Genetic Uniformity of two Aquatic Plants, *Egeria densa* PLANCH. and *Elodea nuttallii* (PLANCH.) ST. JOHN, Introduced in Japan

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**ABSTRACT**

Genetic variation in two plants introduced into Japan, *Egeria densa* and *Elodea nuttallii*, was investigated by enzyme electrophoresis. As a result, no polymorphism in allozyme patterns was found among 44 and 26 populations, respectively, of *Egeria densa* and *Elodea nuttallii* naturalized in Japan. This result suggests that the populations of the two species are rametes of the same clone which have spread by vegetative means from a single source, though the possibility of multiple introduction is not excluded. The ecological implication of genetic uniformity was briefly discussed in relation to the cause of decline in the population after the peak of abundance.

**Key words**: allozyme, *Egeria*, *Elodea*, genetic uniformity

**INTRODUCTION**

*Egeria densa* PLANCH. and *Elodea nuttallii* (PLANCH.) ST. JOHN are submerged aquatic plants belonging to Hydrocharitaceae, and are native to South America and temperate North America, respectively (COOK and URMII-KÖNIG, 1984, 1985). They are said to have been introduced to Japan as experimental plants for plant physiology (OHTAKI and ISHIDO, 1980). The oldest record of naturalization of *Egeria densa* can be traced back to the 1940s, which was documented by the presence of a herbarium specimen collected from Yamaguchi Prefecture, south-western Honshu (KADONO, 1994). On the other hand, *Elodea nuttallii* was recorded in Lake Biwa for the first time in the early 1960s (IKUSIMA and KABAYA, 1965). Since their escape into natural waters, both species have caused serious weed problems by their explosive growth and have had a profound influence on the aquatic plant communities native to Japanese inland waters (e.g., TANIMIZU and MIURA, 1976; IKUSIMA, 1984; KURITA and MINEMURA, 1985a, b). Now they have spread widely in Japan excluding Hokkaido, a northern island, and have become among the most common aquatic plant species in some regions (KADONO, 1988, 1994).

To date some studies have been conducted regarding ecological traits as related to the mechanism of successful colonization and dominance of these exotic plants (KUNII, 1981, 1984a, b, 1988; HARAMOTO and IKUSIMA, 1988).
However, little is known of the exact manner of their introduction and distribution, though it seems generally assumed that man's activities rather than natural agents are involved in their dispersal as suggested by Cook and Urm-König (1984). Ikusima (1980) is of the opinion that Elodea nuttallii has spread by transportation of fragments together with the stocking of fry of Plecoglossus altivelis (Ayu-fish) from Lake Biwa.

To trace the history of the introduction and spread of exotic species, comparative studies of isoenzyme banding patterns have proven useful (Wain et al., 1985; Triest, 1991), because the banding patterns are indicative of genotypes of the strains introduced. This approach will be especially effective in plants which propagate vegetatively. Egeria densa and Elodea nuttallii are such instances since only male plants have been introduced in Japan.

The present study was conducted to determine the genetic variations of the two species in Japan in the hope of shedding light on the routes of introduction and expansion.

MATERIALS AND METHODS

Collection of materials
The materials of Egeria densa and Elodea nuttallii were collected from 44 and 26 populations, respectively, shown in Figs. 1 and 2. The habitats included lakes, irrigation ponds, rivers and ditches. The plants of one population were assumed to be the same clone because of the lack of sexual reproduction, and several plants were collected and brought back to Kobe University for cultivation. Voucher specimens were also prepared and have been kept at the herbarium of Kobe University.

Electrophoresis
Horizontal starch gel electrophoresis was conducted with the following five enzymes: aconitase (ACO), 6-phosphogluconate dehydrogenase (6PG), phosphoglucoisomerase (PGI), phosphoglucomutase (PGM) and shikimate dehydrogenase (SkDH).

The plant materials were supplied from the cultivated stocks. The apical part of the shoot was ground in ice-cold Tris-HCL-PVP buffer (Soltis et al., 1983) and the extracts were centrifuged. The supernatant was soaked onto filter paper wicks for insertion into 12% starch gel. Electrophoresis was conducted by the following system: 0.065 M L-histidine and 0.007 M citric acid, pH 6.5, as an electrode buffer and its 1:4 dilution as a gel buffer (Goodman et al., 1980). Staining methods for enzymes followed Soltis et al. (1983).

Genetic interpretations of zymograms were inferred from isozyme number and subunit structures of each enzyme (Gottlieb, 1982; Weedon and Wendel, 1989). Isozymes were numbered sequentially beginning with the most anodally migrating one; allozymes were labeled alphabetically, also beginning with the most anodal form. These numbers and letters correspond
Fig. 1. Location of the sampling sites of *Egeria densa*. One plot represents more than two adjacent populations in some cases.

Fig. 2. Location of the sampling sites of *Elodea nuttallii*. One plot represents more than two adjacent populations in some cases.
RESULTS AND DISCUSSION

There were two regions of activity in ACO, 6PG, PGI and PGM. The banding patterns observed in the two species are shown in Fig. 3. 6PG-2 and PGI-1 were not clear enough to be scored.

No genetic variations were detected in the assumed loci studied among the populations in either *Egeria densa* or *Elodea nuttallii*. In other words, the plants of the two species studied had the same genotype, respectively, so far as the five enzyme systems tested were concerned. This suggests that they are rametes of the same clone, which is consistent with the hypothesis that they spread from one source by vegetative means. Strictly speaking, this does not necessarily exclude the possibility of multiple introduction of the species, because it may be that plants with the same genotype were introduced independently on several occasions. Especially in case of *Egeria*
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densa, such a possibility is likely since it has been a popular aquarium plant and widely distributed commercially. To discuss such a case, however, it is necessary to know the range of genetic variation in other areas, especially in their original distribution area.

The ecological implications of genetic uniformity in the two species may be important in understanding their population dynamics after establishment. Both *Egeria densa* and *Elodea nuttallii* often become rapidly dominant due to their explosive growth after invasion. However, decline of their population after a peak of abundance has also been observed in some water bodies (Momose, 1986; Funakoshi, 1989; Hamabata, 1991), though they are still increasing in abundance in many other waters in Japan. This kind of phenomenon is very similar to the well-known case of *Elodea canadensis* in Europe (Sculthorpe, 1967; Kunii, 1988).

As to the cause of decline in populations, some hypotheses have been proposed; e.g., genetic explanations such as the loss of vitality owing to lack of sexual reproduction, depletion of some nutrient, and so on (for a review, see Hutchinson, 1975). But there has been no conclusive evidence to support any of the hypotheses still now. Hutchinson (1975) suggested the involvement of "as yet unrecognized biotic rather than physicochemical factors." Considering the genetic uniformity of these plants, they must be very vulnerable to attacks by pathogens or fungi. The involvement of such organisms as a possible cause of a rapid decline in population should also be explored in future studies.

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拡散のため、オオカナダモの遺伝的変異の欠如

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要

オオカナダモと北米原産のコカナダモは、現在までに北海道をのぞく日本各地に分布を広げている。両者の侵入や分布拡大の経路を明らかにする研究の一環として両種の遺伝的変異を酵素多型を利用して解析した。その結果、オオカナダモ44集団、コカナダモ26集団について調査した5酵素7遺伝子座における変異は認められなかった。これは日本各地に広がっている両種の集団がそれぞれひとつのクローンであることを利用しておき、単一の系統が栄養繁殖によって分布を拡大した可能性が高いと結論した。また、このような遺伝的変異の欠如は様々な感染に対する抵抗力の低下をもたらすため、各地で観察される群落の衰退の要因のひとつとして今後の研究が必要であることに言及した。