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Growth of Over-wintered and Pre-seasonally Produced Post-larvae of *Penaeus semisulcatus* in the Subtropics

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Abstract

Growth performance of *Penaeus semisulcatus* under semi-intensive and intensive systems in pond/tank culture conditions with pre-seasonally or over-wintered animals was studied in sub-tropical climate conditions of Turkey. In Pond A, the pre-seasonally produced post-larvae (PL) grew linearly from 0.2 g to 22.6 g in 140 days (Y = 0.19 X- 2.69; R^2= 0.97) with DGR (daily growth rate) of 0.06 g day^{-1}. In Pond B, the over-wintered juveniles grew from 3.8 g to 30.5 g with DGR of 0.41 g during the first 30 days (weight gain of 14.42 g) and 0.13 g between 30 and 140 days (weight gain of 14.32 g). Regression equation for growth was calculated to be Y = 9.62 Log (X) + 4.51 (R^2 = 0.99). Compensatory growth due to starvation or over-winter fasting has, for the first time, been demonstrated in this penaeid shrimp species in the present study. Food deprivation during the winter months resulted in growth compensation after re-feeding under appropriate culture conditions. During the compensatory growth period (first month after re-feeding), the shrimps gained an average weight of 2.87 g week^{-1}, but after this period, growth rate declined to 0.91 g week^{-1} (over three-fold less) for the rest of the growth period (between 2nd and 5th months). This preliminary finding is a promising area on which studies should be focused on, as fasting and re-feeding strategy at low temperature can provide a chance to increase marketable size of shrimps or to even produce two crops per year in the sub-tropics. The shrimps (0.2 g) reached to 13.7 g at 30 PL per m^2 (DGR 0.10 g), 6.44-7.37 g (DGR 0.05 g) at 40-50 PL per m^2 in 140 days. The estimated yields were 880-1,150 kg ha^{-1} in semi-intensive ponds and 1,597-2,673 kg ha^{-1} in intensive ponds. The shrimps grown in concrete Tanks displayed even poorer growth performance resulting in only 879 kg and 793 kg ha^{-1} of yield.

Keywords: *Penaeus semisulcatus,* grow-out, over-wintering, growth, feed conversion rate.

Yarı-tropik Koşullarda Kışlatılmış ve Mevsim-öncesinde Üretilmiş Olan *Penaeus semisulcatus* Post-larvalarında Büyüme

Özet

Türkiye'nin yarı-tropik iklim şartlarında, kışlatılmış veya mevsim-öncesinde üretilmiş olan *Penaeus semisulcatus*'un yarı-entansif ve entansif sistemlerdeki havuz/tank kültür koşullarında büyüme performansı çalışılmıştır. A Havuzunda, mevsim-öncesinde üretilen post-larvalar (PL) 0,06 g günlük büyüme oranıyla (GBO), 140 günde, 0,2 g'dan 22,6 g'a kadar doğrusal bir şekilde büyümüştür (Y = 0.19X- 2,69; R^2 = 0,97). B Havuzunda, kışlatılmış yavrular ilk 30 gün içerisinde 0.41 g GBO ile (14,42 g'lık canlı ağırlık kazancı) ve 30. ile 140. günler arasında ise 0,13 g GBO ile (14,32 g canlı ağırlık kazancı) 3,8 g'dan 30,5 g'a kadar ulaşmışlardır. Bu grup için regresyon büyüme eşitliği Y = 9,62 Log (X) + 4,51 (R^2 = 0,99) olarak hesaplanmıştır. Bu çalışma, bu penaeid karides türünde kışlatma periyodu esnasındaki açlığın telafi büyüme üzerine olan etkisini ilk kez ortaya koymuştur. Kış aylarındaki yem kısıntısı ve ardından uygun yetiştiricilik koşulları ve yeniden besleme telafi büyüme ile sonuçlanmıştır. Telafi büyüme periyodunda (yeniden beslenmenin başlatıldığı ilk ay) karidesler ortalama hafta da 2,87 g canlı ağırlık kazanmış, ancak bu dönem sonrasındaki büyütme periyodunun geri kalan kısmında (2. ve 5. aylar arasında) haftalık büyüme oranı 0,91 g'a (3 kattan daha az) kadar düşmüştür. Bu önemli öncü bulgu üzerinde yürütülmesi gerekli olan çalışmalar, düşük su sıcaklıklarında açlık ve yeniden besleme stratejisi ile yarı-tropik bölgelerde karideslerin pazarlama boyutlarının irileştirilebilmesi ve hatta yılda iki ürün alınabilmesine olanak yaratabilecektir. Karidesler (0,2 g), 140 gün içerisinde, 30 adet/m^2 PL stok yoğunluğunda 13,7 g'a (GBO 0,10 g) ve 40-50 adet/m^2 PL yoğunluğunda ise 6,44-7,37 g'a (GBO 0,05 g) ulaşmışlardır. Elde edilen ürün miktarı yarı-entansif havuzlarda 880-1.150 kg/ha, entansif havuzlarda ise 1.597-2.673 kg/ha olarak hesaplanmıştır. Beton havuzlarda büyütülen karidesler daha da düşük bir performans göstermiş ve bu havuzlardan sadece 879 ile 793 kg/ha ürün alınabilmiştir.

Anahtar Kelimeler: *Penaeus semisulcatus,* semirtme, kışlatma, büyüme, yem çevrim oranı.

Introduction

The green tiger shrimp *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. Several studies have been carried out on its biology (Shelagman *et al*., 1986 cited in Issar *et al*., 1987; Kumlu *et al*., 1999a), induced off-season maturation and spawning in captivity (Browdy and Samocha, 1985a; 1985b; Aktas and Kumlu, 1999; 2003) and on its tolerance to environmental conditions during larval and post-larval stages (Kumlu *et al*., 1999b; 2000a,b). Only a limited number of studies concerning pond culture of this species have been carried out in Israel (Yashouv, 1971; Issar *et al*., 1987; Seidman and Issar, 1988) and more recently in Turkey (Kumlu *et al*., 2003; Türkmen, 2007a, 2007b). A few commercial farms in Turkey had already practiced its culture on a small scale. Yet, up to date, different culture strategies by using over-wintered and/or pre-seasonally produced post-larvae have received little attention in the subtropics for this species.

Subtropical climatic conditions, long coastline, clean coastal waters and close proximity to European markets are the main reasons which favor shrimp farming in the eastern Mediterranean (Issar *et al*., 1987). Yet, unlike in the tropics, the typical grow-out period for shrimp in this climate is limited to only 5-6 months, during which only one crop per year can be realized. A number of strategies could be suggested to produce either more crops or to increase final market size of shrimp grown under such conditions. The first could be head-start in order to allow shrimp farmers to stock grow-out ponds earlier in the year. To achieve this, spawning, larval and nursery culture has to be carried out in greenhouses during winter months (Sturmer and Lawrence, 1988) until water temperature of grow-out ponds is warm enough for fast growth. Another strategy could utilize geothermal waters where available (Appelbaum *et al*., 2002) or to over-winter post-larvae (PLs) throughout the cold season at the cheapest possible cost (Kumlu and Kır, 2005) and then stock them into grow-out ponds in the next warm season (Kumlu *et al*., 2003).

Although a number of studies have shown that past nutritional history and over-winter fasting followed by re-feeding and optimal culture conditions provoke faster growth called 'compensatory growth' in many fish species (Wilson and Osbourn, 1960; Jobling, 1994; Boujard *et al*., 2000; Ali *et al*., 2003; Pottinger, *et al*., 2003), this has received little attention in crustaceans Wu *et al*., 2001, 2002).

The goals of this study were therefore to test different culture strategies with over-wintered and pre-seasonally produced *P. semisulcatus* under semi-intensive and intensive growing conditions to provide a strategy that may be suitable for the subtropical regions as well as to examine the effects over-winter fasting on growth performance of this shrimp species.

Materials and Methods

Shrimps and Experimental Design

This study was conducted at Marine Research Station of Faculty of Fisheries, University of Çukurova, Yumurtalık, Turkey. Broodstock were captured off the Yumurtalık Bight and spawned at the station and larvae cultured until PL on live feeds as described in Kumlu *et al*. (1999b and 2000a).

The experimental design used in the present study is summarized in Table 1. Larvae were cultured in April (2002) and PLs (0.2±0.01 g initial weight) until the end of May in tanks in a greenhouse prior to stocking into grow-out ponds (A, C, D, E) and tanks (F, G), in order to allow the shrimp to be stocked into grow-out ponds earlier in the year. Grow-out period for pond A, C, D, E, Tanks F and G took place between 1 June and 20 October 2002 (140-days). In pond B, the PLs, which had been produced in the same manner in September 2001 and grown in tanks until about 3.8±0.2 g, were over-wintered in two 50 m^2 ponds situated in a greenhouse from November 2001 until May 2002. During the over-wintering period, ponds water temperature was maintained via space heating only during extremely cold days. The animals were fed on a diet (45% protein) at a feeding rate of about 0.5% body weight day^{-1} throughout the over-wintering period.

Approximately 2 wk prior to onset of the experiment, ponds and tanks were filled with sea water (40 ppt). No fertilization is required because secchi disc readings never exceeded 40 cm throughout the rearing period. Initial water exchange rate was almost zero, but increased to 10% (ponds A and B) and 30% (ponds C, D, E and tanks F and C) towards the end of the culture (Table 1). Pond water was aerated and circulated by using two submersible water pumps in each pond. Dissolved oxygen (DO) was maintained about 4-5 mg L^{-1} throughout the culture period.

Pond water temperature, pH, salinity and DO were

Table 1. Definition of the grow-out procedures used during the culture of *Penaeus semisulcatus* for 140 days in ponds

	Semi-Intensive		Intensive				
	Pond A	Pond B	Pond C	Pond D	Pond E	Tank F	Tank G
Size of ponds (m^2)	120 (20x6x1 m)	120 (20x6x1 m)	120 (20x6x1 m)	50 (10x5x1 m)	50 (10x5x1 m)	12 (Round)	12 (Round)
Stocking Density (shrimps per m^2)	5	5	30	40	50	20	20
Duration of growth (days)	140	140	140	140	140	140	140
Size at stocking (g)	0.2	3.8	0.2	0.2	0.2	0.2	0.2
Water Exchange Rate (% day^{-1})	5-10	5-10	5-20	5-25	5-30	5-20	5-20

monitored regularly throughout the study with readings obtained from the middle of water column (~50 cm depth). DO measurements were performed twice daily, at 06:00 and 14:00 h using a YSI DO meter (Yellow Springs Instrument Company, Yellow Springs, Ohio, USA). pH was measured weekly using a WTW pH-meter (pH 315i Set, WTW Measurement Systems, Inc., Germany). Total ammonia nitrogen (TAN), nitrite and nitrate were measured weekly using colorimetric test kits (Merck).

Diet and Feeding

A local extruded feed produced by Pınar A.Ş. (Izmir, Turkey) was offered to shrimp at appropriate particle size and feeding rate during the study. Feeding rate was calculated as percentage of the total shrimp biomass in the ponds and adjustments were made by feeding trays after each weighing. Feeding rate was high (15% of the shrimp body weight (BW) per day) during the early PLs but decreased down to 3% BW day^{-1} towards the end of the experiment. Feed was administered mainly at night as the animals were active between 18:00 and 07:00. Pertinent characteristics of this feed were: 45% crude protein; 12% crude fat; 12% ash and 12% moisture. Daily rations were administered three times daily (equal portions at 06:00, 22:00 and 02:00) by hand to a level slightly below satiation. After feeding (2 h), the remaining feed on the trays was checked to adjust the next feeding rate.

The feed used in this study was immersed in 20x10x10 cm plastic containers in triplicate to determine dry matter (DM) loss (leaching rate) by weighing before and after drying at 105ºC until constant weight (16 h) and cooling in a desiccator's. The samples were kept in the water (5-L in each container), which was continuously aerated for periods of 0.5, 1, 2, 3, 4, 5 and 6 h. At the end of the immersion periods, the samples were removed onto 50-µm mesh rinsed with distilled water and dried at 105ºC until constant weight (Smith *et al*., 2002).

Growth and Measurements

During the study, about 30 animals were randomly sampled every 10 days in each pond or tank and were weighed individually (whole-body wet weight) on an electronic balance to the nearest 0.01 g.

The following parameters were calculated at the end of the experimental period: daily growth rate (DGR) = (initial weight–final weight)/culture period, specific growth rate (SGR, % day^{-1}) = 100 x [(ln final body weight – ln initial body weight)/number of days], survival (%) = 100 x (N_f – N_i)/N_i (where N_i = initial number of shrimp and N_f= final number of shrimp) and feed conversion rate (FCR) = feed supply/ weight gain.

Statistical Analysis

Regressions were used to derive equations for growth curves and to determine relationships between stocking rate and weight/survival as well as SGR by using Microsoft Excel package program.

Results

Feed Properties and Water Parameters

The feed pellets remained fully intact until about 3-h of immersion in water. DM loss was about 10% during the 1st h and rose to 14.74% 4 h post- immersion. Leaching rate was rapid during the first 2 h, but was much lower thereafter (Figure 1).

In ponds A and B, the grow-out period started at the beginning of June 2003 when the water temperature was 25°C and ended on 20 October 2003. Water temperature reached to a peak of 33.6ºC in the mid July-August then declined down to 25.6°C at the end of the culture period (20 October 2003) (Figure 2). The pH and dissolved oxygen levels were always above 8 and 3.6 mg L^{-1} respectively. Salinity ranged between 39 and 40 ppt (normal sea water salinity). Highest measurements of TAN, nitrite and nitrate levels were 0.36 mg L^{-1}, 0.15 mg L^{-1} and 53.0 mg L^{-1}, respectively.

Semi-intensive Culture Strategy

The pre-seasonally produced PLs (Pond A) displayed a linear growth throughout the growing period reaching a mean weight of 22.6 g in 140 days (Figure 2A

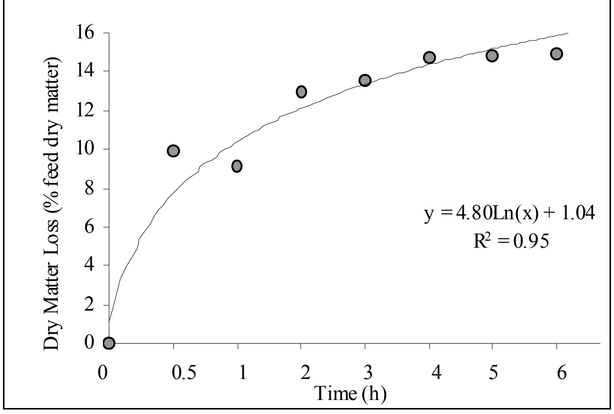

Figure 1. Dry matter loss (% feed dry matter) of the feed over time.

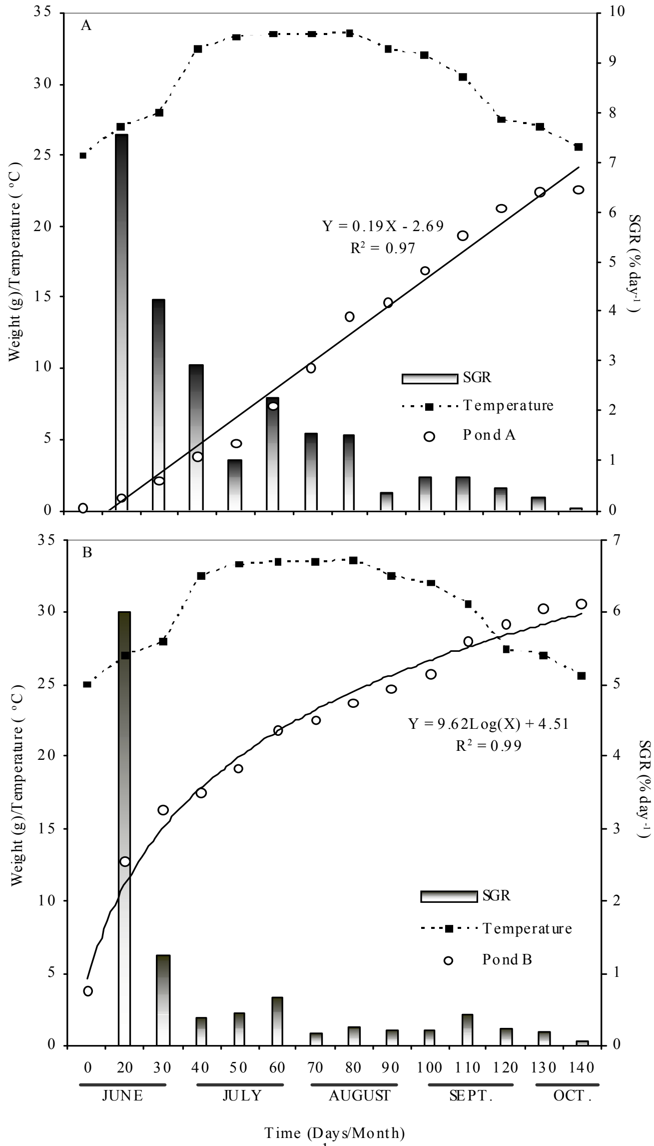

Figure 2. Water temperature, specific growth rate (SGR: % day^{-1}) and fitted growth lines of pre-seasonally produced (A) and over-wintered (B) *Penaeus semisulcatus* grown in ponds for 140 days.

and Table 2). Regression equation for growth was calculated as Y = 0.19X - 2.69 (R^2 = 0.97). While mean weight gain over the first 30 days was 1.93 g, this increased up to 20.44 g during the last 110 days (Figure 2A). DGR (daily growth rate) was 0.06 g day^{-1} during the first 30 days but increased over 3-fold (0.19 g day^{-1}) thereafter (Table 2). In over-wintered PLs (Pond B), growth rate was almost 7-fold higher during the first 30 days but about 1.4-fold lower than that in Pond A during the later grow-out period.

The PLs in Pond B grew from 3.8 g to 30.5 g with a mean daily growth rate of 0.41 g during 0-30 days and 0.13 g between 30 and 140 days (Figure 2A). Regression equation was calculated to be Y = 9.62Log (X) + 4.51 (R^2 = 0.99). Weight gain was 14.42 g during the first 30 days with a DGR of 0.41 g (2.87 g week^{-1}) and again 14.32 g with DGR of 0.13 g (0.91 g week^{1}) thereafter (Figure 2B and Figure 3A, 3B). SGR was much higher during the early growth phase as compared to that obtained towards the end in both ponds (Figure 2A and 2B).

Mean FCR (food conversion ratio) was 2.41 and 2.55 in Pond A and B, respectively. Final survival rate was 78% in Pond A and 74% in Pond B (Table 2). Estimated yield (kg ha^{-1}) was calculated to be 880 kg in Pond A and 1130 kg in Pond B.

Intensive Culture Strategy

Water quality parameters were similar to those reported above for Pond A and B except that water exchange rate was increased up to 30% towards the end of the culture period. The pH and dissolved oxygen levels were always above 8.1 and 3.1 mg L^{-1} respectively. The highest measurements of TAN, nitrite and nitrate levels were 0.43 mg L^{-1}, 0.22 mg L^{-1} and 73.0 mg L^{-1}, respectively.

Shrimps at the stocking density of 30 animals per m^2 (Pond C) grew linearly from 0.2 g to 13.7 g with a mean

Table 2. Daily growth rate (DGR), specific growth rate (SGR), survival, final weight and food conversion ratio (FCR) of *Penaeus semisulcatus* reared in earthen ponds or concrete tanks for 140 days in semi-intensive and intensive systems

	Semi-Intensive		Intensive				
	Pond A*	Pond B*	Pond C*	Pond D*	Pond E*	Tank F**	Tank G**
DGR (g day^{-1})	0.16		0.10	0.05	0.05	0.05	0.04
0-30 days	0.06	0.41					
30-140 days	0.19	0.13					
SGR (g day^{-1})			3.02	2.48	2.58	2.50	2.48
0-30 days	7.88	4.84					
30-140 days	2.15	0.58					
Survival (%)	78.00	74.00	65.00	62.00	57.00	66.5	58
Final Weight (g)***	22.57±2.66	30.54±5.24	13.71±1.63	6.44±0.86	7.37±0.99	6.61±1.13	6.42±0.72
FCR	2.41	2.55	3.24	2.41	2.04	3.95	4.15
Regression Equations for growth ****	Y = 0.19X–2.69	Y=9.62Log(X)+4.51	Y= 0.10X+0.64	Y = 0.06X-1.13	Y = 0.05X–1.07	Y = 0.05X-0.46	Y = 0.05X-0.51
R^2	0.97	0.99	0.97	0.95	0.95	0.98	0.98
Estimated yield (kg ha^{-1})	880	1130	2673	1597	2100	879	793

* Earthen ponds; ** Concrete tanks; *** Data for final weight is a mean ± sd (n is 25-30 animals);
**** Y and X represents weight and time, respectively.

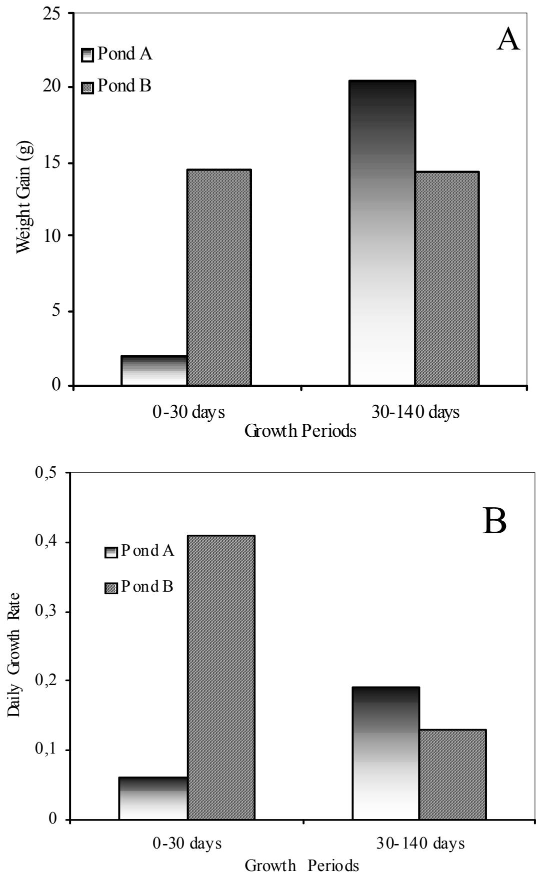

Figure 3. Mean weight gain (A) and daily growth rate (DGR: g day^{-1}) of pre-seasonally produced (Pond A) and over-wintered (Pond B) *Penaeus semisulcatus* grown in ponds for 140 days.

daily growth rate of 0.10 g in 140 days (Table 2). Regression equation was Y = 0.10X + 0.64 with R^2 = 0.97. At higher densities, the shrimps reached to only 6.44 in Pond D (Y = 0.06X - 1.13, R^2 = 0.95) and 7.37 g in Pond E (Y= 0.05X - 1.07, R^2 = 0.95) (Table 2). Mean FCR was calculated as 3.24 in Pond C, 2.41 in Pond D and 2.04 in Pond E. SGR ranged between 2.48 and 3.02 at these high stocking densities (Table 2). The yields obtained in these ponds were 2,673 kg (Pond C), 1,597 kg (Pond D) and 2,100 kg (Pond E).

The shrimps grown in concrete Tanks F and G displayed poorer growth performance resulting in only 879 kg and 793 kg of yield (Table 2). FCR and survival were also lower in these concrete ponds as compared to earthen ponds.

Discussion

This study has demonstrated that it is possible to grow *P. semisulcatus* to a marketable size of over 20 g when stocked in early June with pre-seasonally produced PLs having an initial mean weight of 0.2 g and harvested in late October under semi-intensive systems (5 shrimps per m^2). Our results agree with the finding of Lumare *et al.* (1999) who also reported that *P. semisulcatus* originating from Turkey reached from PL44 to 21.6 g when stocked at 2 PL per m^2 in 123 days in Italy. Türkmen (2007a, b), who studied with the same species in the Aegean region of Turkey reported that this species at 15 and 20 pieces per m^2 reached to sizes of 16.46 and 18.72 g, respectively, in 150 days. Kumlu *et al.* (2003) indicated that there was no advantage in stocking the PLs of this shrimp species into outdoor grow-out ponds before water temperature reaches 25ºC as growth rate was only 0.14 g $week^{-1}$ in temperatures between 18 and 23°C (April and second week of May). Seidman and Issar (1988) also stated that minimum temperature to get good growth from *P. semisulcatus* must be at least 23°C. *P. semisulcatus* appears not to be a good candidate for culture in colder waters as opposed to, for example, *P. californiensis* (Martinezcordova *et al*., 1998). The latter species was reported to grow between 16.7 and 21ºC at an average growth rate of 0.46 g $week^{-1}$ during winter period in Mexico. It appears that, in order to obtain higher growth rates, nursery culture of *P. semisulcatus* has to be prolonged in greenhouses until the grow-out pond water temperature is about 25°C. Average growth rate obtained throughout the current study in Pond A (1.12 g $week^{-1}$) at temperatures between 25 and 33.6ºC was comparable to other commercial shrimp species grown at similar conditions.

Results obtained from Pond B indicate that over-wintered juveniles provide an opportunity to increase the marketable size of this shrimp species well above 30 g in the limited growing season (June – October) in the sub-tropics. Over-wintered shrimps having mean initial weight of 3.8 g stocked into Pond B in 1st of June 2003 reached to about 22 g in only 2 months (in early August). This should obviously give flexibility and increase profitability of shrimp farms and may even provide a chance to produce two crops in one season with an average marketable size of about 20 g.

P. semisulcatus consume very low amount of food at temperatures between 14 and 18ºC and exhibit almost zero growth during the over-wintering period in closed systems in greenhouse (Kir, 2004; Kumlu and Kır, 2005). Extremely rapid growth displayed in the present study in Pond B during the first 30-days by the over-wintered shrimps is thought to be due to compensatory growth, which is a response to restore original growth trajectory. Many organisms exhibit faster growth during recovery from total or partial food deprivation (Wilson and Osbourn, 1960; Jobling, 1994). Compensatory growth due to starvation, over-winter fasting and re-feeding has been demonstrated for many different fish species (Boujard *et al*., 2000; Ali *et al*., 2003; Pottinger *et al*., 2003) as well as for *Fenneropenaeus chinensis* (Wu *et al*., 2001; 2002). In our study, during the compensatory growth period (appeared to last for about 1-month after re-feeding), the shrimps gained an average weight of 2.87 g $week^{-1}$, but after this period, growth rate declined to 0.91 g $week^{-1}$ (over three-fold less) for the rest of the growth period (between 2nd and 5th months). Not so striking but slightly similar results were reported by Seidman and Issar (1988), who found a growth rate of 1.12 g $week^{-1}$ in the first 70-80 days post-wintering culture period and 0.74-0.94 g $week^{-1}$ during the rest of the grow-out period with the same species in Israel. These authors reported that when stocked at 30 per m^2, the over-wintered animals (initial weight of 7.1-8.0 g) reached to 22.1-25.6 g in 134-140 day in ponds. Much higher growth rate we obtained in the current investigation (2.87 g $week^{-1}$) than that (1.12 g $week^{-1}$) obtained by Seidman and Issar (1998) is thought to be due to lower stocking density and possibly the past nutritional history of the animals we used in our study. The growth rate we obtained during the post-compensatory growth period is similar to those reported by these authors as well as by Kumlu *et al.* (2003), who grew the same species at 10 shrimps per m^2 stocking density under similar culture conditions. From the present results, it is evident that after a partial fasting period due to unfavorable conditions (i.e. feed deprivation and low water temperatures) encountered during over-wintering period, *P. semisulcatus* also display an over growth-compensation when re-fed and cultured in adequate rearing conditions. This finding is thought to be a promising area on which studies should focus on to assess the type of compensation (full, partial or over compensation) and its relation with temperature and/or food deprivation period and whether over-wintering costs could be compensated and two crops could be produced in temperate regions by including over-wintering systems in shrimp farms.

It is well known that there is an inverse relationship between stocking density and growth rate in aquatic animals including shrimps. At the low stocking density (5 shrimps m^2), SGR was 5.22 % day^{-1} in comparison to 2.58% day^{-1} obtained at the highest stocking density (50 shrimps m^2). At the stocking density of 5 per m^2, the shrimps (Pond A), with a mean daily growth rate of 0.16 g, grew from 0.2 g to 22.6 g within 140 days. This finding is similar to that reported in Israel by Issar *et al.* (1987), who obtained a growth rate of 0.12 g day^{-1} at the stocking density of 8 shrimps per m^2 during a grow-out period of 162 days. However, at higher stocking densities growth rate declined from 0.10 g day^{-1} at 30 m^2 to 0.05 g day^{-1} at 50 shrimps per m^2. Issar *et al.* (1987) also obtained similar growth rates (0.06-0.09) at 28-29 shrimps per m^2 during the nursery culture of *P. semisulcatus*, which continued for 38 days. Şereflisan *et al.* (1998) report that 0.10-0.12 g day^{-1} growth rate can be achieved with *P. semisulcatus* at stocking densities of between 20 and 40 pieces per m^2 at 23-26°C in fiberglass tanks. Likewise, Seidman and Issar (1998) obtained DGR of 0.12-0.14 g day^{-1} with stocking densities of between 20 and 30 animals m^2. The results of the current work and those in the literature may suggest that *P. semisulcatus* is not a very good candidate for intensive culture systems, at least for stocking densities above 30 pieces per m^2. Yet, it is believed that further work is required with better quality feeds and feeding management strategies for more concrete conclusions to be drawn. It is well known that shrimps are slow feeders and that their feeds must remain stable in water at least for several hours. Our diet remained intact in water for about 3 h, after which it lost 14.74% of its dry matter. In the study of Smith *et al*. (2002), the shrimp pellet used for feeding *P. monodon* remained intact for 4 h and dry matter leach loss was 12% during this period. Therefore, it may be reasonable to assume that one of the reasons for poorer performance we obtained in our study as compared to that reported by Seidman and Issar (1988) at high stocking densities (30-50 per m^2) might be due to incomplete content or nutrient leach-loss of the feed. The shrimps might have utilised natural productivity at low densities but have had to rely more on artificial feed at the higher densities. The above reasons might also explain the high FCR values obtained during the study. Therefore, it is reasonable to expect that better growth performance and lower FCR should be achieved with better quality feeds in high densities. Similar conclusions have also been made for *P. monodon* by Millamena and Trino (1997) who found that growth, survival and FCR was the best at the lowest stocking density (5 m2) and the poorest at the highest stocking density (20 m^2) when fed on incomplete diet.

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