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EFFECTS OF LIGHT AND TEMPERATURE ON GROWTH, NITRATE UPTAKE, AND TOXIN PRODUCTION OF TWO TROPICAL DINOFLAGELLATES: *ALEXANDRIUM TAMIYAVANICHII* AND *ALEXANDRIUM MINUTUM* (DINOPHYCEAE)[1]

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The two tropical estuarine dinoflagellates, *Alexandrium tamiyavanichii* Balech and *A. minutum* Halim, were used to determine the ecophysiological adaptations in relation to their temperate counterparts. These species are the two main causative organisms responsible for the incidence of paralytic shellfish poisoning (PSP) in Southeast Asia. The effects of light (10, 40, 60, and 100 µmol photons $\cdot m^{-2} \cdot s^{-1}$) and temperature (15, 20, and 25° C) on the growth, nitrate assimilation, and PST production of these species were investigated in clonal batch cultures over the growth cycle. The growth rates of *A. tamiyavanichii* and *A. minutum* increased with increasing temperature and irradiance. The growth of *A. tamiyavanichii* was depressed at lower temperature (20° C) and irradiance (40 µmol photons $\cdot m^{-2} \cdot s^{-1}$). Both species showed no net growth at 10 µmol photons $\cdot m^{-2} \cdot s^{-1}$ and a temperature of 15° C, although cells remained alive. Cellular toxin quotas (Q_t) of *A. tamiyavanichii* and *A. minutum* varied in the range of 60–180 and 10–42 fmol PST $\cdot$ cell^{-1}, respectively. Toxin production rate, R_{tox}, increased with elevated light at both 20 and 25° C, with a pronounced effect observed at exponential phase in both species (*A. tamiyavanichii*, $r^2 = 0.95$; *A. minutum*, $r^2 = 0.96$). Toxin production rate also increased significantly with elevated temperature ($P < 0.05$) for both species examined. We suggest that the ecotypic variations in growth adaptations and toxin production of these Malaysian strains may reveal a unique physiological adaptation of tropical *Alexandrium* species.

Key index words: ***Alexandrium minutum*; *Alexandrium tamiyavanichii*; growth; light; temperature; toxin production; tropical**

Abbreviations: ***E*, irradiance; µ, growth rate; NR, nitrate reductase; PSP, paralytic shellfish poisoning; PPFD, photosynthesis photon flux densities; Q_t, cell toxin quota; R_{tox}, toxin production rate**

In Southeast Asia, thousands of paralytic shellfish poisoning (PSP) incidents have been reported since the early 1970s. In the Philippines alone, 2107 cases and 117 fatalities have been reported (Gonzales et al. 2002). Initially, PSP in this region was associated solely with the blooms of *Pyrodinium bahamense* Plate var. *compressum* Böhm (Roy 1977, Maclean 1979, 1989). However, since the late 1980s, there have been increasing PSP events due to other species. The first was toxicity due to *Alexandrium tamiyavanichii* Balech in the Strait of Malacca in 1991 (Usup et al. 2002a), which was followed by the events in the Philippines (Montojo et al. 2003). Most recently, *Alexandrium minutum* Halim has emerged as an important PSP-causing species in the regions (Usup et al. 2002a, Bajarias et al. 2003, Lim et al. 2004). Previously, *A. minutum* was reported from Thailand (Matsuoka et al. 1997, Piumsomboon et al. 2001) and Vietnam (Yoshida et al. 2000), although no human toxicity was mentioned.

Many studies on PST-producing dinoflagellates have been focused on the genus *Alexandrium*. This was probably due to the fact that about one third of the 30 currently known *Alexandrium* species are PST producers, in addition to the wide biogeographical

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