Malays. Appl. Biol. (2016) 45(2): 29–36

SURVIVAL AND GROWTH RATES OF SUTCHI CATFISH *(Pangasianodon hypophthalmus)* JUVENILES UNDER DIFFERENT LIGHT WAVELENGTHS AND INTENSITIES

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Accepted 10 October 2016, Published online 21 December 2016

ABSTRACT

This study report the effects of light intensity on the optimum light wavelength and intensity on the survival rate, specific growth rate, and production index of sutchi catfish (*Pangasianodon hypophthalmus,* Sauvage, 1878) juveniles. The sutchi catfish juveniles (69 days old) with average initial body length of 5.14 cm and body weight of 1.11 g were reared for 11 days (20 individuals/30 L) under five light wavelengths (white with λmax 446 and 566 nm, blue 454 nm, green 520 nm, yellow 590 nm, and red 632 nm) with three light intensities (1.40×10^{-3}, 1.40×10^{-2} and 1.40 μmol/m²/s) in triplicates. A two-way ANOVA analysis showed that light intensities had significantly ($P < 0.05$) affected the survival and specific growth rates of sutchi catfish juveniles. A Bonferroni post hoc analysis showed that the survival and specific growth rates were significantly high ($P < 0.05$) under the light intensity of 1.40 μmol/m²/s. In addition, there was a tendency of high growth rate, specific growth rate and production index under red light. Thus, the light intensity of 1.40 μmol/m²/s under red light is recommended for the rearing of sutchi catfish juveniles for better survival rate, growth rate and production index.

Key words: Sutchi catfish, *Pangasianodon hypophthalmus*, survival rate, growth rate, light intensities, light wavelengths

INTRODUCTION

Sutchi catfish (*Pangasianodon hypophthalmus,* Sauvage, 1878) is one of the important species in Asian aquaculture (Rahman *et al.,* 2006). This species is widely cultured in Southeast Asia such as Vietnam, Malaysia, Indonesia, Laos and Cambodia due to its high market demand, (Roberts & Vidthayanon, 1991; Paripatananont, 2002; Chheng *et al.,* 2004; Rohul Amin *et al.,* 2005). Despite their expensive price when compared to African catfish (*Clarias gariepinus*), sutchi catfish has a high demand where 95 to 97% of the Vietnam's total production of catfish (1,200,000 tons), was sutchi catfish (Malaysia Fisheries Department, 2011; Angela & Nneji, 2013). However, the survival and growth rates of sutchi cafish are low at the early stages.

Lighting conditions influence the survival and growth rates of fish (Boeuf & Le Bail, 1999). Previous studies done by Mukai (2010) and Mukai *et al.* (2013) showed that the sutchi catfish is sensitive to different white light intensity. As different fish species have different sensitiveness to light, rearing sutchi catfish under optimum light conditions could increase their survival and growth rates (Karakatsouli *et al.,* 2010).

The effects of different light wavelengths and intensities on sutchi catfish juveniles are still unknown, especially in relation to their survival and growth rates. Previous studies also indicated that a specific light wavelength could increase the survival and growth of certain fish species (Ullman *et al.,* 2011). For example, the survival rates of haddock (*Melanogrammus aeglefinus*) larvae were higher when reared under blue and green light wavelengths (Downing, 2002). Other studies had suggested that red light was better for the growth of rainbow trout

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(*Oncorhynchus mykiss*) (Karaksouli *et al.,* 2007). There was no information on the effects of light wavelengths and light intensities on their survival and growth rates (Subagja *et al.,* 1998). Thus, the objective of the present study is to determine the optimum light wavelength and intensity for sutchi catfish juveniles in increasing their survival rates, growth rates and production index.

MATERIALS AND METHODS

Juvenile specimen

Sutchi catfish juveniles (59 days old) were obtained from a private fish farm in Temerloh, Pahang. The juveniles were reared in 40 L acrylic aquaria with aeration and water temperature was between 26.0 and 28.0°C. The juveniles were fed twice daily with a commercial pelleted diet (Cargill Sdn. Bhd., Melaka; 45% protein level and 8% lipid level), and were acclimatized for 10 days to laboratory conditions until the day of the experiment (69 days old).

Experimental design

Experiments were conducted in a dark room in the aquaculture laboratory of Kulliyyah of Science, International Islamic University Malaysia (IIUM). Light emitting diodes (LED) (10W high power LED, Wayjun Technology Co., Ltd., Shenzhen) were used as the light source, while the light intensities were adjusted by using a dimmer (Songyuan Electronics Technology Co., Guangdong Province) and neutral-density filters (ND8, HOYA, Tokyo). Light intensities were measured by a reflection spectrophotometer (USB4000, Ocean Optics, Inc., Florida). The experiments were conducted for 11 days under five different light wavelengths represented by light colors of white with λmax 446 and 566 nm, blue 454 nm, green 520 nm, yellow 590 nm, and red 632 nm (Fig. 1), with three light intensities of 1.40×10^{-3}, 1.40×10^{-2}, and 1.40 µmol/m²/s.

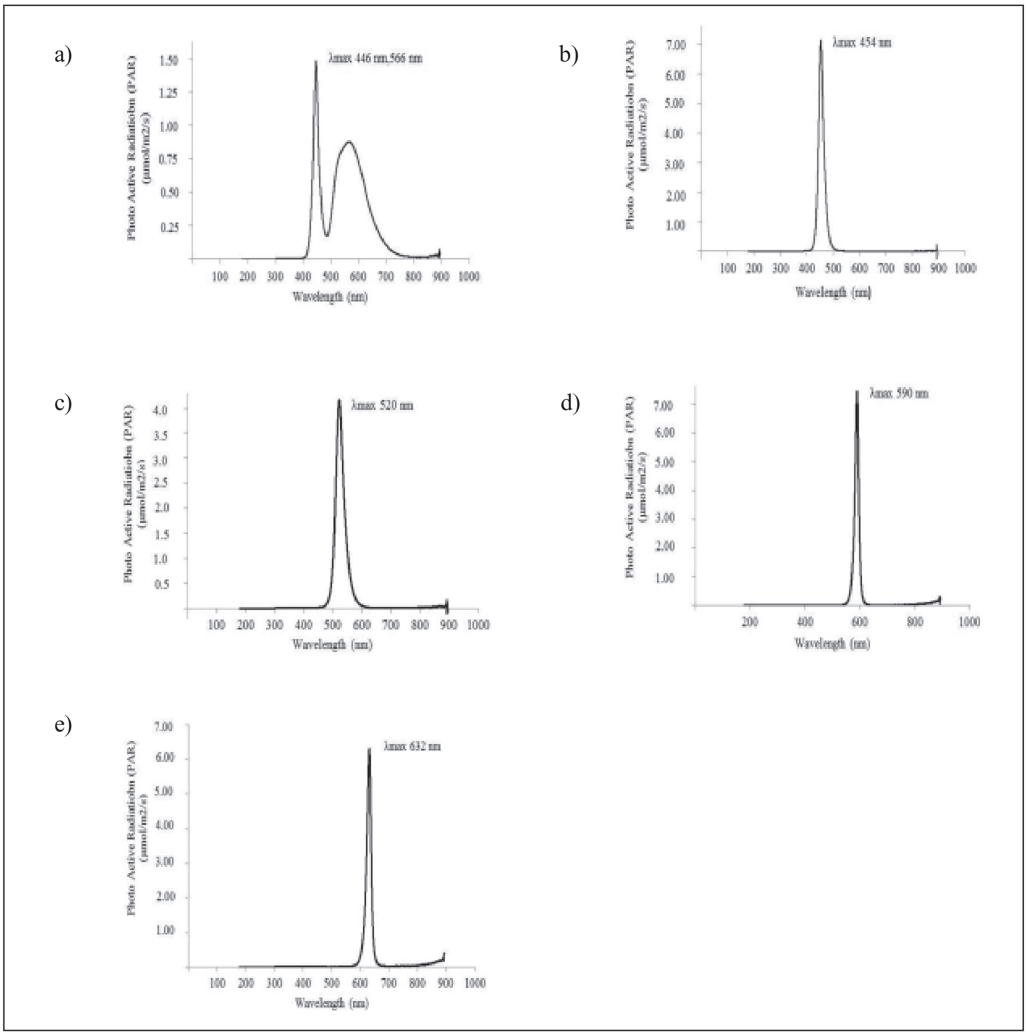

Fig. 1. Graphs of different light wavelengths measured using a reflection spectrophotometer. (a) White light with λmax at 446 and 566 nm, (b) blue light with peak at 454 nm, (c) green light with peak at 520 nm, (d) yellow light with peak at 590 nm, and (e) red light with peak at 632 nm.

For each light condition, 20 juveniles were put into 40 L acrylic aquaria with 30 L water. The experiments were done in triplicates. The initial body length (average of 5.14 cm) and weight (average of 1.11 g) of the juveniles were measured and recorded before the rearing experiments. The duration of illumination for these experiments was set to 0600 hours on and 1800 hours off. The juveniles were fed with 0.5 g of pellets twice per day, which was increased to 0.6 g from day seven of the experiments. To maintain water quality, the aquaria were bottom cleaned every day to remove fish waste and uneaten food. Ten percent of the water volume in all aquaria was changed daily. The experimental aquaria were exposed to laboratory light within 10 minutes during a bottom cleaning session. Water temperature (26.0–28.0°C), dissolved oxygen (7.0–8.0 ppm), and water pH (7.0–7.5) were monitored daily.

Fish survival rate, specific growth rate and production index

At the end of the experiment, the juveniles were anesthetized with Transmore (Nika Trading Co., Selangor) to determine the number of surviving fish and their body weights. The juveniles' survival rates and specific growth rates (*SGR*) were calculated using these formulae:

$S = 100 \times (N_f / N_i)$
S = survival rate (%)
N_f = final number of fish
N_i = initial number of fish

$SGR = 100 \times (\ln BW_f - \ln BW_i)/D$
SGR = specific growth rate (%/day)
BW_f = final mean body weight (g)
BW_i = initial mean body weight (g)
D = rearing period (days)

The production index (*PI*) was calculated by combining the fish growth and survival rates (Rosas *et al.,* 1999; Zacharia & Kakati, 2002). The formula for *PI* is as follows:

$PI = (BW_f - BW_i) / D \times S$
BW_f = final mean body weight (g)
BW_i = initial mean body weight (g)
D = rearing time (days)
S = survival rate (%)

Statistical analysis

Homogeneity was tested before ANOVA. When appropriate, data were arcsine transformed to obtain homogeneity of variance. Then, the data were analyzed using two-way analysis of variance (ANOVA) with the light wavelengths and light intensities as the factors. A multiple comparison was carried out using the Bonferroni test when the differences were significant ($P < 0.05$).

RESULTS

Survival rates

The survival rate of the juveniles under different light wavelengths and intensities was shown in Fig. 2. Based on the analysis of two-way ANOVA, light intensities were significantly differed in the survival rate of sutchi catfish juveniles ($P = 0.006$; < 0.05) (Table 1). The survival rate of sutchi catfish juveniles had no significant differences in light wavelength ($P = 0.860$; > 0.05). In addition, there was no interaction was found between light wavelength and light intensity ($P = 0.474$; > 0.05). However, the Bonferroni post hoc analysis showed that the survival rate of sutchi catfish juveniles under light intensity of 1.40 μmol/m²/s (mean of survival rate was 76.3 %) was significantly higher ($P < 0.05$) from those under light intensity of 1.40×10^{-2} μmol/m²/s (means of survival rate was 46.7 %).

Final body weight

Fig. 3 showed the final body weight of the sutchi catfish juveniles under different light wavelengths and light intensities. Two-way ANOVA analysis showed that final body weight of sutchi catfish juveniles had no significant differences for

Table 1. Results of two-way ANOVA and Bonferroni test of survival rates of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths (white with λmax 446 and 566 nm, blue 454 nm, green 520 nm, yellow 590 nm, and red 632 nm) and light intensities (1.40×10^{-3}, 1.40×10^{-2} and 1.40 μmol/m²/s)

Variable	Significance (*P* value)			Bonferroni test							
				Light wavelength					Light intensity		
	LW	LI	LW × LI	White	Blue	Green	Yellow	Red	1.40×10^{-3}	1.40×10^{-2}	1.40
Survival rate	NS	*	NS	53.3	65.6	61.1	58.3	56.7	54.0	46.7^a	76.3^b

LW = Light wavelength; LI = Light intensity; LW×LI = interaction of light wavelength and light intensity. Mean values in the same row with no superscript in common differ significantly ($P < 0.05$). If the effects are significant, ANOVA was followed by Bonferroni test. *$P < 0.05$; NS, not significant.

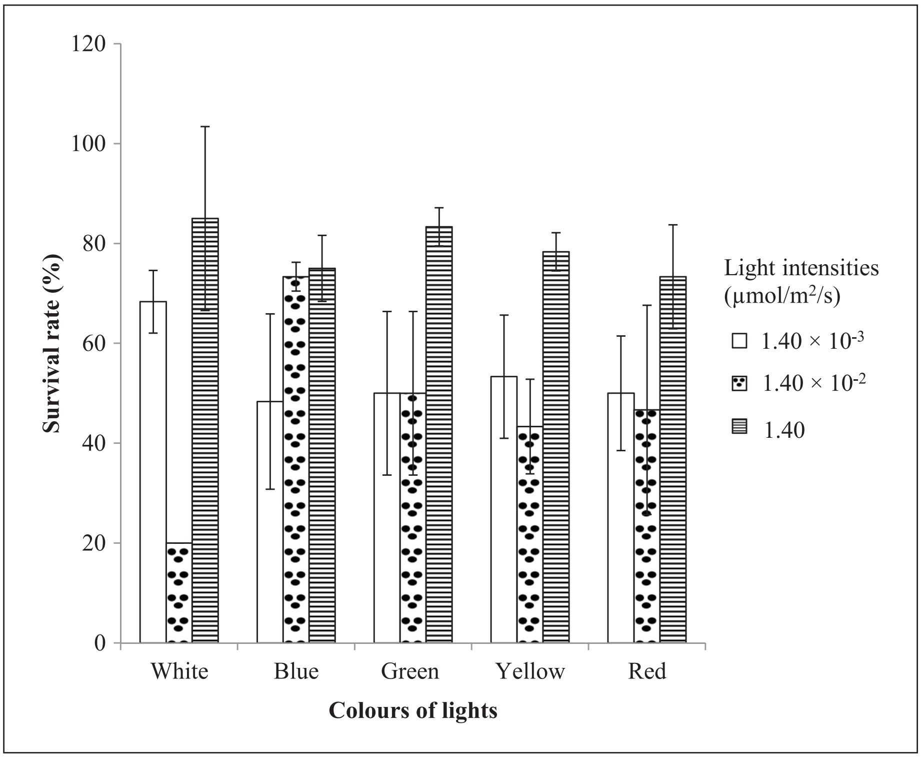

Fig. 2. Survival rate (%) of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths and light intensities. Light wavelengths were white (λmax at 446 and 566 nm), blue (454 nm), green (520 nm), yellow (590 nm), and red (632 nm), with light intensities of 1.40×10^{-3}, 1.40×10^{-2}, and 1.40 µmol/m²/s. Data were presented as mean ± SD.

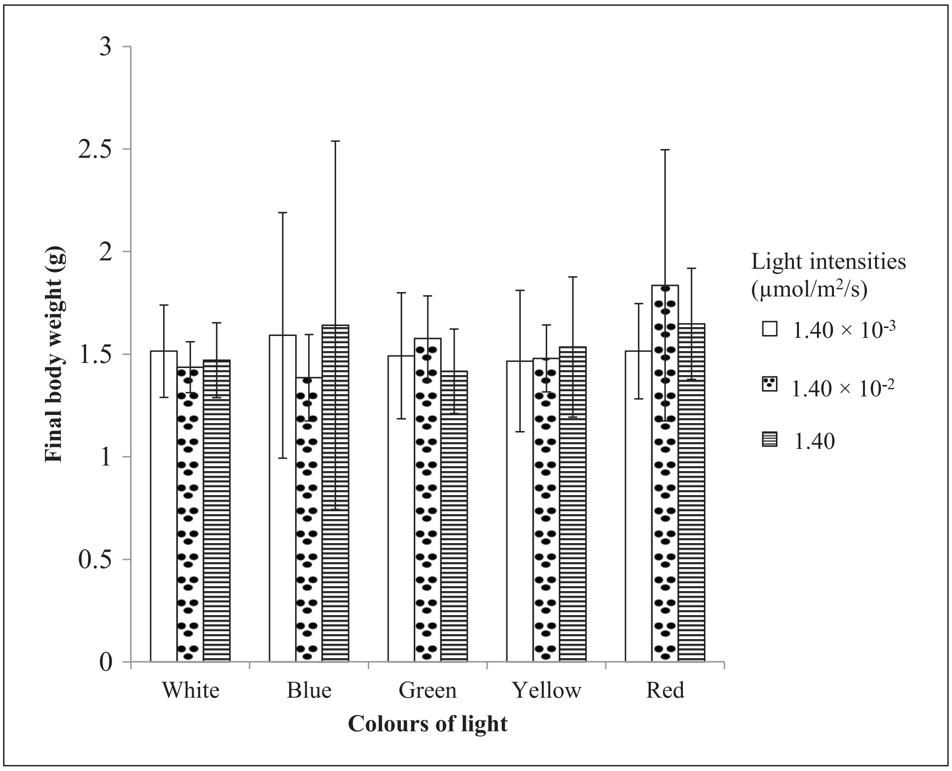

Fig. 3. Final body weight of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths and light intensities. Light wavelengths were white (λmax at 446 and 566 nm), blue (454 nm), green (520 nm), yellow (590 nm), and red (632 nm), with light intensities of 1.40×10^{-3}, 1.40×10^{-2}, and 1.40 µmol/m²/s. Data were presented as mean ± SD.

light wavelengths ($P = 0.979$; > 0.05) and intensities ($P = 0.355$; >0.05) (Table 2). Nevertheless, a tendency of higher final body weight (average of 1.84 g) was observed under the red light wavelength with a light intensity of 1.40×10^{-2} µmol/m²/s.

Specific growth rates (*SGR*)

Fig. 4 showed the specific growth rate (*SGR*) of the sutchi catfish juveniles under different light wavelengths and light intensities. Two-way ANOVA analysis showed that light intensities had differed significantly in the *SGR* of the sutchi catfish juveniles ($P = 0.03$; < 0.05) (Table 3). The *SGR* of

Table 2. Results of two-way ANOVA of final body weight (g) of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths and intensities

Source	df	MS	F	p-value
Light wavelength (LW)	4	0.027	0.111	0.979
Light intensity (LI)	2	0.255	1.036	0.355
Light wavelengths * light intensities	8	0.297	1.205	0.292

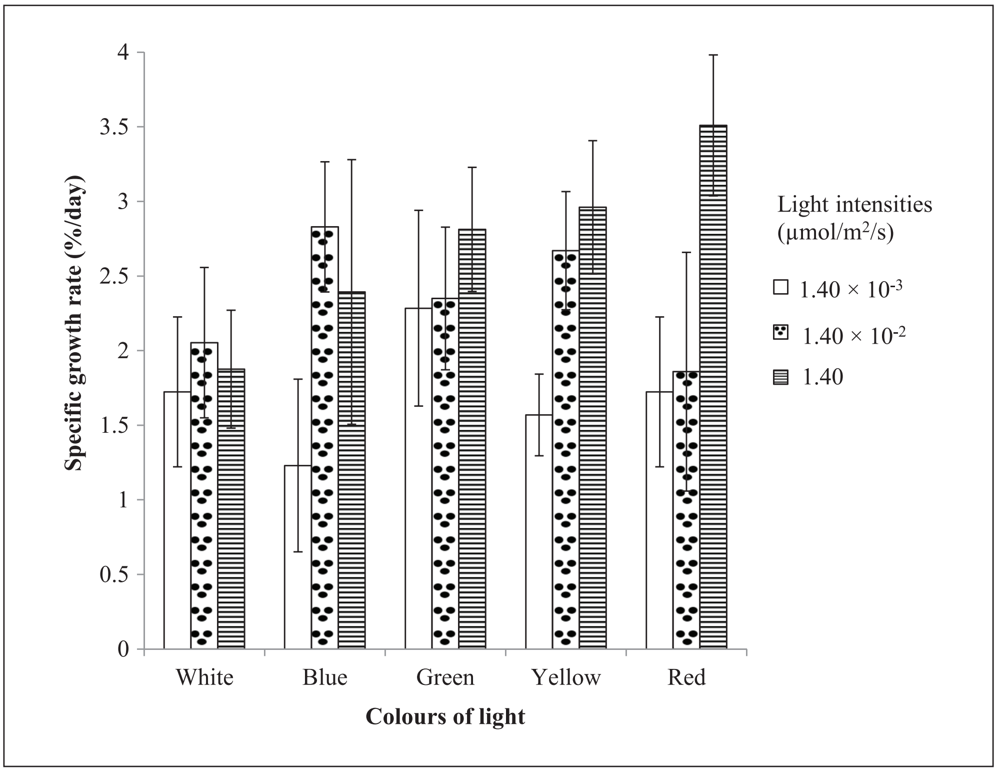

Fig. 4. Specific growth rates (SGR) of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths and light intensities. Light wavelengths were white (λmax at 446 and 566 nm), blue (454 nm), green (520 nm), yellow (590 nm), and red (632 nm), with light intensities of 1.40×10^{-3}, 1.40×10^{-2}, and 1.40 µmol/m²/s. Data were presented as mean ± SE.

Table 3. Results of two-way ANOVA and Bonferroni test of specific growth rates (SGR) of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths (white with λmax 446 and 566 nm, blue 454 nm, green 520 nm, yellow 590 nm, and red 632 nm) and light intensities (1.40×10^{-3}, 1.40×10^{-2} and 1.40 µmol/m²/s)

Variable	Significance (*P* value)			Bonferroni test							
				Light wavelength					Light intensity		
	LW	LI	LW × LI	White	Blue	Green	Yellow	Red	1.40×10^{-3}	1.40×10^{-2}	1.40
SGR (% body weight/day)	NS	*	NS	2.396	3.587	2.786	2.853	3.707	2.850^a	2.921	3.426^b

LW = Light wavelength; LI = Light intensity; LW×LI = interaction of light wavelength and light intensity. Mean values in the same row with no superscript in common differ significantly ($P < 0.05$). If the effects are significant, ANOVA was followed by Bonferroni test. *$P < 0.05$; NS, not significant.

sutchi catfish juveniles did not show any significant differences in light wavelength ($P = 0.845$; > 0.05). There was no interaction found between light wavelength and light intensity in the *SGR* of the sutchi catfish juveniles ($P = 0.679$; > 0.05). The Bonferroni post hoc analysis showed that the *SGR* (3.426 % body weight/day) was significantly higher under light intensity of 1.40 μmol/m²/s than 1.40×10^{-3} μmol/m²/s (2.850 % body weight/day). Although light wavelengths showed no significant difference in *SGR* of sutchi catfish juveniles, tendency of the higher *SGR* of sutchi catfish juveniles was observed under red light wavelength.

Production index (*PI*)

The production index of the sutchi catfish juveniles under different light conditions was shown in Fig. 5. Two-way ANOVA analysis showed no significant differences in light wavelengths ($P = 0.283$; > 0.05) and intensities ($P = 0.246$; > 0.05) (Table 4). However, the tendency of higher production index was observed under the red light wavelength with the light intensity of 1.40 μmol/m²/s. A low tendency of *PI* was observed under white light wavelength with light intensity of 1.40×10^{-2} μmol/m²/s.

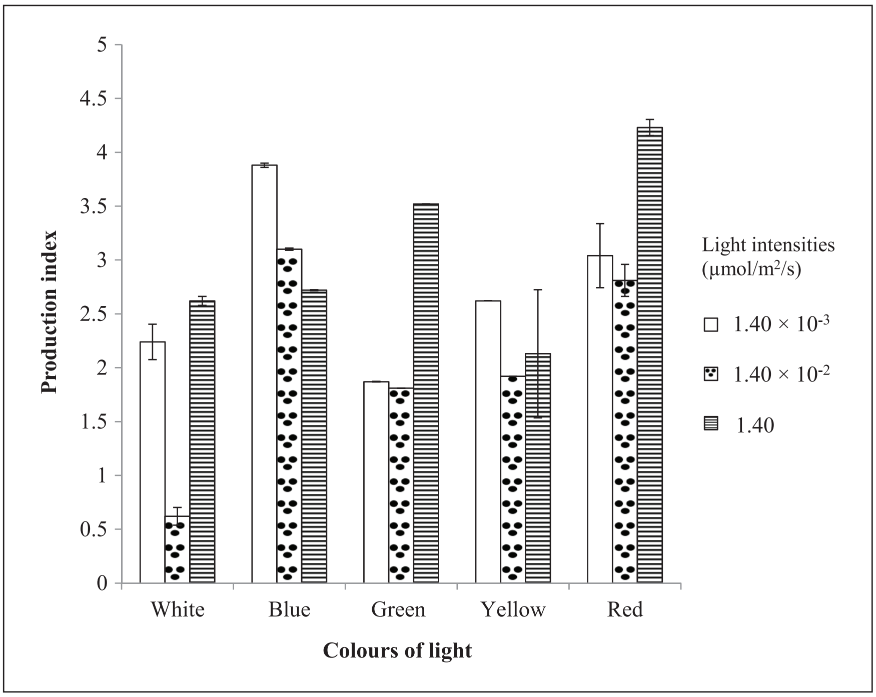

Fig. 5. Production indexes (PI) of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths and light intensities. Light wavelengths were white (λmax at 446 and 566 nm), blue (454 nm), green (520 nm), yellow (590 nm), and red (632 nm), with light intensities of 1.40×10^{-3}, 1.40×10^{-2}, and 1.40 μmol/m²/s. Data were presented as mean ± SD.

Table 4. Results of two-way ANOVA of production indexes of sutchi catfish, *Pangasianodon hypophthalmus* juveniles under different light wavelengths and intensities

Source	df	MS	F	p-value
Light wavelength (LW)	4	11.426	1.326	0.283
Light intensity (LI)	2	12.653	1.468	0.246
Light wavelengths * light intensities	8	4.917	0.571	0.793

DISCUSSION

The results of the present study showed that the survival and specific growth rate of sutchi catfish juveniles were significantly higher under light intensity of 1.40 μmol/m²/s. In survival rate, final body weight, specific growth rate and production index, the light wavelengths did not differ significantly. However, a tendency of higher final body weight, specific growth rate and production index of sutchi catfish juveniles was observed under red light wavelength.

Light intensity affects fish survival and growth rates. The present study showed that sutchi catfish juveniles reared under light intensity of 1.40 μmol/m²/s have the highest survival rate compared to 1.40×10^{-2} and 1.40×10^{-3}μmol/m²/s. However, a previous study showed that the survival rates of sutchi catfish larvae were reduced under light intensity of 100 lux in white light (equivalent to the light intensity of 1.40 μmol/m²/s) (Mukai, 2010). Due to the differences, it is suggested that the sutchi catfish have different activities in larval and juvenile stages. Thus the required optimum light intensity for their survival and growth rates is different in both larval and juvenile stages.

In the larval stage, sutchi catfish is known to have low survival rate due to high cannibalism starting from 2 days old after hatching (DAH) (Baras *et al.,* 2010; Morioka *et al.,* 2010). As larval sutchi catfish starts exogenous feeding at 2 or 3 DAH, they start to show cannibalism activity once their yolk sac has been consumed. Cannibalism of larval sutchi catfish occurs as a result of high aggressive behavior under high light intensity. However, under dim light intensity, sutchi catfish larvae swim almost constantly at almost the same speed thus increasing their survival rates.

On the other hand, in this study, sutchi catfish juveniles were observed to swim actively and schooling under light intensity of 1.40 μmol/m²/s compared to dimmer light intensities (1.40×10^{-2} and 1.40×10^{-3}μmol/m²/s). The previous study recommended that sutchi catfish larvae should be reared under dim light during their early larval stage in the first 10 days to reduce cannibalism (Mukai, 2010). Since no aggressive behavior observed after 10 days, the sutchi catfish were not necessarily to be reared under dim conditions. Thus, juvenile sutchi catfish were able to survive better in the light condition of 1.40 μmol/m²/s. In addition, the specific growth rates for sutchi catfish juveniles were also significantly higher at 1.40 μmol/m²/s. At this light intensity, all fish were observed to swim actively at almost the same speed, allowing them to search and catch pellet better and thus improve their survival and growth rates. Furthermore, the tendency of better production index of sutchi catfish juveniles was also observed under light intensity of 1.40 μmol/m²/s. Therefore, the light intensity of 1.40 μmol/m²/s improved the survival rate, growth rate and production index of sutchi catfish juveniles.

In term of light wavelength, even though it did not differ significantly in survival rate, growth rate and production index of sutchi catfish juveniles, it has a tendency of better production index under the red light. Meanwhile, sutchi catfish was known to origin from the Mekong River where the water is turbid due to sedimentation. Thus, due to the combination of dispersion and absorption with sediments, long light wavelength (red) predominated at the pelagic zone or shallow waters such as in rivers (Stuart Caplin *et al.,* 2002). In contrast, short light wavelengths (blue) were abundant in the deeper waters such as in the ocean (Stuart Caplin *et al.,* 2002). Thus, sutchi catfish has adapted to the longer light wavelengths such as the red light wavelength in their natural habitat. This explains the tendency of higher growth and production index of sutchi catfish juveniles under the red light wavelength that mimics the light condition in their natural habitat. Other fish species such as the rainbow trout and barramundi also favoured red light for high growth rates (Karakatsouli *et al.,* 2007; Ullman *et al.,* 2011). Thus, red light wavelength increases the tendency of higher growth and production index of sutchi catfish juveniles compared to white, blue, green and yellow light wavelengths. This explains the higher survival, growth and production of sutchi catfish juveniles under the light intensity of 1.40 μmol/m²/s in red light wavelength.

CONCLUSION

The present results showed that sutchi catfish juveniles were sensitive towards different light intensities. The survival and specific growth rates of sutchi catfish juveniles were increased when reared under the light intensity of 1.40 μmol/m²/s. A tendency of higher growth rate and production index of sutchi catfish juveniles was observed under the red light. In conclusion, red light with the light intensity of 1.40 μmol/m²/s is recommended for the sutchi catfish juveniles rearing.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Mr. Azizul Aziz for his technical assistance during this research. We are also grateful to Mr. Sarifuddin Sulaiman from HTWO Gemilang Jaya Enterprise for providing the juvenile sutchi catfish.

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