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Effects of irradiance and salinity on the growth of carpospore-derived tetrasporophytes of *Gracilaria edulis* and *Gracilaria tenuistipitata* var *liui* (Rhodophyta)

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Abstract *Gracilaria edulis* and *Gracilaria tenuistipitata* var *liui* are agarophytes with high commercial value which are currently cultivated in countries like India and Thailand. They have great potential for mariculture in Malaysia. Experiments were carried out to study carpospore germination and determine the effects of irradiance and salinity on the growth of these two species. Both species showed the *Dumontia* type of carpospore development. Both species showed increased daily growth rate (% day^{-1}) with increasing irradiance and tolerance for a wide range of salinity with a preference for low salinity. *G. edulis* grew best at 100 μmol photons m^{-2} s^{-1} and 15 psu while *G. tenuistipitata* var *liui* grew best at 60–130 μmol photons m^{-2} s^{-1} and 15 psu. The highest growth rate obtained for *G. edulis* and *G. tenuistipitata* var *liui* was 13.57 and 19.7 % day^{-1} respectively. *tenuistipitata* var *liui*. ANOVA showed that both irradiance and salinity have significant effect on the growth of both species ($P<0.05$). The results showed that *G. tenuistipitata* var *liui* is a good candidate for mass cultivation in Malaysian brackish waters. Besides, this study also showed the feasibility of using spore culture to provide stocks for sustainable farming of *Gracilaria*.

Keywords Carpospore culture · *Gracilaria edulis* · *Gracilaria tenuistipitata* var *liui* · Irradiance · Salinity · Rhodophyta

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Introduction

Gracilaria Greville is one of the largest genera of seaweeds with over 150 species distributed worldwide (Tseng and Xia 1999) with 22 species recorded in Malaysia (Lim and Phang 2004). *Gracilaria* has economical importance as food for humans and marine animals and as a source of agars (Zemke-White and Ohno 1999). It produces around 80 % of the world's total agar and it is cultivated mainly in Indonesia and Chile and to a lesser extent in Thailand, China and Malaysia (Bixler and Porse 2010). The small-scale cultivation of *Gracilaria changii* in Malaysia has been experimentally carried out in shrimp ponds, mangrove ponds and irrigation canals (Phang et al. 1996; Phang 2006).

Malaysia has suitable areas for the farming of *Gracilaria* as it possesses an extensive coastline of about 3,432 km with the northwest of Peninsular Malaysia mainly covered by mangrove forests which are very suitable for cultivation of *Gracilaria*. Currently, only *Kappaphycus alvarezii* and *Eucheuma denticulatum* are cultivated commercially in Malaysia (Phang 2006; Tan et al. 2012) for raw material used in carrageenan production. Therefore, it is timely for Malaysia to venture into mass cultivation of *Gracilaria* to produce raw material for the production of agar to meet the ever increasing demand.

Gracilaria edulis (S.G. Gmelin) P.C. Silva is found abundantly on intertidal mudflats, fish cages, mangroves, corals and mangrove estuary throughout Malaysia (Phang 1994; Lim and Phang 2004). *Gracilaria tenuistipitata* var *liui* Zhang and Xia can be found along the west coast of Peninsular Malaysia growing on rock, bedrock and stones (Phang 2006). A few studies have been performed on the growth of *G. edulis* (Raikar et al. 2001; Ganesan et al. 2011) and *G. tenuistipitata* var *liui* (Israel et al. 1999; He et al. 2002; Xu et al. 2009) in laboratory as well as outdoor cultivation. However, all these earlier growth studies involving *G. tenuistipitata* var *liui* used specimens directly from