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The Colonization of *Lemna paucicostata* and *Spirodela polyrhiza*

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좀개구리밥(*Lemna paucicostata*)과 개구리밥(*Spirodela polyrhiza*)의 定着能力

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ABSTRACT

Colonization ability was studied with *Lemna paucicostata* and *Spirodela polyrhiza*. Colonization ability of each species was defind as its ability to; (1) tolerate to desiccation, (2) multiplicate and spread in the new habitat, (3) inhibit the other species competitively. *Lemna paucicostata* was inferior to *Spirodela polyrhiza* in ability (1), but superior to *Spirodela polyrhiza* in abilities (2) and (3).

Whenever *Lemna paucicostata* and *Spirodela polyrhiza* are colonized recently, only these three abilities can not explain which species is better colonist. Even short unsuitable periods would eliminate a species, with time lag occurring before recolonization. This would result in a discontinuous of the species concerned.

INTRODUCTION

The spatial distributions of both plants and animals have received considerable attention from ecologists. Savile(1956) noted: "Many aquatic plants occur sporadically over wide areas, being plentiful in one lake or group of lakes, but absent from others within a few miles. Their distributions show no clear pattern explainable. Although they are unexplainably absent from some bodies of water, a number of these plants have nearly world-wide distribution."

Since ponds are islands of water surrounded by land, it seems reasonable to extend island biogeographic theory (MacArthur and Wilson, 1967) to explain such distribution.

The chances of extinction are higest in the colonization phase. Successful colonization depends upon at least three characteristics of the species concerned (Keddy, 1976): (1) Ability to disperse, (2) Ability to multiply and spread in the new habitat, (3) Ability to compete with established species.

At first, island biogeographic theory was supported largely by data from birds and plants on oceanic islands. More recently, it has been applied to wide range of habitats: mice on islands, insects on islands, birds and mammals on mountains.

With respect to aquatic vascular plants, Darwin (1859) commented on their wide geographical distributions and dealt with possible dispersal mechanisms in detail. Later, Godwin(1923) stressed that chance plays a strong role in determining pond floras, and that plant ecologists too often assum that each given species grows in every areas which is suitable.

Keddy (1976) commented that dispersal rate of vascular plants (and of many small aquatic organisms) are much higher than that of fish; thus with the former it is probable that the dynamics of inter-island dispersal and colonization, rather than the simple occurrence of long-term island isolation, will be most interest in explaining species distributions. And he examined precisely the role of dispersal and colonizing in determining the distributions of two aquatic vascular plants.

Lemnaceae is a group of small floating plants commonly called duckweeds. All aspects of the study of duckweeds have been reviewed extensively by Hillman(1961). *Lemna paucicostata* and *Spirodela polyrhiza* are aquatics which belong to Lemnaceae and display the characteristics of distribution and wide geographic range. Kwon(1984) surveyed ponds in the suburbs of Seoul and revealed the sporadic nature of their distribution. Many of the ponds surveyed had had no duckweed; 6 had *Lemna paucicostata* alone, and 3 had only *Spirodela polyrhiza*. There were 18 ponds with both species present. However, in spite of this scattered local distribution both species existed within wide geographic range from the Arctic Southward to Mexico. They also coexist in Eurasia and Australia.

Generally, one frond of *Lemna paucicostata* (7.3 mm^2) is smaller than that of *Spirodela polyrhiza* (27.6mm^2).

In this study, from the island biogeographical viewpoint, we attempted to explain the observed frequencies of occurrence of *Lemna paucicostata* and *Spirodela polyrhiza*, and to evaluate their relative colonization abilities.

METHODS

Ability to Disperse In order to test the tolerance of fronds of *Lemna paucicostata* and *Spirodela polyrhiza* to desiccation, specimens were dried on hardware mesh at room condition (27°C, relative humidity=70%) for the time periods of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 hours. Three replicates of 100 fronds of *L. paucicostata* and 50 fronds of *S. polyrhiza* were dried for each time period. After drying, the fronds were transferred to their growth soultion.

All specimens wilted during drying, but some recovered when transferred to the solution. The number of fronds survived was counted after 24 hours. Chlorophyll was extracted by 80% acetone and determined spectrophotometrically. The number of survivors, wet weight and chlorophyll content of fronds after drying were measured and calculated the percentage to the control(0.0 hours drying).

Ability to Multiplicate and Spread in the New Habitat A comparison of the potential population growth rates between the two species should result in some measure of their relative colonization abilities. Potential rate of increase for *L. paucicostata* and *S. polyrhiza* was measured under the following conditions; (1) low density(minimal intraspecific competition), (2) no interspecific competition, (3) complete nutrient solution, (4) ample light, (5) pH well with the limits (Hicks, 1932) of both species.

The two species were grown in 100m*l* erlenmeyer flask aseptically on 50 m*l* Half-strength Hutuer's medium(Hutner, 1953) under photoperiodic cycles of 16 hour light and 8 hour dark under 3,000 lux light intensity at 25±1°C.

Three replicates of 30 fronds for *L. paucicostata* and 10 fronds for *S. polyrhiza* were grown for 3 weeks. Fronds were counted every 4 days. At each counted time, the area of surplus fronds were determined by planimeter and they were removed at

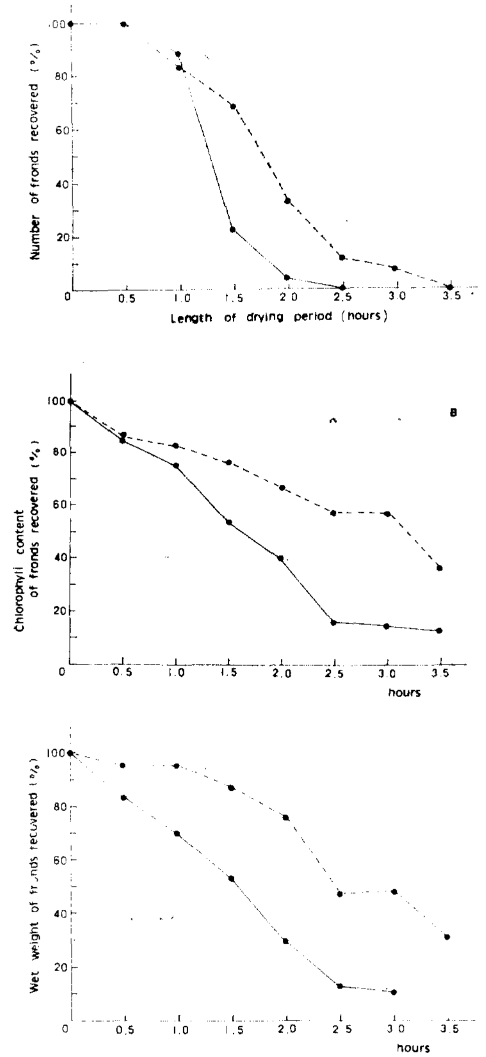

Fig. 1. The response of *L. paucicostata* and *S. polyrhiza* to desiccation. (A) Numbers, (B) Chlorophyll content, and (C) Wet weight of fronds recovered. —●— *L. paucicostata*, ··●·· *S. polyrhiza.*

random to prevent overcrowding and the nutrient solution was changed. And "r" was calculated by the area.

Ability to Inhibit the other Species Competitively With respect to *L. paucicostata* and *S. polyrhiza* intrageneric competition for a given space would appear to be significaint since they both require light.

L. paucicostata and *S. polyrhiza* were grown together in 50m*l* Half-strength Hutner's medium in 100m*l* erlenmeyer flask in growth chamber. Initial surface area of fronds were equal in both species. At every 4 days, surface area of each species grown together was estimated by planimeter. After 4 weeks dry weight of total fronds of each species was measured. Three replicates of sample were used.

RESULTS

Ability to Disperse As shown in Fig. 2, both species, *L. paucicostata* and *S. polyrhiza*, exhibited the same response to drying, but the former tended to suffer higher mortality. A t-test was performed for each time period. There was a significant difference($P<0.01$) after 1.5 hrs drying.

Since a frond of *L. paucicostata* is smaller than that *S. polyrhiza*, the former contains less water, the latter seemed to tolerate longer drying period than the former. Wet weight and chlorophyll content of the latter were more decreased rapidly than the former.

Ability to Multiplicate and Spread in the New Habitat The increase rate of surface area of *L. paucicostata* was 1.77mm^2/day and that of *S. polyrhiza* was 1.29mm^2/day. They proved to be significantly different($P<0.01$). This would dramatically affect their abilities to colonize. To illustrate this, potential maximum population size was predicted (Table 1) for 10 weeks, using the experimentally defined "r" values and assuming that the surface area of both species was equal at the start of experiment. As shown in Table 1, *L. paucicostata* produced 4,382 fronds and *S. polyrhiza* produced 138 fronds at the 5th week.

Dispersion within the new habitat would also reduce the chances of a single disastrous event eliminating the entire newly-established population. *L. paucicostata* would not only produce more fronds, but these would be more likely to disperse.

Table 1. A comparison of potentially attainable population size and dispersion over a 10-wk period beginning with equal surface area of either *L. paucicostata* and *S. polyrhiza*. It was calculated from experimentally derived "r" values

Week	*L. paucicostata*		*S. polyrhiza*	
	Surface area of fronds	Number of fronds	Surface area of fronds	Number of fronds
0	1.0	1.0	1.0	0.1
1	4.2	4.3	3.4	0.9
2	28.4	29.0	11.4	3.4
3	151.3	154.4	38.6	11.9
4	805.9	822.3	130.6	40.6
5	4,294.1	4,381.7	441.4	137.8
6	22,879.6	23,346.5	1,492.2	466.1
7	121,905.3	124,393.2	5,044.2	1,576.1
8	649,527.2	662,782.9	17,051.6	5,328.5
9	3,460,764.2	3,531,392.0	57,641.6	18,012.8
10	18,439,395.6	18,815,709.8	194,852.9	60,891.4

$1 = 0.074 cm^2$

It took shorter time for *L. paucicostata* to spread on equal space than *S. polyrhiza*. Table 1 shows these differences in dispersion as well. Evaluation of the ability shows clearly that: *L. paucicostata*> *S. poyrhiza.*

Intrageneric Competition *L. paucicostata* spread out more fast on the water surface than *S. polyrhiza*. After the surface of the medium was completely covered with both species, they continued to grow and make new fronds. So they formed a mat folded the surface. Then under the experimental condition in which the space was limited, as both species were growing together, *L. paucicostata* formed a thick mat over and shade *S. polyrhiza*. But the reason has not yet been resolved. Fig. 3 shows the increase of frond area of *L. paucicostata* and *S. polyrhiza* when the space is not limited.

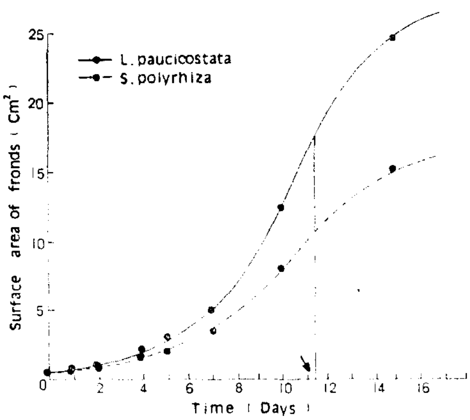

Fig. 2. Intrageneric competition beginning with equal surface area of either *L. paucicostata* and *S. polyrhiza*. Arrow indicates the day when the surface of medium was fully covered with both species.

In the mixture of *L. paucicostata* and *S. polyrhiza*, if the surface area of fronds of both species are equal at the start of growing together, the former not only occupied the larger surface first, but also gave a higher yield of dry weight than latter. Evaluation of competitive ability shows that *L. paucicostata*>*S. polyrhiza.*

DISCUSSION

It should now be possible to determine which species is the better colonist. Table 2 summarizes the results of the experiment. One frond of *L. pau-*

cicostata is smaller than that of *S. polyrhiza*, so the former contains less water and less tolerate to desiccation than the latter. The dispersal ability of *L. paucicostata* is inferior to *S. polyrhiza*. As shown in Table 1, *L. paucicostata* covered not only water surface more rapidly, but also produce more fronds than *S. polyrhiza*. And so *L. paucicostata* would be likely to disperse.

With respect to *L. paucicostata* and *S. polyrhiza*, intrageneric competition for a given space would appear to be significant since *L. paucicostata* and *S. polyrhiza* spread out on the water surface and do not have any other mechanism when they are crowded such as aerenchyma in *L. gibba* (Clatworthy and Harper, 1962) or submerging in *L. trisulca* (Keddy, 1976). So it is important to expand more widely and receives much light in intrageneric competitive ability. In the mixture of both species, *L. paucicostata* occupied larger space first (arrow in Fig. 3). After the surface of the medium was completely covered wtih both species, they continued to grow and form a thick mat. In this condition, most of the *L. paucicostata* grew over and shade the *S. polyrhiza*. So *S. polyrhiza* would receive smaller amount of light and appeared to be white and died. Harvest after growing 4 weeks shows that *L. paucicostata* produced more.

Table 2. The relative colonization abilities of *L. paucicostata* and *S. polyrhiza*

Factor	Assessment
Dispersal	*L. paucicostata* < *S. polyrhiza*
Colonization	*L. paucicostata* > *S. polyrhiza*
Competition	*L. paucicostata* > *S. polyrhiza*

From all the above results, it is difficult to determine which is the best survivor in the natural habitat. Because in the natural conditions in which the habitat is more complex, we must consider the flow rate of water, wind velosity and other aquatics which seemed to influence Lemnaceae. Changinging physical conditions may be one of extinction mechanism. Even short unsuitable period could eliminate a species, with time lag occurring before recolonization. This would result in a discontinuous distribution of the species concerned. For example, Hicks (1932) demonstrated that the Lemnaceae are very sensitive to pH.

Possibility of extinction always remains and as MacArthur and Wilson (1967) pointed out, successful colonization does not guarantee persistence.

From these results and his paper, we also conclude that island biogeographic theory can, with respect to *L. paucicostata* and *S. polyrhiza*, account for the distributional pecularity of the aquatic plant described by Savile (1956). As he pointed out, the island biogeographic element is superimposed upon the distributional patterns already by the physical requirements of a particular species.

摘 要

일부의 水生식물들은 地理的으로는 넓게 分布하나 地域的으로는 드물게 나타나는 수가 있다. 一群의 湖水들은 島嶼들로 간주하면 그곳에 存在하는 식물들의 分布를 설명하는데 島嶼 生物地理學 理論을 적용시킬 수가 있다. 개구리밥과(Lemnaceae)의 두 種-좀개구리밥(*Lemna paucicostata*)과 개구리밥(*Spirodela polyrhiza*)의 分布를 島嶼 生物地理學의 견지에서 연구하였다.

각 種의 새로운 立地에 대한 定着能力(Colonization Ability)은 다음 3가지 능력으로 정의된다 ; (1) 乾燥에 대한 耐性, (2) 새로운 立地에서 增殖하여 分散되는 能力. (3) 競爭的으로 다른 種의 成長을 阻害하는 能力. 좀개구리밥은 (1)의 능력에서 개구리밥보다 열등하였으나 (2)와 (3)의 능력은 우세하였다.

그러나 좀개구리밥과 개구리밥이 새로이 정착된 지역에서는 위의 3가지 능력만으로는 어느 種이 더 빈번하게 나타날지를 설명할 수가 없다. 物理的 環境의 變化에 의해 種이 消滅되기도 한다. 짧은 期間이라도 適切하지 않은 환경은 再定着이 일어나기 전에 種을 消滅시킬 수 있다. 그러므로 問題가 된 종이 地域的으로는 不連續的인 分布를 나타내게 된다.

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