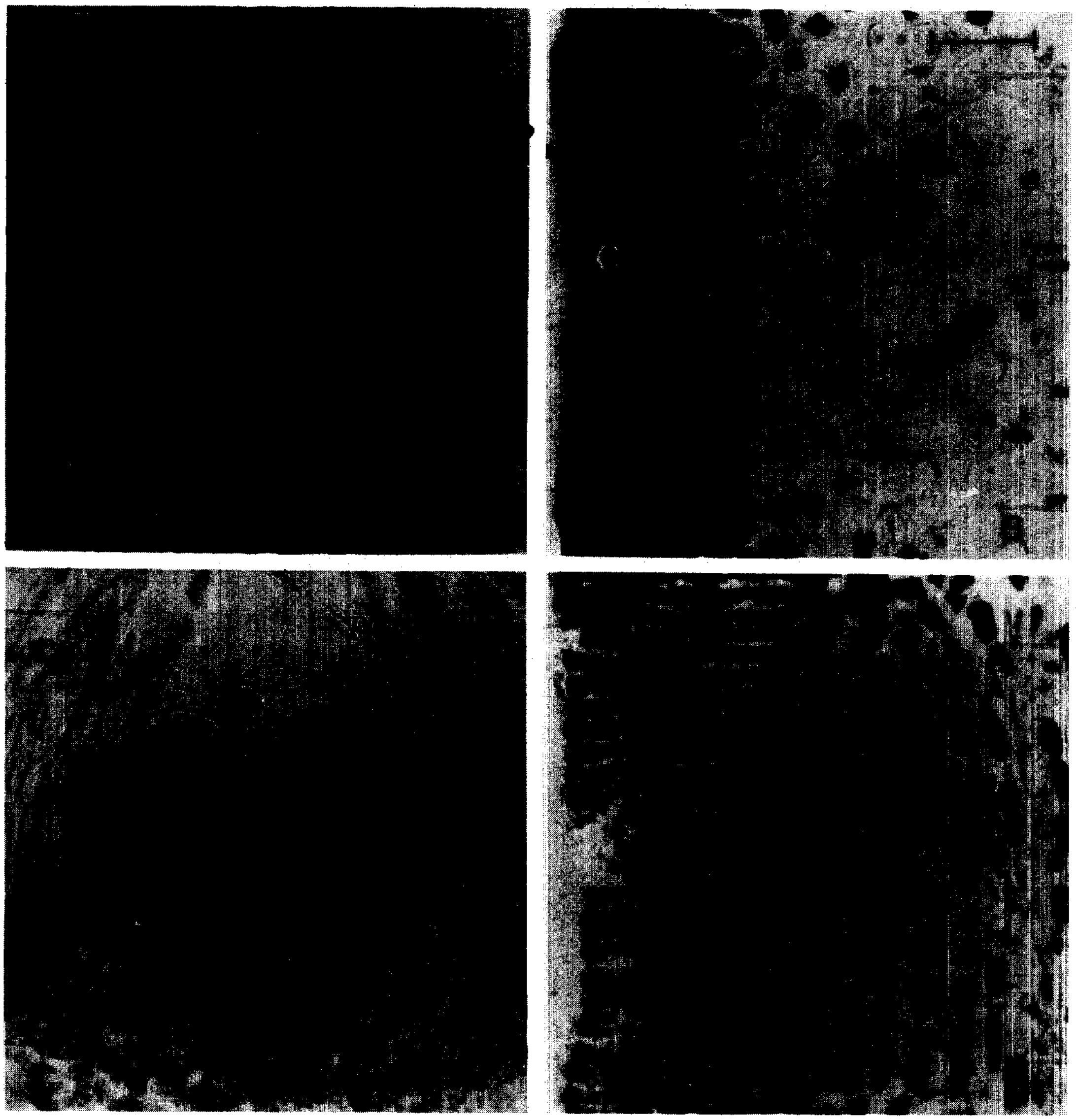

Fig. 6. Anatomical view of Korean *P. siliquosa* plants. Transversal veiw of basal (A), middle blade (B), receptacle (C), and longitudinal view of blade (D). (C; cortex, E; egg, Ep; epidermal layer, M; medulla, P; paraphysis, and S; Spermatangium). Scale bars; 100 μm.

Many other specimens were deposited in the same file of the type specimen sheet. They were collected during May and August. The shape of receptacles was fusiform, rod and club form. Vesicles were not found, as the prologue said. In the lower part of the plants, the branching was divaricate, branch angle becoming progressively smaller upwards.

DISCUSSION

Korean *Pelvetia* plants agree well with the type specimen of *P. siliquosa* from China. There seems to be variable in different month and locations, but the variation is considered to be in the range of the species.

P. siliquosa plants in the study area occurred throughout the year. Wet weight and reproduction showed the maximum in August whereas the minimum in February and March. This agrees with the results of Brophy and Murray (1989), that reproduction in benthic brown algae depends on blade length, wet weight and seasonal factors.

According to Sideman and Mathieson (1983), reproductive curve is bimodal in a stable environment while unimodal in a disturbed place. The unimodal reproduction curve of *P. siliquosa*, as seen in Figure 3, may be a reflex of physiological stress under the extreme upper tidal habitat.

Korean plants of the genus *Pelvetia* had been known under a name *P. wrightii* (Harvey) Yendo by Kang (1966) or f. *japonica* of the same species by Okamoto (1964) who

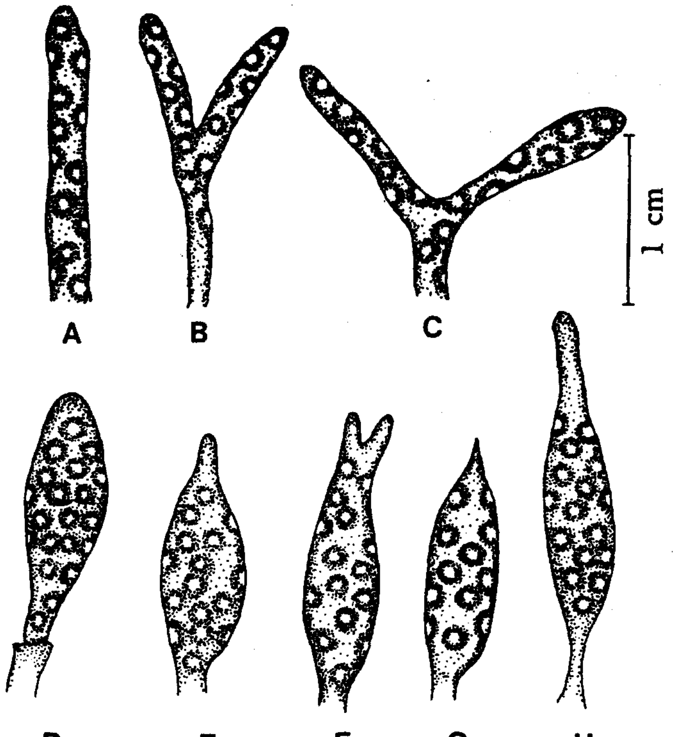

Fig. 7. Receptacles of Korean *P. siliquosa* (A-H). A-C; rod shape, D; club shape, E-H; fusiform.

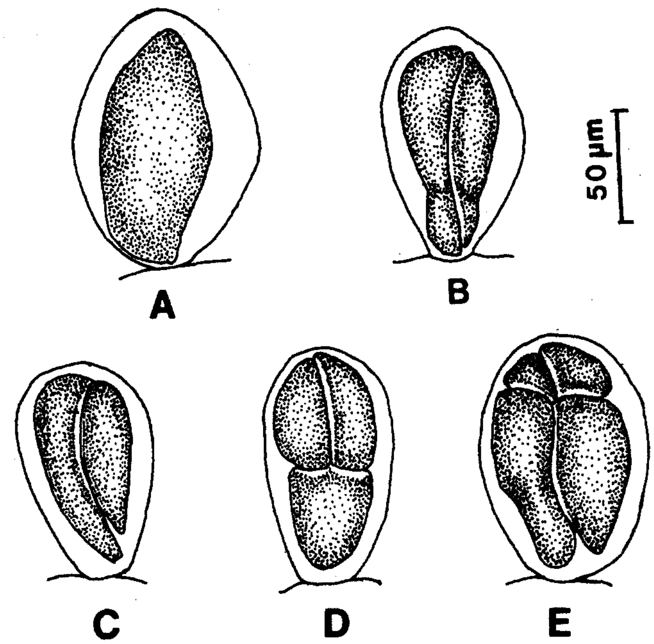

Fig. 9. Divisional form of eggs in *P. siliquosa* from Korea (A-E). A; one egg, B and C; two eggs of longitudinal division, D; three eggs of longitudinal and transversal division and E; four eggs in a single oogonium.

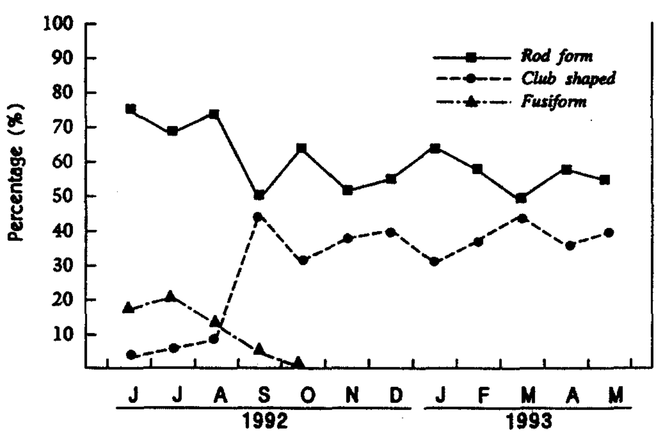

Fig. 8. Percentages of rod, club and fusiform receptacles of *P. siliquosa* plants in different months in Taean.

accepted the subspecific separation by Yendo (1907) and Okamura (1936). But, Yoshida and Silva (1992) found that *P. babingtonii* Harvey is the legitimate scientific name for *P. wrightii.* They also reported that because the features used for separation of the subspecific taxa depended on the ecological conditions, all three forms of Yendo and Okamura couldn't be considered to be under the species.

On the basis of the commercial plants of the local market from Korea, Tseng and Chang (1953) reported that Korean *Pelvetia* plants belonged to the *P. siliquosa* species, which was described on the specimen from the Yellow sea coast. Recently, the Korean plants in a check-list of Korean marine algae have been given a name *P. siliquosa* (Lee and Kang 1986).

The distinguishing features of *P. siliquosa* are short size of thallus with thick segments and narrow branch angle, and presence of fusiform receptacles (Tseng and Chang 1953). The largest plant collected in this study was 18.4 cm, which is much smaller than *P. babingtonii* plants with a size of 10-90 cm (Okamura 1936) and *P. fastigiata* plants of 15-40 cm size (Smith 1944). But Korean plants of Fig. 2 showed very diverse morphologies, which are probably seen in the other species(unpublished data). It is also difficult for the thickness of segments and angle of dichotomous branches to separate *P. siliquosa* from the other two species because of continuity of the features.

Fusiform receptacles in the Korean plants occurred at a low frequency throughout the year. They were rare in the locations on the southern coast. This observations say that fusiform receptacles may be a morphological form under eco-physiological stress within morphological range of the species. This result requires a further comparative studies with *P. babingtonii* and also *P. fastigiata* plants.

The number of egg in a single oogonium has been accepted the most important feature distinguishing the

Table 1. Comparison of morphometric features for *Pelvetia siliquosa* plants

	Taean (n = 150)	Jindo (n = 29)	Dolsando (n = 112)	Geojedo (n = 38)
Disc diameter (cm)	0.4±0.3	0.3±0.1	0.4±0.2	0.3±0.1
Stem number	1.4±0.7	1.2±0.4	1.4±0.6	3.3±0.6
Plant length (cm)	3.6±1.6	3.5±1.3	3.9±1.1	3.9±0.6
Bifurcation number	2.5±0.9	3.2±1.1	3.7±1.1	3.0±0.8
Bifurcation angle				
upper (°)	69.1±18.2	64.4±19.1	67.1±17.2	57.0±18.7
lower (°)	70.1±22.3	69.1±22.7	75.0±21.0	76.8±23.5
Branch width (cm)	0.3±0.1	0.2±0.1	0.2±0.1	0.2±0.1
Receptacle				
form (%)	C;39,R;61	C;5,R;92,F;3	C;4,R;96	C;1,R;98,F;1
diameter (cm)	0.4±0.1	0.4±0.1	0.4±0.1	0.4±0.1
length (cm)	1.5±0.4	2.2±0.6	2.1±0.6	2.0±0.4
Perennial (%)	24	2	2	2

C; club shape, R; rod shape, F; fusiform

genus *Pelvetia* and the related genera (see Clayton 1984). As seen in Fig. 9, the number of egg in an oogonium of our plants seems to be variable, that needs a quantitative study between different local plants as well as species of the genus *Pelvetia*.

The above results show that *P. siliquosa* shares many features with *P. babingtonii* and *P. fastigiata*. But *P. siliquosa* quite differs from *P. canaliculata* (Ardre 1970), the type species of the genus, which has complanate frond and horizontally divided egg cells. This taxonomic problem requires an urgent intensive study on the genus *Pelvetia*.

On the basis of luxuriant growth of *P. siliquosa* plants in Korea Tseng and Chang (1983/1984, p. 50) suggested that the species was speciated in southern Korean coast, then further distributed to the Liadong and the Shantung Peninsula in China. But, if the hypothesis of speciation is correct, we can get another simple question; where does the ancestor of the Korean plants come from?

As pointed out by Tseng and Chang (1953, 1983/1984), it seems sure that the *Pelvetia* species grow well in the places where the cold current and the warm meet together. Although *P. siliquosa* is isolated from *P. babingtonii* and *P. fastigiata*, the three species have been reported to occur in the upper intertidal in the north Pacific (Smith 1944, Tseng and Chang 1953, Yoon and Boo 1991). The similarity of ecological habitat among the three species suggests that one parental taxon might move to new places and evolve as a vicariant species.

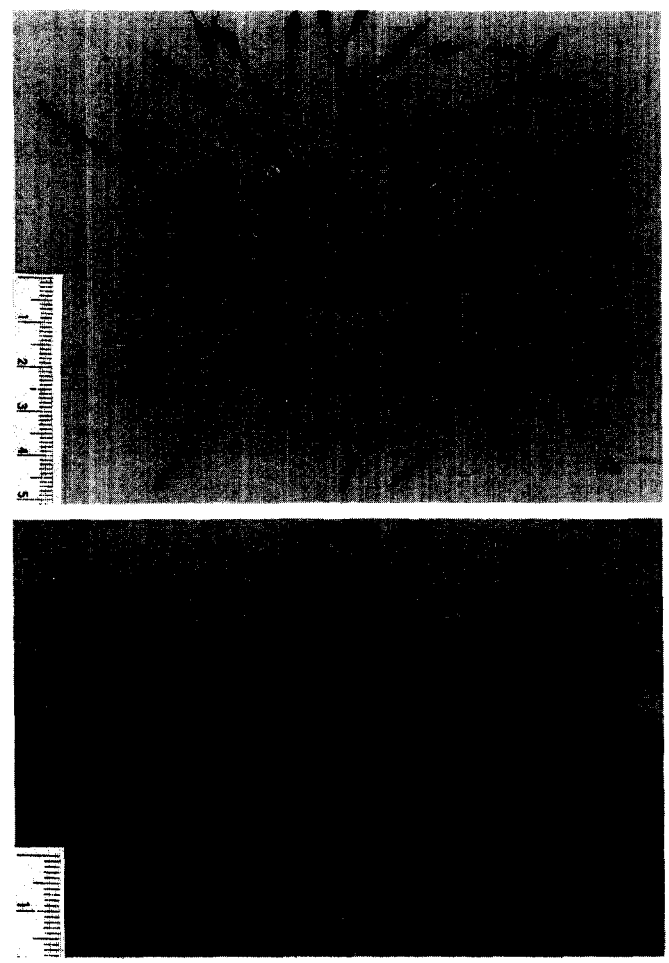

Fig. 10. The type specimen of *Pelvetia siliquosa* housed in AST. A: Type specimen of AST No. 51-942, B; A plant from the type locality. Arrows indicate fusiform receptacles.

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