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Natural Habitats and Geographic Distribution of Diploid *Lilium lancifolium* in Islands of the Bay of Kyunggi, Korea

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Habitats and geographic distribution were investigated for diploid and triploid *L. lancifolium* grown in 16 islands of the Bay of Kyunggi, the western region of South Korea. Most of natural populations were found at the coastal areas in the islands: 103 (72.5%) of 142 natural populations inhabited in sea cliffs, 28 (18.4%) in beaches, and the remainder in forests, roadside, riverside, grassy slopes and gardens. Among 16 islands investigated, 13 islands located in the southern and central area of the bay were inhabited by diploid populations alone. Kanghwa-do, the nearest island to the mainland of South Korea, was inhabited by eight diploid and six triploid populations. Backryung-do and Sochung-do, the northernmost islands in South Korea, were inhabited by triploid populations alone. Combined with previously demonstrated facts on ploidy distribution of *L. lancifolium*, the results suggest that diploid *L. lancifolium* is indigenous to the middle western to southern islands and coasts of the Korean Peninsula, and Kanghwa-do and the neighbor islands are approximate northern limit of the distribution of diploid *L. lancifolium*.

INTRODUCTION

It has been well confirmed that tiger lily, *Lilium lancifolium* (synonym *L. tigrinum*), is a polyploid complex involving both diploid and triploid forms (Noda, 1978, 1986, 1991). Noda (1986) hypothesized from his cytological studies that the triploid form may be either the allotriploid produced by natural hybridization between the diploid form and closely related diploid species such as *L. leichtlinii* var. *maximowiczii*, or the autotriploid directly originated from the diploid form through the production of unreduced gametes.

To understand the origin of triploid in nature, entire natural distribution of diploid and triploid forms must be investigated. Several reports (Willson, 1925; Lightly, 1968; Noda, 1986; Noda and Lee, 1980; Song, 1997) mentioned the distribution of *L. lancifolium* in Korea, but, little has been known about exact geographic distribution of each ploidy form. Noda (1991) reported that the diploid form is confined to the southern part of Korea including two relatively large islands, Cheju Island (South Korea) and Tsushima Islands (Japan), whereas the triploid form is widely distributed in East Asia. We previously found the fact that the reproductive individuals of *L. lancifolium*

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frequently set capsules in western islands and coasts of South Korea, indicating that diploid forms are common in those regions (Kim *et al.*, 2004).

This study demonstrates the natural habitats and geographic distribution of diploid *L. lancifolium* in islands of the Bay of Kyunggi located in the western region of South Korea.

MATERIALS AND METHODS

Populations of *L. lancifolium* were investigated in 16 islands of the Bay of Gyunggi located in the western region of the Korean Peninsula from 2000 to 2003. Of all the islands, autogenous populations of *L. lancifolium* were found in the coastal areas but not in the inland. Approximate number of reproductive individuals and frequency of capsule set were investigated for each population. The populations geographically isolated at least more than 100 m distance from other populations were judged as independent populations. The ploidy level was determined by the combination of counting chromosome number of root tip cells and measuring relative DNA content of leaf cells with flow cytometer (Partec PA Ploidy Analyzer, Germany).

Somatic chromosomes in root-tips were observed by the aceto-carmine squash method as follows: Root tips of the two representative plants from each island were pretreated with 0.002 M 8-hydroxyquinolin at room temperature for 24 hrs, fixed with ethanol acetic acid (3:1) at 5 °C for 1 hr, hydrolyzed with 1 N HCl at 60 °C for 5 min. The macerated root tips were placed on a glass slide with a few drops of 1% carmine solution diluted with 45% acetic acid at room temperature for 5 to 15 min, squashed under a cover glass, then observed with a microscope. Plants cytologically estimated to be diploid and triploid were used as controls for flow cytometric analysis.

Procedure of flow cytometric analysis followed that by Ozaki *et al.* (1998). Leaf tissues of three plants collected from each population were chopped with a sharp razor blade in a plastic Petri dish with 500 μL nucleus-isolation buffer (High resolution DNA kit, Partec), and the suspension was filtered through a 30 μm mesh filter. Then, 1mL staining solution (High resolution DNA kit, Partec) containing 4'-6-diamidiono-2-phenylindole (DAPI) was added into the filtered solution. The prominent signal peak for diploid and triploid was adjusted at channel 100 and 150, respectively.

RESULTS AND DISCUSSION

Habitat and putative dispersion mode of insular *L. lancifolium*

We found 142 populations in 16 islands of the Bay of Kyunggi. The localities and descriptions of the natural habitat, and the ploidy form for each population are summarized in Table 1. Population sizes varied considerably with 10 to 1,000 reproductive individuals per population. Relatively large and well-reserved natural populations were found in the coast of Acha-do (Isl. No. 3) and Ahnmyun-do (Isl. No. 16).

Among 142 *L. lancifolium* populations, 103 (72.5%) were growing on cliffs by the sea and 28 (19.7%) were on beaches (Table 2). Distribution in forests, at roadside, riverside, gardens and grassy slopes occupied below 10% in these islands, although such habitats are common in the inland of South Korea (Kim *et al.*, 2004). These growth

Table 1. Localities, habitats, and ploidy forms of *L. lancifolium* populations found in 16 islands in the Bay of Kyunggi.

Island No.[z]	Population	County, province	Island, locality and habitat	Population size[y]	Ploidy form
1	A	Incheon, Ongjin-gun	Backryung-do, Jincheonri, Sea cliff	100	Triploid
	B	Incheon, Ongjin-gun	Backryung-do, Jincheonri, Sea cliff	100	Triploid
	C	Incheon, Ongjin-gun	Backryung-do, Sahangpo, Sea cliff	50	Triploid
	D	Incheon, Ongjin-gun	Backryung-do, Dumoojin, Sea cliff	50	Triploid
	E	Incheon, Ongjin-gun	Backryung-do, Yeonhwari, Sea cliff	50	Triploid
	F	Incheon, Ongjin-gun	Backryung-do, Joonghwadong, Riverside	50	Triploid
	G	Incheon, Ongjin-gun	Backryung-do, Bookpori, Seaside	50	Triploid
	H	Incheon, Ongjin-gun	Backryung-do, Mt. Yonggiwon, Seaside	50	Triploid
	I	Incheon, Ongjin-gun	Backryung-do, Mt. Yonggiwon, Seaside	50	Triploid
	J	Incheon, Ongjin-gun	Backryung-do, Kongdol beach, Seaside	50	Triploid
2	A	Incheon, Ongjin-gun	Sochung-do, Yaedong, Sea cliff	50	Triploid
	B	Incheon, Ongjin-gun	Sochung-do, Nohwadong, Sea cliff	50	Triploid
	C	Incheon, Ongjin-gun	Sochung-do, Tapdong, Sea cliff	50	Triploid
	D	Incheon, Ongjin-gun	Sochung-do, Tapdong, Sea cliff	50	Triploid
	E	Incheon, Ongjin-gun	Sochung-do, Boonampogu, Sea cliff	50	Triploid
	F	Incheon, Ongjin-gun	Sochung-do, Boonampogu, Sea cliff	50	Triploid
	G	Incheon, Ongjin-gun	Sochung-do, Boonampogu, Sea cliff	50	Triploid
	H	Incheon, Ongjin-gun	Sochung-do, Ajinpogu, Sea cliff	50	Triploid
	I	Incheon, Ongjin-gun	Sochung-do, Ajinpogu, Sea cliff	50	Triploid
	J	Incheon, Ongjin-gun	Sochung-do, Ajinpogu, Sea cliff	50	Triploid
3	A	Incheon, Kanghwa-gun	Acha-do, Sea cliff	200	Diploid
	B	Incheon, Kanghwa-gun	Acha-do, Sea cliff	200	Diploid
	C	Incheon, Kanghwa-gun	Acha-do, Sea cliff	200	Diploid
	D	Incheon, Kanghwa-gun	Acha-do, Sea cliff	200	Diploid
	E	Incheon, Kanghwa-gun	Acha-do, Sea cliff	200	Diploid
	F	Incheon, Kanghwa-gun	Acha-do, Sea cliff	200	Diploid
	G	Incheon, Kanghwa-gun	Acha-do, Sea cliff	200	Diploid
	H	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
	I	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
	J	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
	K	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
	L-I	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
	L-II	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
	M	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
	N	Incheon, Kanghwa-gun	Acha-do, Sea cliff	300	Diploid
	O	Incheon, Kanghwa-gun	Acha-do, Sea cliff	300	Diploid
	P	Incheon, Kanghwa-gun	Acha-do, Sea cliff	300	Diploid
	Q	Incheon, Kanghwa-gun	Acha-do, Sea cliff	300	Diploid
	R	Incheon, Kanghwa-gun	Acha-do, Sea cliff	100	Diploid
4	A	Incheon, Kanghwa-gun	Suckmo-do, Josanggot, Sea cliff	10	Diploid
	B	Incheon, Kanghwa-gun	Suckmo-do, Josanggot, Sea cliff	10	Diploid
	C	Incheon, Kanghwa-gun	Suckmo-do, Eoreujung, Sea cliff	10	Diploid
	D	Incheon, Kanghwa-gun	Suckmo-do, Eoreujung, Sea cliff	50	Diploid
	E	Incheon, Kanghwa-gun	Suckmo-do, Eoreujung, Sea cliff	20	Diploid
5	A	Incheon, Kanghwa-gun	Kanghwa-do, Gilsang, Donggumri, Sea cliff	30	Diploid
	B-I	Incheon, Kanghwa-gun	Kanghwa-do, Hwado, Dongmakri, Grassy slope	20	Diploid
	B-II	Incheon, Kanghwa-gun	Kanghwa-do, Hwado, Dongmaksunsudae, Beach	20	Diploid
	C	Incheon, Kanghwa-gun	Kanghwa-do, Hwado, Naeri, Grassy slope	20	Diploid
	D	Incheon, Kanghwa-gun	Kanghwa-do, Yangdo, Gunpyungri, Roadside	15	Diploid

Table 1. Continued.

Island No.[z]	Population	County, province	Island, locality and habitat	Population size[y]	Ploidy form
	E	Incheon, Kanghwa-gun	Kanghwa-do, Yangdo, Hwangkol, Margin of forests	40	Triploid
	F - I	Incheon, Kanghwa-gun	Kanghwa-do, Naega, Guhari, Beach	20	Diploid
	F - II	Incheon, Kanghwa-gun	Kanghwa-do, Naega, Guhari, Roadside	30	Triploid
	G	Incheon, Kanghwa-gun	Kanghwa-do, Yangsa, Inhwasung, Beach	30	Triploid
	H	Incheon, Kanghwa-gun	Kanghwa-do, Yangsa, Inhwai, Garden	20	Diploid
	I	Incheon, Kanghwa-gun	Kanghwa-do, Yangsa, Kyosanri, Margin of forests	30	Triploid
	J	Incheon, Kanghwa-gun	Kanghwa-do, Songhae, Dangsanri, Sea cliff	20	Diploid
	K - I	Incheon, Kanghwa-gun	Kanghwa-do, Songhae, Hadori, Garden	20	Triploid
	K - II	Incheon, Kanghwa-gun	Kanghwa-do, Songhae, Hadori, Garden	20	Triploid
6	A	Incheon, Ongjin-gun	Jangbong-do, Yongam beach, Sea cliff	30	Diploid
	B	Incheon, Ongjin-gun	Jangbong-do, Yongam beach, Sea cliff	30	Diploid
	C	Incheon, Ongjin-gun	Jangbong-do, Yongam beach, Sea cliff	30	Diploid
	D	Incheon, Ongjin-gun	Jangbong-do, Yongam beach, Sea cliff	30	Diploid
	E	Incheon, Ongjin-gun	Jangbong-do, Jinchon beach, Sea cliff	30	Diploid
	F	Incheon, Ongjin-gun	Jangbong-do, Jinchon beach, Sea cliff	30	Diploid
	G	Incheon, Ongjin-gun	Jangbong-do, Jinchon beach, Sea cliff	30	Diploid
	H	Incheon, Ongjin-gun	Jangbong-do, Jinchon beach, Sea cliff	30	Diploid
	I	Incheon, Ongjin-gun	Jangbong-do, Chookdong, Sea cliff	30	Diploid
	J	Incheon, Ongjin-gun	Book-do, Sea cliff	30	Diploid
7	A	Incheon, Ongjin-gun	Yungjong-do, Yedanpo, Sea cliff	30	Diploid
	B	Incheon, Ongjin-gun	Yungjong-do, Yedanpo, Sea cliff	30	Diploid
	C	Incheon, Ongjin-gun	Yungjong-do, Yedanpo, Sea cliff	30	Diploid
	D	Incheon, Ongjin-gun	Yungjong-do, Yedanpo, Sea cliff	30	Diploid
	E	Incheon, Ongjin-gun	Yungjong-do, Yedanpo, Sea cliff	100	Diploid
	F	Incheon, Ongjin-gun	Yungjong-do, Yedanpo, Sea cliff	30	Diploid
	G	Incheon, Ongjin-gun	Yungjong-do, Yedanpo, Sea cliff	30	Diploid
8	A	Incheon, Ongjin-gun	Eulwang-do, Eulwangri, Sea cliff	30	Diploid
	B	Incheon, Ongjin-gun	Eulwang-do, Eulwangri, Sea cliff	30	Diploid
	C	Incheon, Ongjin-gun	Eulwang-do, Eulwangri, Sea cliff	30	Diploid
	D	Incheon, Ongjin-gun	Eulwang-do, Eulwangri, Sea cliff	30	Diploid
9	A	Incheon, Ongjin-gun	Mooeui-do, Port, Sea cliff	30	Diploid
	B	Incheon, Ongjin-gun	Mooeui-do, Hanakke beach, Beach	30	Diploid
	C	Incheon, Ongjin-gun	Mooeui-do, Hanakke beach, Beach	30	Diploid
	D	Incheon, Ongjin-gun	Mooeui-do, Hanakke beach, Beach	30	Diploid
	E	Incheon, Ongjin-gun	Mooeui-do, Goorackkkuji, Sea cliff	30	Diploid
	F	Incheon, Ongjin-gun	Mooeui-do, Goorackkkuji, Sea cliff	30	Diploid
10	G	Incheon, Ongjin-gun	Deokjuck-do, Mocksum, Beach	50	Diploid
	H	Incheon, Ongjin-gun	Deokjuck-do, Mocksum, Sea cliff	100	Diploid
	I	Incheon, Ongjin-gun	Deokjuck-do, Mocksum, Beach	30	Diploid
	J	Incheon, Ongjin-gun	Deokjuck-do, Parackkeumi, Beach	50	Diploid
	K	Incheon, Ongjin-gun	Deokjuck-do, Parackkeumi, Beach	50	Diploid
	L	Incheon, Ongjin-gun	Deokjuck-do, Sundolbawui, Sea cliff	100	Diploid
	M	Incheon, Ongjin-gun	Deokjuck-do, Sundolbawui, Beach	50	Diploid
	N	Incheon, Ongjin-gun	Deokjuck-do, Neungdong, Beach	50	Diploid
	O	Incheon, Ongjin-gun	Deokjuck-do, Seopori, Roadside	10	Diploid
	P	Incheon, Ongjin-gun	Deokjuck-do, Seopori beach, Sea cliff	20	Diploid
	Q	Incheon, Ongjin-gun	Deokjuck-do, Seopori beach, Sea cliff	20	Diploid
	R	Incheon, Ongjin-gun	Deokjuck-do, Keunima, Sea cliff	20	Diploid
	S	Incheon, Ongjin-gun	Deokjuck-do, Batjireum beach, Sea cliff	20	Diploid

Table 1. Continued.

Island No.[z]	Population	County, province	Island, locality and habitat	Population size[y]	Ploidy form
11	A	Incheon, Ongjin-gun	Jawol-do, Yokol, Sea cliff	30	Diploid
	B	Incheon, Ongjin-gun	Jawol-do, Yokol, Sea cliff	30	Diploid
	C	Incheon, Ongjin-gun	Jawol-do, Yokol, Sea cliff	30	Diploid
	D	Incheon, Ongjin-gun	Jawol-do, Eoryukol, Sea cliff	30	Diploid
	E	Incheon, Ongjin-gun	Jawol-do, Tuckbawui, Sea cliff	30	Diploid
	F	Incheon, Ongjin-gun	Jawol-do, Hanapo, Beach	30	Diploid
	G	Incheon, Ongjin-gun	Jawol-do, Jangkol beach, Beach	30	Diploid
	H	Incheon, Ongjin-gun	Jawol-do, Sogonhwon, Beach	30	Diploid
	I	Incheon, Ongjin-gun	Jawol-do, Sogongwon, Sea cliff	30	Diploid
	J	Incheon, Ongjin-gun	Jawol-do, Dalbawui, Sea cliff	30	Diploid
	K	Incheon, Ongjin-gun	Jawol-do, Mocksum, Sea cliff	30	Diploid
12	A	Incheon, Ongjin-gun	Youngheung-do, Naedong, Beach	20	Diploid
	B	Incheon, Ongjin-gun	Youngheung-do, Naedong, Beach	50	Diploid
	C	Incheon, Ongjin-gun	Youngheung-do, Sibripo beach, Beach	50	Diploid
	D	Incheon, Ongjin-gun	Youngheung-do, Sibripo beach, Beach	50	Diploid
13	A	Incheon, Ongjin-gun	Backa-do, Earyu, Sea cliff	10	Diploid
	B	Incheon, Ongjin-gun	Backa-do, Earyu, Sea cliff	20	Diploid
	C	Incheon, Ongjin-gun	Backa-do, Gaegunneor, Sea cliff	20	Diploid
	D	Incheon, Ongjin-gun	Backa-do, Gaegunneor, Sea cliff	20	Diploid
	E	Incheon, Ongjin-gun	Backa-do, Gaegunneor, Sea cliff	20	Diploid
	F	Incheon, Ongjin-gun	Backa-do, Gaegunneor, Sea cliff	20	Diploid
	G	Incheon, Ongjin-gun	Backa-do, Gaegunneor, Sea cliff	20	Diploid
	H	Incheon, Ongjin-gun	Backa-do, Gaegunneor, Sea cliff	20	Diploid
	I	Incheon, Ongjin-gun	Backa-do, Mockgasi, Sea cliff	20	Diploid
	J	Incheon, Ongjin-gun	Backa-do, Mockgasi port, Beach	20	Diploid
	K	Incheon, Ongjin-gun	Backa-do, Mockgasi, Sea cliff	20	Diploid
	L	Incheon, Ongjin-gun	Backa-do, Keunmal, Sea cliff	20	Diploid
	M	Incheon, Ongjin-gun	Backa-do, Keunmal, Sea cliff	20	Diploid
14	A	Choongnam, Dangjin-gun	Daenanji-do, port, Sea cliff	10	Diploid
	B	Choongnam, Dangjin-gun	Daenanji-do, port, Sea cliff	10	Diploid
	C	Choongnam, Dangjin-gun	Daenanji-do, port, Sea cliff	10	Diploid
15[x]	A	Choongnam, Taeahn-gun	Iwon, Naeri, Sea cliff	300	Diploid
	B	Choongnam, Taeahn-gun	Iwon, Baemyunri, Sea cliff	500	Diploid
	C	Choongnam, Taeahn-gun	Wonbook, Hwangchonri, Beach	200	Diploid
	D	Choongnam, Taeahn-gun	Wonbook, Hakampo, Beach	200	Diploid
	E	Choongnam, Taeahn-gun	Wonbook, Sinduri, Beach	50	Diploid
	F	Choongnam, Taeahn-gun	Sowon, Euihangri, Sea cliff	30	Diploid
	G	Choongnam, Taeahn-gun	Sowon, Backripo, Sea cliff	30	Diploid
	H	Choongnam, Taeahn-gun	Nammyun, Magumpo, Sea cliff	1,000	Diploid
	I-I	Choongnam, Taeahn-gun	Nammyun, Gomsum, Sea cliff	500	Diploid
	I-II	Choongnam, Taeahn-gun	Nammyun, Gomsum, Sea cliff	2,000	Diploid
16	A	Choongnam, Taeahn-gun	Ahnmyun-do, Hwangpo, Sea cliff	1,000	Diploid
	B	Choongnam, Taeahn-gun	Ahnmyun-do, Sinyari, Sea cliff	200	Diploid
	C	Choongnam, Taeahn-gun	Ahnmyun-do, Geatga, Beach	1,000	Diploid

[z] Island No. corresponds to the number in Fig. 1.

[y] Population size estimated by approximate number of reproductive individuals.

[x] Population A to G in island 15 were located in seaside of Taeahn peninsula, and population H, I-I and I-II were located in small islands.

Table 2. Classification and observation frequency of habitat types of *L. lancifolium* populations observed in 16 islands of the Bay of Kyunggi.

Type of natural habitat	No. of population	% of population
Sea cliff	103	72.5
Beach	28	19.7
Roadside	3	2.1
Forest	2	1.4
Others[z]	6	4.2
Total	142	100

[z] Habitats such as grassy slopes, gardens and riverside.

environments lead us to suppose that insular populations of *L. lancifolium* seem to have been established from seeds and bulbils dispersed by the forces of sea waves and currents running north to south along the west coasts of the Korean Peninsula.

Sea cliff populations were growing in the narrow zones from 2–3 m above sea level to the margin of the forests within 10 m above sea level. Such sites presumably give high salinity stress. In those habitats, thus, maritime species such as *Gypsophila oldhamiana*, *Dianthus japonicus*, *Aster spathulifolius*, *Crepidiastrum lancedatum*, *Sedum kamtschaticum*, *Allium monanthum* and *Chrysanthemum boreale* often grow together with *L. lancifolium*. These herbal plants live toughly in the little sediment in the crack of large rocks. In several beach populations of Ahnmyun-do (Isl. No. 16), the larger bulbs were submerged more than one meter below the ground. The fact suggests the beach populations have been autonomously established and preserved for a long time.

Geographic distribution of diploid *L. lancifolium*

One hundred and sixteen (82%) of 142 populations consisted of diploid forms, and triploid forms were restricted only in three islands (Table 1, Fig. 1). In the northernmost islands of South Korea, Backryung-do (Isl. No. 1) and Sochung-do (Isl. No. 2), there were no diploid, but only triploid individuals. Eight diploid and six triploid populations occupied in Kanghwa-do (Isl. No. 5), the nearest island to the mainland of South Korea. Triploid plants in these islands set no capsules and were growing in the habitats similar to those in the other islands inhabited by diploid forms; i.e., most were growing in sea cliffs.

There has been no report on the geographic distribution of diploid *L. lancifolium* except that by Noda (1986). Thus, this study gives additional fact on the geographic distribution of diploid *L. lancifolium*.

Only triploid form has been found in the inland of South Korea (Noda, 1986; Kim *et al.*, 2004). It seems that Kanghwa-do (Isl. No. 5) and the neighbor islands (Isl. No. 3, 4) are the approximate northern limit of the distribution of diploid *L. lancifolium* and the middle western to southern coasts and islands of the Korean Peninsula may be the origin of diploid *L. lancifolium*. To make clear this point, the further investigation for the coastal regions of Yellow Sea, especially in Sandong Peninsula in China and the western islands and coasts in North Korea is necessary.

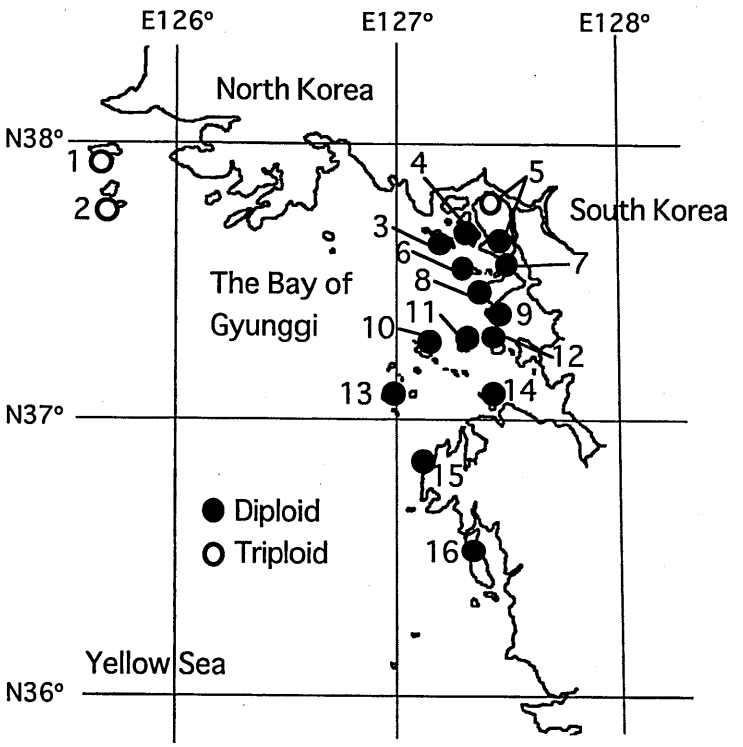

Fig. 1. Geographic distribution of diploid and triploid *L. lancifolium* in 16 islands of the Bay of Kyunggi.

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