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铜绿微囊藻和斜生栅藻非稳态营养盐限制条件下的生长竞争特性

Growth competition characteristics of *Microcystis aeruginosa* Kutz and *Scenedesmus obliquus* (Turp.) Kutz under non-steady-state nutrient limitation

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作者	单位	E-mail
赵晓东	中国计量学院计量测试工程学院, 杭州 310018	zhaoxd@cjlu.edu.cn
潘江	中国计量学院计量测试工程学院, 杭州 310018	
李金页	中国计量学院计量质量与安全工程学院, 杭州 310018	
陶晓磊	中国计量学院计量测试工程学院, 杭州 310018	
庞坤	中国计量学院浙江省生物计量及检验检疫重点实验室, 杭州 310018	

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中文摘要:

采用“脉冲”添加方法进行了非稳态条件下铜绿微囊藻(M.)和斜生栅藻(S.)分别在氮磷单营养盐和双营养盐限制时的共培养试验。试验结果显示:当添加频率为1d时,无论何种营养盐限制,M.均成为优势藻种。氮限制条件下,氮时均浓度范围在0.3-2.4 mg/L时,M.始终具有竞争优势。磷限制条件下,磷浓度范围在0.018-0.035 mg/L时,S.只在生长初期阶段占优。氮磷双营养盐限制条件下,添加液的氮磷质量比为35:1(设定为最优比),添加频率为8 d时,两种藻表现出共生特征;而偏离最优比时(N:P=70:1,17:1),在不同的添加频率下均未出现共生现象,且氮的时均浓度为0.6-4.8 mg/L时(70:1),M.具有竞争优势,而降低为0.15-0.3 mg/L时(17:1),S.占优。随着添加频率的变化,两种藻的细胞大小也会随之改变,S.随着营养盐浓度的降低而增大,且在双营养盐限制条件下变化更显著。上述试验结果分析表明:两种藻竞争能力与添加频率相关,在藻种浓度的变化上,按照‘拾遗-机会’交替竞争理论,M.表现出机会主义者特征,而S.则表现出拾遗者的特征,两者的共生特征也符合‘中度干扰’假说。藻细胞大小变化表明,两种藻均可以改变大小实现最大限度争夺受限营养盐。在低浓度时,S.细胞大小的变化同样也体现出了“拾遗者”的特征。

English Summary:

To test the growth characteristics of *Microcystis aeruginosa* Kutz (M.) and *Scenedesmus obliquus* (Turp.) Kutz (S.) under non-steady-state conditions, a culturing experiment was performed using the “pulse” adding method. The culture solutions were matched according to different mass ratios of nitrogen and phosphorus (35 : 1, 70 : 1 and 15 : 1). The two kinds of cells were also separately cultured with a ratio of nitrogen to phosphorus of 35 : 1, demonstrating the similar ratio of growth in the same culture solution with sufficient nutrients. However, different ratios of growth were observed under conditions of limited nutrients. From these findings, a ratio of 35 : 1 was considered to be optimal. The experimental results showed that M. was almost always the predominant algae when the frequency of addition was once per day during the whole culturing process, regardless of the availability of nutrients. M. also gained a competitive advantage as the limited time-average concentration of nitrogen varied from 0.3 to 2.4 mg/L. S. was only dominant at the initial growth stage as the limited phosphorus concentration varied from 0.018 to 0.035 mg/L, with M. finally becoming dominant. When nitrogen and phosphorus were both limited at a ratio of 35:1, the symbiosis of these algae was observed under two different frequencies of nutrient addition, i.e., once per day and once every eight days. However, when cultured at the former frequency, symbiosis occurred and both algae showed similar growth characteristics. When the nitrogen:phosphorus ratio departed from the optimum value, symbiosis did not occur at any of the frequencies of addition. M. was the predominant algae when the time-average concentration of nitrogen ranged from 0.6 to 4.8 mg/L, and S. became predominant when the concentration varied from 0.15 to 0.3 mg/L. Images of the cells were recorded and used to analyze variations in size. The results showed that the cell size of the two algae changed with the frequency of addition. The cell size of S. increased as the nutrient concentration decreased when simple nutrients were limited, and larger changes in cell size were observed when phosphorus was limited. Similarly, S. cells grew larger when two nutrients were limited than when simple nutrients were limited, with the largest change in size being from 26.33 μm^2 to 57.60 μm^2 . However, the size of M. cells was not changed as significantly as S. cells, with differences of no more than 3 μm^2 being observed whatever the nutrient availability. Analysis of the experimental results indicated that competition between the two algae was related to the frequency of addition of nutrients. According to the theory of gleaner-opportunist trade-off, M. showed the characteristics of an opportunist and S. was more likely to be a gleaner. The symbiosis of the two algae coincided with the intermediate disturbance hypothesis. The two algae were able to change their cell size to strive for more nutrients. The gleaner characteristic of S. was also confirmed by cell size changes at low concentration.

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