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Growth and toxin production of tropical *Alexandrium minutum* Halim (Dinophyceae) under various nitrogen to phosphorus ratios

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Abstract Effects of nitrogen to phosphorous (N/P) ratios of two nitrogen sources (nitrate and ammonium) on growth and toxin production of a tropical estuarine dinoflagellate, *Alexandrium minutum* Halim, were examined using a strain isolated from a bloom at Tumpat Estuary, Malaysia in September 2001. Experiments were carried out in batch cultures, using either nitrate ($N\text{-}NO_3$) or ammonium ($N\text{-}NH_4$) as the nitrogen source at a constant amount, and with initial N/P ratios ranging from 5 to 500. Cell density, residual N and P in the medium, cellular toxin quota (Q_t), and toxin composition were analyzed throughout the growths. Our results showed that cell densities and growth rates of *A. minutum* were severely suppressed under high N/P ratios (>100) in both $N\text{-}NO_3$ and $N\text{-}NH_4$ treatments. Cells tended to be larger at lower growth rate and P-limited cultures. Toxin profile was relatively constant throughout the experiments, with GTX4/GTX1 as the dominant toxin congeners. Cellular toxin quota (Q_t) increased with elevated N/P ratios in both $N\text{-}NO_3$ and $N\text{-}NH_4$ treatments. Toxin production rate, R_{tox}, however was enhanced in $N\text{-}NH_4$-grown cultures when P was limited, but showed no difference between $N\text{-}NO_3$- and $N\text{-}NH_4$-grown cultures when P was replete. Our results clearly showed that N/P ratios as well as the nitrogen compounds not only affected the growth of *A. minutum*, but also the cellular toxin quota and its toxin production rate.

Keywords *Alexandrium minutum* · N/P ratio · Growth · PST production · Tropical

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Introduction

Coastal eutrophication has been increasingly reported not only in developed but also in developing countries, mainly due to the increasing of coastal inhabitants, maricultures, terrestrial origin runoff, as well as other human activities. Dissolved organic nitrogen (N) and phosphorus (P) and nutrients from allochthanous sources in eutrophic waters are the main source of eutrophication (Glibert et al. 2001). Increases of nitrogenous and phosphorus nutrients in estuarine and coastal waters have resulted in changes in nutritional status which favored the proliferation of a selected group of phytoplankton (Balode et al. 1998), and decreases in N/P ratios due to phosphorus loading have been related to harmful algal bloom events (Hodgkiss and Ho 1997). This includes toxic dinoflagellates of the genus *Alexandrium* that are frequently associated with paralytic shellfish poisoning intoxications.

In tropical estuarine coastal regions, seasonal and intratidal fluctuation in nitrogen to phosphorus (N/P) ratios is common over the annual cycle. For example, these ratios vary from 25:1 to ca. 70:1 during monsoonal rainy and dry seasons as well as neap and spring tides in Malaysian mangrove estuaries (Tanaka and Choo 2000). Changes of the nutrient pool affect