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EFFECTS OF LIGHT, TEMPERATURE AND FEEDING ON GROWTH OF ARTIFICIALLY PROPAGATED CORALS Dipsastraea pallida (DANA, 1846) AND Dipsastraea speciosa (DANA, 1846)

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

EFFECTS OF LIGHT, TEMPERATURE AND FEEDING ON GROWTH OF ARTIFICIALLY PROPAGATED CORALS *Dipsastraea pallida* (DANA, 1846) AND *Dipsastraea speciosa* (DANA, 1846)

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December 2018

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This study examines the parameters that influence the growth of turbid water coral; *Dipsastraea pallida* and *Dipsastraea speciosa* from Tanjung Tuan, Port Dickson including variances in light intensity, temperature and feeding, to generate turbid water coral aquaculture protocol for conservation purposes. *Dipsastraea pallida* and *D. speciosa* were subjected to six different light treatments under LED and fluorescent lights, showed better growth under light intensity at 60 µmol m^{-2} s^{-1}. At this light intensity, *D. pallida* recorded highest specific growth rate (SGR), which were 1.66 ± 0.15 mg $week^{-1}$ under LED and 1.65 ± 0.18 mg $week^{-1}$ under fluorescent lights, while *Dipsastraea speciosa* reached 1.65 ± 0.16 mg $week^{-1}$ (LED) and 1.63 ± 0.16 mg $week^{-1}$ (fluorescent) respectively. Coral specimens were tested for thermal tolerance with increasing temperature up to bleaching point. Results showed *Dipsastraea* pallida and *D. speciosa* can withstand temperature up to 34 °C for five days continuously and bleached once exposed to 35 °C and do not recover from bleaching. *Artemia* sp. nauplii were fed to *D. pallida* and *D. speciosa* to examine the optimal feeding time and feeding rate. Both species presented diurnal feeding behavior with highest feeding rate in the afternoon from 1200h to 1400h, with preferable feeding density of *Artemia* sp. nauplii at 5 ind mL^{-1} with average 107.20 ± 2.47 ind^{-1} $polyp^{-1}$ h^{-1} (*D. pallida*) and 113.60 ± 3.59 ind^{-1} $polyp^{-1}$ h^{-1} *(D. speciosa)*. Present study concludes that *D. pallida* and *D. speciosa* from Tanjung Tuan exhibit diurnal feeding behavior. Result showed evident showed that these two species have adapted to Tanjung Tuan low light water conditions with better growth performance at light intensity 60 µmol m^{-2} s^{-1}. These two species from the intertidal zone have higher heat tolerance with bleaching point at 35 °C.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Master Sains

KESAN INTENSITI CAHAYA, SUHU DAN PEMAKANAN TERHADAP PERTUMBUHAN PROPAGASI BATU KARANG *Dipsastraea pallida* (Dana, 1846) DAN *Dipsastraea speciosa* (DANA, 1846)

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Kajian ke atas parameter yang mempengaruhi pertumbuhan terumbu karang dari pantai perairan keruh; *Dipsastraea pallida* dan *Dipsastraea speciosa* dari Tanjung Tuan, termasuk kepelbagaian intensiti cahaya, suhu dan pemakanan, tujuannya untuk menghasilkan protokol akuakultur terumbu karang dari perairan keruh. *Dipsastraea pallida* dan *D. speciosa* tertakluk kepada enam rawatan cahaya yang berbeza di bawah lampu LED dan lampu pendarfluor, menunjukkan keputusan pertumbuhan yang lebih baik di bawah intensiti cahaya pada 60 µmol m^{-2} s^{-1}. Pada intensiti cahaya ini, *D. pallida* mencatatkan kadar pertumbuhan spesifik (SGR) yang paling maxima iaitu 1.66 ± 0.15 mg $minggu^{-1}$ di bawah LED dan 1.65 ± 0.18 mg $minggu^{-1}$ di bawah lampu pendarfluor, manakala *Dipsastraea speciosa* mencapai 165.5 ± 0.16 mg $minggu^{-1}$ (LED) dan 163.2 ± 10.16 mg $minggu^{-1}$ (lampu pendarfluor). Spesimen terumbu karang juga diuji untuk toleransi suhu dengan meningkatkan suhu air laut sehingga mencapai suhu pelunturan terumbu karang. Keputusan tersebut menunjukkan *D. pallida* dan *D.speciosa* dapat bertahan peningkatan suhu sehingga 34 °C selama lima hari secara berterusan dan dilunturkan sekali terdedah kepada 35 °C dan tidak pulih daripada pelunturannya. Naupli *Artemia* sp. diberi makan kepada *D. pallida* dan *D. speciosa* untuk memeriksa tempoh pemakanan dan ketumpatan pemakanan yang optimum. Kedua-dua spesies ini menunjukkan tingkah laku pemakanan diurnal dengan kadar pemakanan tertinggi pada waktu petang dari jam 1200h hingga 1400h petang, dengan ketumpatan makan yang lebih baik pada 5 ind mL^{-1} dengan purata 107.20 ± 2.47 ind^{-1} $polip^{-1}$ jam^{-1} (*Dipsastraea pallida*) dan 113.60 ± 3.59 ind^{-1} $polip^{-1}$ jam^{-1} (*Dipsastraea speciosa*). Kajian semasa menyimpulkan bahawa *D. pallida* dan *D. speciosa* dari Tanjung Tuan menunjukkan tingkah laku pemakanan diurnal. Keputusan membuktikan bahawa kedua-dua spesies ini telah menyesuaikan diri dengan keadaan perairan cahaya rendah di Tanjung Tuan dengan prestasi pertumbuhan yang lebih baik pada intensiti cahaya 60 µmol m^{-2} s^{-1}. Kedua-dua spesis dari zon pasang surut mempunyai toleransi suhu yang tinggi dengan suhu perlunturan pada 35 ° C.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

%	percentage
Δ time	experiment time
Δt	growth interval in weeks
°C	degree Celsius
cm^2	centimeter square
D. Pallida	*Dipsastraea pallida*
D. speciosa	*Dipsastraea speciosa*
$Density_i$	initial number of *Artemia* sp. nauplii
$Density_r$	remaining number of *Artemia* sp. nauplii after two hours
E	east
h	hour
ind mL^{-1}	individual of *Artemia* sp. nauplii per milliliter
ind $polyp^{-1}$ h^{-1}	individual of *Artemia* sp. nauplii per polyp per hour
LED	light emitting diode
mg	milligram
mg $week^{-1}$	milligram per week
mL s^{-1}	milliliter per second
N	north
n of polyp	number of polyp
NOAA	national oceanic and atmospheric administration
PPFD	photosynthetic photon flux density
ppt	part per thousand
SGR	specific growth rate
SGR ($week^{-1}$)	specific growth rate expressed in milligram per week
W	watt
Wt	final weight of corals
Wt – 1 =	initial weight of corals
µmol m^{-2} s^{-1}	micromole per second per meter square

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Scleractinian corals also known as hard corals or stony corals are reef builders which have a skeleton made up by calcium carbonate ($CaCO_3$). Scleractinian corals usually have polyps that secrete cup (calyx) with the theca surrounding it while the basal plate is a floor of the polyps. As polyps die and keep on reproducing, corals leave their skeleton and new living polyps will grow on top of it. As time passes, calcium carbonate accumulated layer by layer and become solid structure known as coral reefs. However, the process of reef-building is slow which can takes decades or centuries (Weber, 1980; Ginsburg *et al*., 2001) and the growth rate of corals can be affected by some factors such as air pollution (Minchin, 2013), food (Miller, 1995; Ferrier Page *et al*., 2003a), temperature (Miller, 1995; Ward *et a*l., 2007), salinity (Kuanui *et al*., 2015), light intensity (Miller, 1995; Rodolfo-Metalpa *et al*., 2007; Fitzgerald, 2010; Schutter *et al*., 2011), and water quality (Lee *et al*., 2004; Wenger *et al*., 2015).

In Southeast Asia, about 18% of the corals were damaged (Burke *et al*., 2001). Coral reefs in Malaysia are currently facing development related threats, including pollution from land based sources, illegally coral poaching, destroyed habitats, and anthropogenic stresses (Wilkinson, 2008; Lim, 2015). Excessive demand on marine resources such as overfishing (Burke *et al*., 2011; Satran, 2015) led to over exploitation and degradation of coral reefs. Nowadays, human activities threaten about 88% of reefs in Southeast Asia (Burke *et al*., 2002), thus jeopardizing their biological and economic value to society. In addition, natural disasters such as the El-Nino triggered the first coral bleaching during 1980s (Strong *et al*., 1997; Huppert and Stone, 1998; Chumkiew *et al*., 2011; NOAA, 2017; Hughes *et al*., 2018).

Corals in Tanjung Tuan are unique as they are located at intertidal area which is exposed to the air for several hours during low tide. Large coral colonies which have adapted to intertidal area are usually grow in micro-atoll formed as an adaptation to environmental conditions on the reef flat due to the exposure to the air (Lee *et al*., 2004). Sea surface temperature has higher temperature during the low tide and corals are expected to bleach with water temperature of 2 to 3 °C above its normal range. However, large coral colonies in Tanjung Tuan which submerged in the water with high seawater temperature during the low tide remain healthy.

1.1.1 Problem statement

Decline of coral diversity in Tanjung Tuan is a major issue. Coral diversity in the west coast of Peninsular Malaysia is relatively low due to turbid condition. Coral reefs in Peninsular Malaysia which located in the shallow water of Sunda Shelf are affected by monsoon season have been fairly studied. There are estimated 4,006 km^2, 350 coral species found in Peninsular Malaysia and 550 species in East Malaysia (Burke *et al*., 2002). Port Dickson is one of the famous tourist attractions in Peninsular Malaysia. Due to a huge number of visitors to Port Dickson beaches, heavy development along the beach and anthropogenic activities have brought harm to coral reefs at the adjacent Tanjung Tuan waters. As corals have increased in popularity in marine ornamental industry, poachers are collecting corals from Tanjung Tuan (Faizan *et al*., 2016). Several studies shown coral reefs in Port Dickson are severely threatened as the coral cover percentage has reduced from 32.9% (Goh and Sasekumar, 1981) in 1976 to 14.3% after approximately 30 years (Lee *et al*., 2004). Suspended sediment reduces intensity received by the corals, and it was commonly believed that corals prefer clearer water as some experiments have shown that the growth rates of corals increase with increasing intensity (Rodolfo-Metalpa *et al*., 2007; Fitzgerald, 2010; Schutter *et al*., 2011).

Besides, information on the culture protocol for turbid water coral is insufficient. Coral aquaculture has high demand as coral is one of the most popular marine organisms in marine ornamental industry (Wabnitz *et al*., 2003). However, keeping live coral healthy in captivity is not completely successful due to different requirement needed by different coral species (Wabnitz *et al*., 2003; Arvedlund *et al*., 2008; Houlbrèque and Ferrier-Pagès, 2009). Thus, several restoration methods such as fragment propagation, larval rearing and artificial reefs have been studied and developed to increase the survival rate and coral coverage. Even if restoration techniques have been developed and improved, some are only at the experimental stage which require furthers investigation. Techniques such as seeding and larval rearing can maintain genetic diversity of a coral species (Omori and Fujiwara, 2004) but nutritional and physical parameter requirement to maintain live and healthy corals in captivity remain a constraint.

Effort on culture corals in captivity have becoming popular for ornamental trades, however there are limited research on the culture of turbid water corals. In order to make coral aquaculture economically viable, the optimization of aquaculture protocol is crucial. Corals located at Tanjung Tuan (west coast Peninsular Malaysia) faced higher turbidity and sedimentation rate (Lee *et al*., 2004) compared to the east coast, which reduces light penetration into water column and might slow down the growth rate of corals. Although Lee *et al*. (2004) had performed *ex-situ* experiment on *Porites lutea* and *Favites adbita* from Tanjung Tuan, and stated that scleractinian corals could survive in turbidity environments as long as the corals get sufficient light for photosynthesis process, no qualitative experiment has been carried out to study the culture light requirement and intensity needed for corals species from turbid condition.

Besides, most of the reef corals perform both heterotrophic and autotrophic behaviors, and usually perform heterotrophic behavior by expanding tentacles at night. Some corals are diurnal which expand during daytime only and some expand continuously (Porter, 1976; Levy *et al*., 2001). However the feeding behavior of *D. pallida* and *D. speciosa* from Tanjung Tuan remain unclear.

1.2 Objectives of the Study

i. To determine the preferred light type and light intensities of the culture of propagated *Dipsastraea pallida* and *Dipsastraea speciosa* in captivity.

ii. To investigate the effect of prolonged temperature and upper thermal tolerance limit of the *Dipsastraea pallida* and *Dipsastraea speciosa*.

iii. To examine the feeding time and optimum food densities for *Dipsastraea pallida* and *Dipsastraea speciosa*.

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BIODATA OF STUDENT

Lim Saoi May was born in 1991 in Seremban. She spent most of her childhood in Port Dickson at her maternal hometown before she moved to Bahau and received her primary and secondary education there. After completed her secondary studies in Sekolah Kebangsaan Dato Mansor, she went on to pursue her Bachelor degree in Marine Science at University Terengganu Malaysia for three years. When she was in her final year, she was certified as an Open Water diver and was so captivated by the beauty of the sea. After graduated, she was offered an internship position at the International Institute of Aquaculture and Aquatic Sciences (I-AQUAS), UPM (formerly known as Marine Science Centre, COMAS). She learned a lot during the three months internship training which later encouraged her to further study in marine science. She was employed as a research assistant in I-AQUAS, working on the breeding of *Portunus pelagicus* (blue swimmer crab). After the end of her contract as research assistant, she enrolled in a full-time Master of Science (M.Sc) research programme in Institute of Biosciences in September 2015 at Universiti Putra Malaysia, Serdang. Her research focused on coral feeding behaviour and aquaculture protocol, and she hopes that her study in coral research will contribute to the coral conservation efforts in future.

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