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Effects of Temperature and Substrate on Growth and Survival of *Penaeus semisulcatus* (Decapoda: Penaeidae) Postlarvae

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Abstract: This study was carried out to determine the optimal water temperature and to investigate the effects of additional substrate on growth and survival during the nursery culturing of *Penaeus semisulcatus* in two separate experiments.

At the end of six weeks, survivals of postlarvae (PLs) at 22, 24, 26, 30 and 34°C were 52, 46, 70, 30 and 40%, respectively. The highest (2.76 mm/week) and lowest growth rates in terms of total length (0.43-0.49 mm/week) were displayed by the PLs grown at 34°C and 22-24°C, respectively. Growth rates were 1.75 mm/week at 30°C and 1.03 mm/week at 26°C. Final individual weight showed a drastic increase (over five times) with increasing temperature level from 22°C (55 mg) to 34°C (285 mg). Individual final weights at 22, 24 and 26°C were not significantly different from each other (P>0.05). Weight gain per week was 432 mg/week at 34°C and 58-68 mg/week at 22-24°C. The PLs at 34°C had a growth rate 6-7 times faster than those at 22-24°C. Yield at 34°C (5.7 g) was four times as high as that at 22°C (1.43 g). The yield at 24, 26 and 30°C was 1.40, 3.03 and 2.59 g, respectively.

Artificial substrate constructed of seine netting to increase habitat area did not improve the survival and growth of postlarvae compared with the control.

Key Words: *Penaeus semisulcatus*, postlarvae, temperature, substrate, growth, survival.

Sıcaklık ve Substratın *Penaeus semisulcatus* (Decapoda: Penaeidae) Postlarvalarının Büyüme ve Yaşama Oranı Üzerine Etkisi

Özet: Bu çalışma, iki ayrı deneme halinde, *Penaeus semisulcatus*'un ön-semirtme dönemindeki optimum su sıcaklığının belirlenmesi ve substratın büyüme ve yaşama oranı üzerindeki etkisini belirlemek amacıyla yapılmıştır.

Altı hafta sonunda, 22, 24, 26, 30 ve 34°C'de elde edilen yaşama oranları sırasıyla %52, 46, 70, 30 ve 40 olarak bulunmuştur. Total boyca en yüksek (2,76 mm/hafta) ve en düşük (0,43-0,49 mm/hafta) büyüme oranları 34°C ve 22-24°C'de yetiştirilen postlarvalarda (PL) bulunmuştur. 26°C ve 30°C'lerdeki haftalık büyüme oranları sırasıyla 1,03 mm ve 1,75 mm'dir. Sıcaklığın 22°C'den 34°C'ye çıkmasıyla deneme sonu bireysel ağırlık 55 mg'dan 285 mg'a çıkmıştır (yaklaşık 5 kat artış). 22, 24 ve 26°C'de yetiştirilen PL'lerde büyüme farklı bulunmamıştır (P>0.05). Ağırlıkça büyüme oranı 34°C'de 432 mg/hafta ve 22-24°C'de 58-68 mg/hafta olarak belirlenmiştir. 34°C'de büyütülen PL'ler 22-24°C'dekilere göre 6-7 kat daha hızlı büyümüşlerdir. 34°C'de elde edilen ürün (5,7 g), 22°C'dekinden (1,43 g) 4 kat daha yüksek çıkmıştır. 24, 26 ve 30°C'de elde edilen ürün miktarları, sırasıyla 1,40, 3,03 ve 2,59 g'dır.

Yaşam alanını arttırmak için ağdan yapılmış yapay substrat kullanımı yaşama ve büyüme oranlarını olumlu yönde etkilememiştir.

Anahtar Sözcükler: *Penaeus semisulcatus*, postlarva, sıcaklık, substrat, büyüme, yaşama oranı.

Introduction

Temperature is one of the most important abiotic factors affecting both growth and survival of crustaceans. It acts on metabolic processes and energy utilisation (1). Penaeid shrimps are stenothermal animals living between a minimum temperature level of 15°C and a maximum of 35°C (2).

Penaeus semisulcatus is an Indo-Pacific species distributed along the coast of the Eastern Mediterranean and is one of the most important commercial species in this part of the world. A few commercial farms in Turkey practise its culture on a small scale. A better understanding of the effects of temperature on nursery culturing of this penaeid shrimp species is important in order to define adequate conditions for optimal production. This is especially important in sub-tropical areas where temperature is adequate only for one crop per year. Intensive nursery systems using greenhouses in winter months have been developed in order to allow shrimp farms to stock grow-out ponds earlier in the year (3, 4). These systems increase the grow-out period by

one to two months. No study has been performed to determine the optimal temperature for the nursery culturing of *P. semisulcatus*.

Artificial habitats constructed of seine netting suspended vertically in raceways improved the survival but not the growth of *P. vannamei* (5). Samocha et al., (4) also found no advantage of added substrate in raceway tanks for postlarvae (PLs) of this penaeid species.

The purpose of this study was to determine the optimal temperature and to investigate the effects of added substrate to increase habitat area during nursery culturing of *P. semisulcatus*.

Materials and Methods

Experiment 1

P. semisulcatus PLs (PL20) were stocked in five aquariums (50x30x30 cm) at a density of 50 PLs per aquarium. The PLs were acclimated to five temperature levels (22, 24, 26, 30 and 34°C) at a rate of 5°C per h. The aquariums were placed in water baths equipped with thermostatically controlled heaters or chillers. PLs were fed granulated feeds (45% protein) four times a day in excess. Remaining food particles and faeces were siphoned out and 50% of the culture water was renewed daily. Rearing water was pre-chilled or pre-heated to the desired test temperatures. Throughout the experiment, which lasted six weeks, salinity was 39 ppt. Continuous aeration was supplied by a blower.

Mortalities were monitored every day. Animals were considered dead when they were immobile and did not respond to any mechanical stimulation. Random sampling of 20 PLs from each aquarium was done weekly to measure total length and weight. Total length (TL) was measured from the tip of the rostrum to the end of the telson by vernier callipers. Following removal of excess water by tissue paper, the weight of each animal was measured to the nearest 0.001 g.

Experiment 2

This experiment was conducted in two rectangular tanks (35x144x40 cm) for a period of one month. Initial average total length and weight of the PLs were approx. 18 mm and 37-39 mg, respectively. 250 animals were stocked in each tank (500 PLs/m^2). Four pieces of substrate constructed of seine netting (each 23x55x25 cm) were suspended vertically in one tank to provide an additional surface area of 0.512 m^2 (approx. 50% more than the control). All experimental procedures were carried out as in the 1st experiment. At the end of the experiment, 50 animals were randomly taken from each tank for total length and weight measurements.

Statistical Analysis

Total length and weight data were analysed with one-way ANOVA and any significant difference was determined at 0.05 probability level by Scheffé's test after normality and homogeneity (Bartlett's test) of the data were checked with the Minitab Statistical Package.

Results

Experiment 1

The PLs showed the highest survival throughout the experiment at 26°C. At the end of the experimental period survival was 70% at this temperature (Fig 1A). Survivals at 22, 24, 30 and 34°C were 52, 46, 30 and 40%, respectively.

The highest (2.76 mm/week) and lowest growth rates in terms of total length (0.43-0.49 mm/week) were displayed by the PLs grown at 34°C and 22-24°C, respectively (Fig 1B). The resulting final TL was highest at 34°C and lowest at 22°C ($P<0.05$) (Fig 1B). Growth rates were 1.75 mm/week at 30°C and 1.03 mm/week at 26°C. Final TL was higher at 30°C than at 26°C ($P<0.05$).

Highest (285 mg) and lowest final weights (55-61 mg) were obtained at 34°C and 22-24°C, respectively ($P<0.05$) (Fig 2A, B). The second best growth by weight was displayed by animals grown at 30°C (162 mg). Individual final weights at 22, 24 and 26°C were not significantly different from each other ($P>0.05$) (Fig 2A). Weight gain per week was 432 mg/week at 34°C and 58-68 mg/week at 22-24°C. The PLs at 34°C had 6-7 times faster growth than those at 22-24°C. At 30°C and 26°C, growth rates were 238 and 103 mg/week, respectively (Fig 2A).

Final individual weight showed a drastic increase (over five times) with increasing temperature level from 22°C (55 mg) to 34°C (285 mg) (Fig. 2B). Total yield also had a sharp rise with the increase in temperature. Yield at 34°C (5.7 g) was four times as high as that at 22°C (1.43 g) (Fig. 2B). The yield at 24, 26 and 30°C was 1.40, 3.03 and 2.59 g, respectively.

Experiment 2

PLs grown in tanks with and without artificial habitat had similar growth in terms of TL and weight at the end of the experiment ($P>0.05$) (Table 1). Added substrate

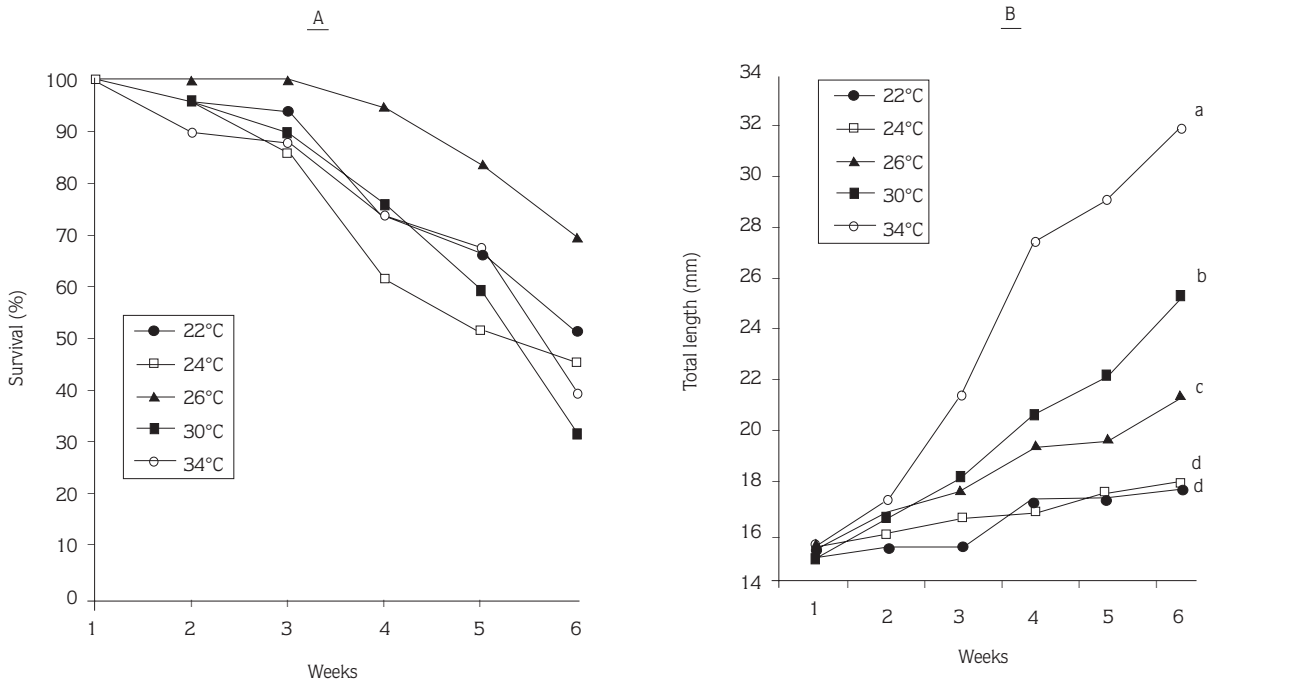

Figure 1. Survival (A) and growth as total length (B) of *Penaeus semisulcatus* postlarvae grown at various temperatures for six weeks.

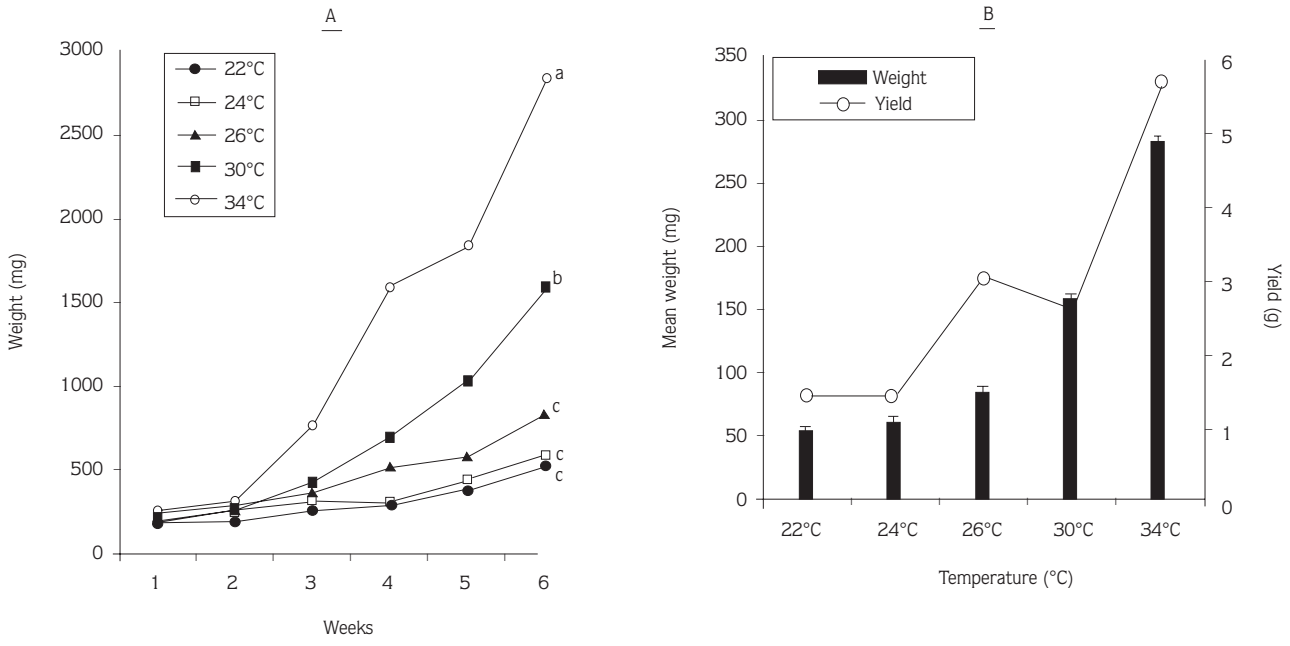

Figure 2. Growth as weight (A), and yield (B) of *Penaeus semisulcatus* postlarvae grown at various temperatures for six weeks.

Table 1. Growth and survival of *Penaeus semisulcatus* postlarvae grown from PL20 to PL50 with and without substrate.

	With Substrate	Without Substrate
Initial total length (mm)	17.78 ± 2.86	17.73 ± 3.11
Initial weight (mg)	39.05 ± 10.80	36.70 ± 13.90
Final mean total length (mm)	23.19 ±5.57a	23.85 ±6.48a
Final mean weight (mg)	152.60 ±116.10a	119.20 ±98.21a
Yield (g)	25.64	21.93
Survival (%)	67.20	73.60

led to a higher individual mean weight (153 mg) than without substrate (119 mg), but the difference was not significant (P>0.05). Nursing the PLs with substrate resulted in increased total yield (25.64 g) compared to nursing without substrate (21.93 g) (Table 1). Additional substrate reduced the survival of PLs over the 30 day culture period.

Discussion

Growth rate of *P. semisulcatus* PLs at 22°C was significantly lower than at the higher temperatures (26-34°C). In fact, postlarval growth was seven times as high at 34°C as at 22°C at the end of the experiment. Similarly, Parado-Estepa (6) also reported that growth of *P. monodon* PLs at 22°C was significantly lower than that at 33°C. It appears that this low temperature level decreases moulting frequency as a result of low metabolic rate in penaeid shrimps. Temperature is known to have a strong influence on the metabolic rate of aquatic organisms. Metabolic rate decreases when the water temperature is below the optimum temperature range and increases when the temperature is above that range (7). Feed intake and growth rate also show a decrease below or above the optimum temperature level. At temperatures above the optimal level, food consumption may increase to accommodate higher metabolic activity. However, as temperature reaches the upper tolerance limit for a particular species, the metabolic rate falls and ultimately mortality occurs. Despite the fact that the PLs at 34°C displayed the highest growth and yield throughout the experiment, survival was considerably lower than at 26°C. This agrees with the findings of Parado-Estepa (6) who stated that 33°C reduces the survival rate of *P. monodon* PLs or juveniles. Vijayan and Divan (8) observed faster moulting frequency in *P. indicus* juveniles but concluded that in extremely high temperatures, more moulting does not produce more growth. Yet in our study, *P. semisulcatus* PLs continued growing even at 34°C for 6 weeks. This shows that *P. semisulcatus* is capable of tolerating a wide range of water temperatures during the PL stages.

There are efforts to intensify nursery culture systems for penaeid shrimps in subtropical countries where the temperature is inadequate for production of more than one crop per year. Intensive nursery systems enable farmers to headstart seed shrimp indoors or in greenhouses before stocking into growing ponds (9). This type of nursery system extends the growout period 1-2 months and may enable farmers to produce two crops per year. In intensive shrimp nursery systems, the primary aim is to grow the PLs as dense as possible for 1-1.5 months with over 70% survival. Although the PLs grown at 26°C appeared to be adequate for the nursery culturing of *P. semisulcatus*, growth was much slower than at higher temperatures. For example, survival and mean weight of PLs at 26°C were 70% and 86.57 mg, respectively, after 6 weeks of culturing while even at the 4th week the PLs at 34°C had 74% survival and a mean weight of 161 mg. Yield obtained at 34°C (5.7 g) was almost twofold that at 26°C (3.03 g) (Fig. 2b). Hence, the present results suggest that optimal temperature for the indoor nursery culturing of our species depends on the production strategy of a particular farm. In temperate regions, if one wants to stock growout ponds in the early spring as soon as water temperature is warm enough, 34°C may be preferred for the nursery culturing of *P. semisulcatus*.

The current results have shown that neither growth nor survival were improved when the nursery vessel was equipped with vertical substrate (which increased the habitat area about 50%) compared to the vessel without supplemental substrate. Similar results were reported for other penaeid shrimp species by various researchers. Sandifer et al., (5) obtained better survival but not better growth with additional substrates in *P. vannamei*. Again, Samocha and Lawrence (10) did not find any beneficial effects of additional habitats on growth, survival or FCR (food conversion ratio) in the same species. In our study with *Metapenaeus monoceros*, we also found no

improvement in growth and survival of PLs grown in aquariums equipped with vertical or horizontal substrates compared to (Kumlu et al., unpublished) those without artificial habitats. Our results and those in the literature show that the presence of artificial habitats in penaeid nursery systems has no advantage and moreover, complicates the PL production management. Hence, their use is not recommended in the nursery culturing of *P. semisulcatus*.

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