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Occurrence of *Dictyosphaerium pulchellum* (Chlorophyceae) Bloom in a Small Pond

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As a part of study on the microalgal dynamics in a small pond in Hongsung, Chungnam, we found a massive bloom of chlorococcalean green alga, *Dictyosphaerium pulchellum* during the year−round survey from January 2000 to January 2001. *D. pulchellum* occurred at a low frequency throughout the year. However, *D. puchellum* began to increase from 12 March, showed a peak of blooming with 59,200 colonies mL^{-1} in 2 April, and abruptly decreased in 16 April. Colonies were 8−celled and 16−celled at early stage of blooming, 32−celled or 64−celled at the midst of blooming, and most of colonies consisted of 64 cells at the end of blooming. Colonies of *D. pulchellum* were healthy at the early stage of blooming, but most of colonies were infected with some parasites at the end of blooming. The infected cells bleached out with decomposing chloroplast and pyrenoids. The infection with parasites, together with irradiance and nutrient limitations, appears to stop *D. pulchllum* bloom. This is the first report on the occurrence of blooming of a green algal genus *Dictyosphaerium* and its infection with parasite in Korea.

Key words : Blooming, *Dictyosphaerium pulchellum*, green algae, parasites, pond

INTRODUCTION

Planktonic algae are mostly unicellular or colonies, and important in ecosystem dynamics as producers at the base of the planktonic food web (Round, 1981). Occasionally, some algal species divide very fast and accumulate into dense, visible patches near the surface of the water, discoloring waters and making 'bloom'. Although most of planktonic algae are not harmful, algal bloom occasionally causes negative effects on freshwater ecosystem (Harper, 1992).

Planktonic algae are parasitized by viruses, bacteria, fungi, and protists (Round 1980). The close association of parasites with phytoplankton cells has fostered their ecological interests. For example, the onset of the aquatic fungal chytridiomycete parasitism is frequently correlated with a rapid decline in host algal populations (see Powell 1993). In Korea, there are two reports on parasites within blooming cells of eukaryotic phytoplankton. Shin and Boo (1999) observed virus−like particles within blooming cells of a green euglenoid, *Euglena viridis* Ehrenberg and Shin *et al.* (2001) found an aquatic fungus, *Entophlyctis apiculata* (Braun) Fischer, parasitized within populated cells of a green alga, *Chlamydomonas* sp.

Dictyosphaerium Naegeli is a chlorococcalean green algal genus and has colonies of which cells lie at the tips of the ultimate branches of a radiating, cruciately or dichotomously, branched series of threads derived from cell walls of previous generations (Smith, 1950). This genus is reported to be ubiquitous and sometimes a conspicuous component of phytoplankton in acid bog lakes (Prescott, 1961). Three species commonly occur

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worldwide; *D. ehrenbergianum* Naegeli, *D. planctonianum* Tiffany et Ahlstrom, and *D. pulchellum* Wood. Among these, *D. pulchellum* is reported to predominate in eutrophic water (Ganf and Oliver, 1982; Pourriot *et al*., 1982; Holmgren, 1985) or bloom in winter (Tucker and Llyod, 1984).

In Korea, seasonal or nutritionally induced algal blooms often occur in waters throughout year. For example, there are blooms of blue-green algal *Microcystis* Lemmermann (e.g. Lee *et al*., 1998), green euglenoid *Euglena* Ehrenberg (e.g. Kim and Boo, 2001), and diatom *Stephanodiscus* Ehrenberg (e.g. Cho and Shin, 1995). As a part of study on the modeling of microalgal dynamics in a small pond, Korea, we introduced the development and decline of *D. pulchellum* bloom during the year-round survey of 2000, and discuss our screened results of a *D. puchellum* bloom.

MATERIALS AND METHODS

A year round survey was carried out in a small pond in Hongsung, Chungnam, having a surface area of 36,800 m^2 and a maximum depth of 5 m. The pond has a constant pondage all the year round, because the pond doesn't have inlets and outlets, and most of the water appears to be supplied from precipitation and ground water. The pond is occupied with various aquatic plants, which may cover most of the surface in the season from summer to autumn.

Water samples were collected every week from 30 January 2000 to 21 January 2001, using plankton net (20 μm in mesh size). Waters were poured 30 times with a 2,000-ml gourd dipper. Fresh samples were observed under the light microscope (Olympus VANOX AHBT3). For counting *D. pulchellum*, the algal suspension was prepared using a 1,000-ml sampling bottle and fixed with LUGOL's iodine solution. The samples were precipitated in a 1,000-ml volumetric flask for a week under cooled dark conditions and concentrated to a 100-ml volume. Because *D. pulchellum* is colonial organism, the number of colonies was determined using the SEDGWICK-RAFTER counting cell and an inverted microscope (Olympus IX70) at 400× or 1,000× magnifications. A total of 50 strips (ten strips multiplied five times) in the S-R cell were counted to derive the colony density per milliliter (Kim and Boo, 1998). The average of five counts was used to assign a density of *D. pulchellum*.

RESULTS AND DISCUSSION

Despite of its infrequent occurrence in other seasons, *Dictyosphaerium pulchellum* showed a big bloom in spring during the survey year of 2000 (Fig. 1A). *D. pulchellum* density began to increase in 5 March and reached up to 13,420 colonies mL^{-1} in 12 March. The density massively increased to an average of 46,320 colonies mL^{-1} in 19 March, then 52,280 colonies mL^{-1} in 26 March, and reached a peak of 59,200 colonies mL^{-1} in 2 April (Fig. 2). *D. pulchellum* abruptly decreased to 12,350 colonies mL^{-1} in 16 April and the density of colonies in 23 April was similar to that in other seasons. After the bloom of *D. pulchellum*, an aquatic nymphaealean plant *Euryale ferox* Salisbury grew and begun to cover the surface water.

The colonies of *Dictyosphaerium pulchellum* showed a diverse number of cells (Fig. 1A). They consisted of 8 cells, 16 cells, 32 cells or 64 cells, which are surrounded by gelatinous matrix. In March 12, approximately 70% of colonies was 8-celled, 20% 16-celled, and 10% 32-celled. In 19 March, with the increase of *D. pulchellum* density, 16-celled colonies increased with 50%, whereas 8-celled colonies decreased with 36%. In 26 March, more than 90% of colonies consisted of 64 cells or 32 cells (Fig. 1B). In April 16, most of colonies consisted of 64 cells (Fig. 1C) and there were few 8-celled colonies.

Colonies of *D. pulchellum* were healthy throughout year except blooming period. However, cells of *D. pulchellum* colonies began to be infected with some parasites (Fig. 1D) in March 26, when the density reached a peak, and most of the colonies were infected in April 9, when cell density abruptly decreased (data not shown). The infected cells bleached with decomposing chloroplast and pyrenoids. The infected colonies were occasionally 42-celled (Fig. 1D).

Our continuous monitoring shows that *D. pulchellum* bloom occurred in spring between the diatom peak in winter and massive development of *Euryale ferox* in early summer. Despite many studies on algal communities dynamics in Korea (e.g. Cho, 2001; Kim and Boo, 2001), there are no reports on the bloom of the green algal genus

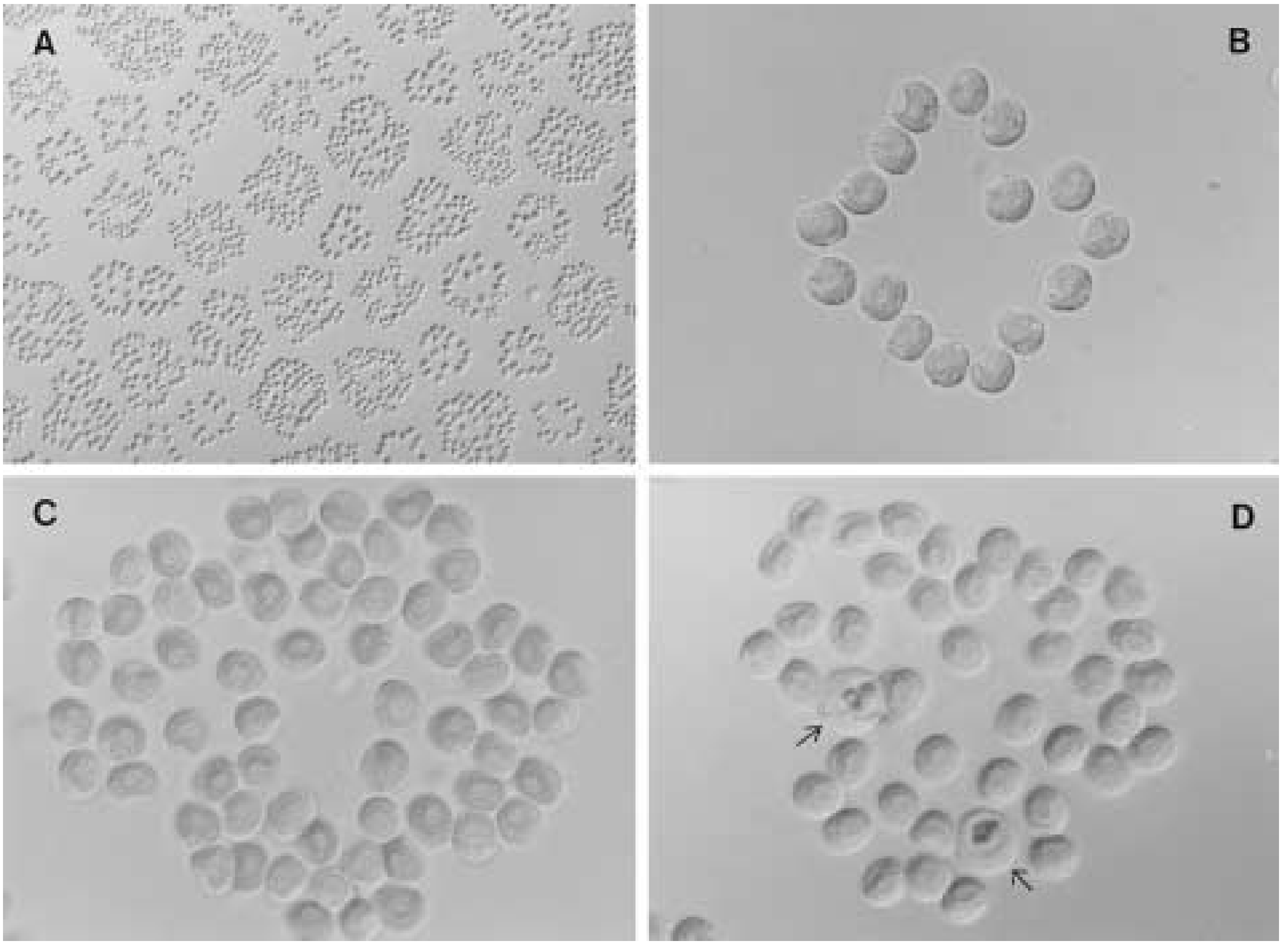

Fig. 1. Colonies of *Dictyosphaerium pulchellum* in the field. A. Blooming of *D. pulchellum*. B. A 16-celled colony. C. A 64-celled colony. D. Bleached and decomposed cells infected with parasites (arrow).

Dictyosphaerium. *D. pulchellum* bloom in our study pond is considered to be due to natural eutrophication. Our study pond, having no outlets and inlets, is nearly natural and stagnant without artificial input or output of waters. Moreover, most of the pond water appears to be supplied from rainfall and upwelling of ground water. According to Reynolds (1988) and Harper (1992), the natural eutrophication may be frequently induced at the small sized stagnant waters as a consequence of a heavy input of organic or inorganic nutrients from surrounding plant detritus. On-going study on the trophic status of our pond will explain the probable cause of *D. pulchellum* bloom. On the other hand, blooms of diatom (Cho and Shin, 1995), blue green algae (Lee *et al*., 1998), and green euglenoids (Kim and Boo, 2001) are reported to occur by organic pollution or artificial eutrophication probably due to human activities.

Nutrients such as ammonium, nitrate, and phosphate, and temperature, irradiance and pH often contribute to development of fresh water algal bloom (Round, 1981). Holmgren (1985) reported that *D. pulchellum* predominated in water, receiving phosphate of 4.5 ton per year, whereas after 2 years *Chlamydomonas* Ehrenberg and Mallomonas Perty occurred in the same water, receiving phosphate of 18~20 kg per year in Sweden. Tucker and Llyod (1984) reported winter bloom of *D. pulchellum* in catfish pond in Mississippi. In the report on the effect of medium composition and pH on the growth of *D. pulchellum* in India, Mathew and Chowdary (1981) showed its preference to alkaline conditions and the occurrence of the nutritional variant in the ammonium nitrate medium. Research is ongoing on what combinations of environmental conditions produced a

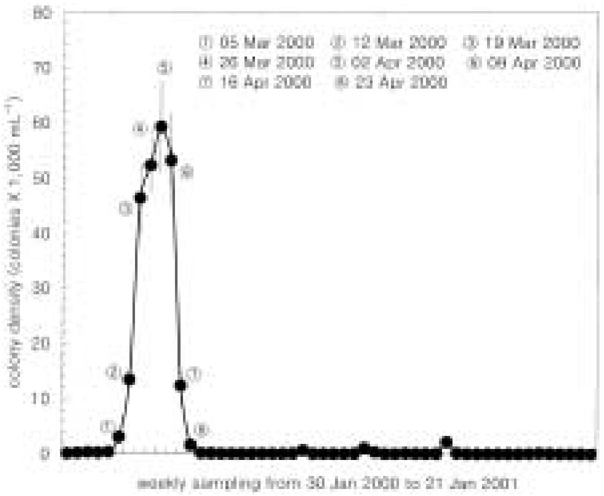

Fig. 2. Weekly changes of density of *Dictyosphaerium pulchellum* from 30 Jan 2000 to 21 Jan 2001. *D. pulchellum* bloom was remarkable in spring.

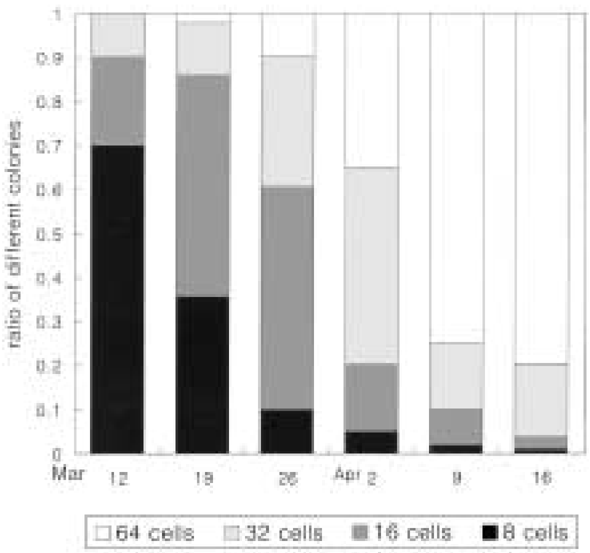

Fig. 3. Ratio of 8-celled, 16-celled, 32-celled and 64-celled colonies to total colonies. Most of colonies at peak of blooming consisted of 64 cells.

D. pulchellum bloom in our pond.

The development of aquatic vascular plant may induce the decline of *D. pulchellum* bloom. Izaquirre and Vinocur (1994) reported that no algal groups were absolutely dominant in the more vegetated shallow lakes. In our study pond, *Euryale ferox* plants vigorously grew, using nutrients such as the nitrogenous and phosphorus nutrients, and covered the surface water. Their overgrowth absolutely decreases photosynthetic light and nutrients for division of the plankton algal cells. Under the limited nutrients and irradiance, *D. pulchellum* bloom may decline and be excluded from the water bodies.

The parasites may play a role of natural controller of algal blooming in freshwaters because they invade rapidly growing cells of the host planktonic algae (Powell, 1993). During our year-round survey, the observation that *Dictyosphaerium pulchellum* cells at the end of blooming were infected with parasites is remarkable. The decline of *Dictyosphaerium pulchellum* bloom may be accelerated by infection with some parasites, resulting that most of colonies were infected in April 16 and the infected cells bleached and decomposed. The occurrence of irregular number of cells (42 cells) in a colony, as seen in Fig. 1D, also indicates that infection with parasite may obstruct regular division of cells. Because infection with parasite may play in a taxon-specific manner (see Round, 2001), the infection processes of parasites in *D. pulchellum* cells are postulated as followings; 1) initiation of *D. pulchellum* bloom; 2) occurrence of parasite as the bloom develops and algal cell number rises; 3) infection and lyses of algal cells; 4) termination of *D. pulchellum* bloom. It is our scenario that *Dictyosphaerium pulchellum* blooms develop at optimal condition of environments, avoiding from nutrient competition with other aquatic organisms. However, at high density, *D. pulchellum* cells are easily infected with some parasites and decrease abruptly. More studies are on-going to understand the complex interactions that exist between *D. pulchellum* bloom and biological or abiological variables. Such understandings would be a great help for resolving several critical issues such as mechanisms regulating development and decline of microalgal bloom.

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<국문적요>

작은 연못에서 녹조류 *Dictyosphaerium pulchellum*의 대발생

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충남 홍성의 작은 연못에서 수행되고 있는 식물플랑크톤 연주기의 모델링 연구 과정에서 녹조류 *Dictyosphaerium pulchellum*의 대발생 과정을 2000년 1월부터 2001년 1월까지 추적하였다. *D. pulchellum*은 연중 드물게 출현하였으나, 밀도는 3월 12일부터 증가하기 시작하여, 4월 2일에는 59,200 colony mL^{-1}로 대발생하였고, 4월 16에 급감하였다. 군체는 보통 8세포와 16세포로 이루어졌으나, 대발생이 진행될수록 32세포와 64세포 군체들로 대치되었고, 대발생 후기에는 대부분의 군체가 64세포였다. *D. pulchellum* 세포들은 대발생의 초기에는 건강하였으나, 3월 19일부터 기생생물에 감염되어 있는 군체들이 나타났으며, 4월 9일에는 대부분의 군체들이 기생생물로 감염되었다. 기생생물로 감염된 세포들은 엽록체가 파괴되었고, 피레노이드도 발달되지 않았다. 현재 진행되고 있는 *D. pulchellum*의 개체군과 환경요인, 경쟁 및 기생생물과의 관계에 대한 연구는 *D. pulchllum*의 대발생 과정에 관한 새로운 정보를 제공할 것이다.