International Journal of Agriculture. Photon 124 (2013) 252-267
https://sites.google.com/site/photonfoundationorganization/home/international-journal-of-agriculture
Original Research Article. ISJN: 7758-2463

International Journal of Agriculture

Photon

# Brood stock dependent seed production and grow-out culture of green tiger shrimp *Penaeus semisulcatus* (De Haan, 1844) at Mandapam, South-east coast of India

G. Maheswarudu[a], Josileen Jose[a], S. Mohan[b], M.R. Arputharaj[c]

[a] Central Marine Fisheries Research Institute, Marine Drive, Kochi, Kerala, India-682018.
[b] Madras Research Centre of Central Marine Fisheries Research Institute, CIBA Campus, IV Floor, NO. 75. Santhome High Road, Raja Annamalaipuram, Chennai, Tamil Nadu, India-600 028
[c] Manadapam Regional Centre of Central Marine Fisheries Research Institute, Marine Fisheries Post, Ramanath Puram District, Tamil Nadu, India-623520

***The authors receive Thomas Edison Award-2013 in Marine Aquaculture for Inspiration and Knowledge Distribution among young research scholars.***

**Article history:**
Received: 21 August, 2013
Accepted: 25 August, 2013
Available online: 21 November, 2013

**Keywords:**
Green tiger shrimp, *P. semisulcatus*, seed production, Intra correlations of hatchery parameters, grow-out culture, brood stock dependent growth

**Corresponding Author:**
Maheswarudu G.*
Email: maheswarudu@yahoo.com
Fax No: 91-04842394909

Jose J.
Email: drjoslin@gmail.com
Fax No: 91-04842394909

Mohan S.
Email: s.mohan1947@yahoo.co.in
Fax No: 91-044 24617290

Arputharaj M.R.
Fax No: 91-04573 241502

**Abstract**
This study was designed and carried out for three consecutive years to evaluate the suitability of *Penaeus semisulcatus* for commercial application and to address the issue of stunted growth in grow-out culture. Nine spawners (18.0 - 62.0 g.), three for each year study, were collected from trawl net operation in the Palk Bay and used for seed production. Nauplii from each spawner were reared (100 Nauplii/ litre) up to Post Larval stage 20 ($PL_{20}$) separately, and stocked three grow-out ponds of each 0.25 ha area, without mixing them. Grow-out culture was carried out for 145 days at the stocking density 5, 6, and 10 PL/ $m^2$ during 1st, 2nd and 3rd year respectively. In the hatchery phase wide range in egg production rate, nauplius production rate, hatching rate and post larval survival rate was recorded. Analysis of partial correlations revealed that high egg production rate leads to high PL survival rate. Since egg production rate is 0spawner dependent high reproductive performance trait can be selected for captive broodstock development of penaeid shrimps to reduce expenditure on less-productive broodstock. In grow-out culture also wide range in survival rate Food Conversion Ratio (FCR), harvested size and production rate were recorded. FCR differed significantly between density trials, yielding better rate at lower stocking density. Growth significantly varied between densities and within each density trial, revealing that growth is spawner dependent. Hence, it is suggested that captive broodstock of penaeid shrimps can be developed by selecting superior growth as a trait to get better economics by eliminating stunted growth. *P. semisulcatus*, characterised with slow growth, is most suitable for live shrimp trade that fetch more profits.

**Citation:**
Maheswarudu G., Jose J., Mohan S., Arputharaj M.R., 2013. Brood stock dependent seed production and grow-out culture of green tiger shrimp *Penaeus semisulcatus* (De Haan, 1844) at Mandapam, South-eeast coast of India. International Journal of Agriculture.. Photon 124, 252-267.

## 1. Introduction

*1.1 Need of the study*
*1.1.1*
The world fish production in 2011 was 154 million tonnes and aquaculture contribution was 63.6 million tonnes with 44.3 million t from inland aquaculture and 19.3 million t from marine aquaculture (FAO, 2012). In India black tiger shrimp (Penaeus monodon) production from aquaculture has increased from 20 t in 1972 to 1,42,967 t in 2006, and thereafter it was declining. *Penaeus vannaei* was introduced to India in 2009 and from 2010

on wards all the farmers preferred this species due to suitability for high stocking densities that fetch high profits. Though *P. vannamei* is having advantageous characteristics such has fast growth, compatibility for high stocking density culture and yields high performance on low protein diet, it is also encountering disease problems in grow-out culture, like tiger shrimp *P. monodon* (FAO, 2012 a ). It is inevitable to find an alternate species of penaeid shrimps for sustaining the shrimp culture industry.

*1.1.2*

In shrimp culture industry farmers are frequently encountering problems like stunted growth and low survival that lead to high values of FCR (low conversion of food), irrespective of the species being cultured either *P. monodon* or *P. vannamei*. Green tiger shrimp *P. semisulcatus* was selected as alternate species and a comprehensive study has been designed and carried out to address these issues.

*1.2 Green tiger shrimp*

*1.2.1*

The green tiger shrimp *Penaeus semisulcatus* De Haan distributed in Indo-West Pacific region: from Red sea (20°16'49'' N; 38°30'45.234'' E) , east and south east Africa to Japan (36°00' N; 138°00' E) Korea (37° 00'-40 00'N; 127°00'-127°30' E), the Malay Archipelago (00°00' N; 120°00' E) and northern Australia (13°00'S; 133°00' E). Eastern Atlantic: the species has reached the eastern Mediterranean through the Suez Canal; it is now found all along the coasts of Egypt (30°06' N; 31°25' E ), Israel (31°30' N; 34°45' E), Lebanon (33°00' N; 35°50' E), Syria (35°00' N; 38°00' E ) and southern Turkey (39°00' N; 35°00' E ) (Holthuis, 1980). The species is of minor to moderate importance in Madagascar (20°00' S; 47°00' E), south east and eastern Africa and the Red sea. In the Gulf of Aden (12°00' N; 48°00' E), the Persian Gulf (26°00' N; 52°00' E) and in Pakistan (30°00' N; 70°00' E) it is of major importance in the offshore fishery (Holthuis, 1980). In India (21°00' N; 78°00' E) though it occurs all along the coast it substantially supports the fishery along the south east coast (Rao et al., 1993; Maheswarudu et al., 1994).

*1.2.2*

Attempts on rearing green tiger shrimp in tank conditions and pond culture were made in different countries; Israel (Samocha and Lewinsohn, 1977; Siedman and Issar, 1988), Italy (Scordella and Zecca, 2002), Kuwait (Ameeri and Cruz, 2006) and Turkey (Turkmen, 2007; 2007a). In India attempts were made on pond culture of this species (Nandakumar, 1982; Maheswarudu et al., 1995; 1997; Maheswarudu and Josileen, 2008). *P. semisulcatus* is less vulnerable to white spot syndrome virus (WSSV) compared to *P. monodon* (Maheswarudu and Josileen, 2008). To find out the suitability of the species on commercial scale a comprehensive study from seed production through grow-out culture was conducted for three consecutive years. Post larvae were produced and stocked (spawner wise) in grow-out pond separately to study the growth performance and other parameters such as survival, FCR, and to draw correlations with hatchery parameters such as egg production rate, nauplius production rate, hatching rate and survival rate up to PL stage. This paper deals with details and discussions on these aspects.

## 2. Materials and Methods

*2.1 Design of the work plan*

The present study was designed to evaluate the suitability of green tiger shrimp *P. semisulcatus* for commercial application in grow-out culture by studying growth performance, survival rate, production rate and FCR at three stocking densities (5/$m^2$, 6/$m^2$, and 10/$m^2$).

In the shrimp hatchery egg production rate, nauplius production rate, hatching rate and post larval survival rate are varied from spawner to spawner. The present study was designed to find out these parameters whether they are spawner dependent or not, by recording these parameters spawner wise, from nine spawners of different sizes. Intra correlations were worked out between these parameters to draw conclusion that will help efficient shrimp hatchery management.

In grow-out culture growth of shrimp is varied and farmers are frequently encountering stunted growth, which affect the economics. The present study was designed to find out the growth of the shrimp is spawner dependent or not, by studying growth performance of nine progenies that were produced from nine spawners at three different stocking densities and within the same stocking density.

The present study was also designed to find out the possibility of establishment of correlations of hatchery parameters such as hatching rate and post larval survival rate, with grow-out parameters such as survival rate, growth of shrimp in terms of total length and

weight, and FCR. These correlations will aid for selection of seed in the hatchery that perform well in grow-out sector for yielding good results.

*2.2 Location of study*

The work was carried out at Regional Centre of Central Marine Fisheries Research Institute, Mandapam Camp, Tamil Nadu, India (09o 16' 16.7"N; 079o 07' 56.0" E) for three consecutive years (1996-1999), during the month of October-April of each culture year.

*2.3 Brood stock*

*2.3.1 Objective*

The objective of the study was to evaluate the reproductive performance of the *P. semisulcatus* spawners ie., egg production rate, nauplius production rate, hatching rate in the hatchery and correlations between them.

*2.3.2*

A total of nine gravid females (three for each year) were collected from the trawl net operation (during night) in the Palk Bay/ Gulf off Mannar. Immediately after collection the spawners were maintained in polythene cans (150 L) containing filtered sea water provided with good aeration (battery operated aerator) till they reach the hatchery in the morning. As soon as reaching hatchery they were transferred to 1000 L capacity oval shaped fibre glass tank and fed with clam meat. Same day evening spawners were transferred to 200 L capacity cylindro-conical fibre glass spawning tanks (one/ tank) provided with mild aeration and chelating agent EDTA (@100 mg / 100 L). After introduction of the spawner each spawning tank was covered with nylon webbing to prevent the escape of the spawner, and black cloth to reduce light intensity. In the following day morning each spawner was collected and recorded the spawning performance. Eggs from respective tank were collected using 100 µm sieve and thoroughly washed in fresh running sea water and kept for spawning in the same tank that was cleaned and filled with 150 L sea water. Good aeration was provided for hatching. Total number of eggs spawned was estimated by taking three sub samples of 100 ml each and counting all the eggs and raising the number of eggs to total volume of the spawning tank. Similarly after hatching (after 12-14 hours) nauplii count was also estimated. Hatching rate (%) was computed by using following formula:

Hatching rate (%) = Total number of nauplii/ Total number of eggs x 100

*2.4 Larval rearing and seed production*

*2.4.1 Objective of research*

The objective of the study is to evaluate larval survival rate from Nauplius1 to Postlarva20, spawner wise, and to find out intra correlations between hatching rate and post larval survival rate that will help to select nauplii for successful larval rearing.

*2.4.2*

Larvae were reared in three 5 t capacity circular fibre glass tanks by stocking nauplii from respective spawner in one rearing tank at the rate 100 nauplii/ litre. Initially, in the rearing tank, sea water was maintained at one ton level until Proto zoea –III (PZ-III) stage, and thereafter increased to two ton level up to Mysis-III (M-III) stage. During post larval stages (PL1 –$PL_{20}$) water level was maintained at full capacity of the rearing tank (ie. 5 t). Larvae, from PZ-I to M-III stages were fed with *Chaetoceros* spp. by maintaing at 1000 cells/ml in the rearing tanks. PL1 to $PL_{20}$ were fed with microencapsulated diet and *Artemia nauplii. Artemia nauplii* were maintained at 1-2 no /ml in the larval rearing tanks and microencapsulated diet was provided at the rate 2-4 mg/ larva/ day. Total quantity of feed/day was divided in to four rations and fed at 6 hours interval. Daily during morning hours after siphoned out settled waste water exchange was given at 10%, 20% and 30% at Proto zoea, Mysis and Post larval stages, respectively using150 µm, 200 µm, and 300 µm filters to prevent the larval escape. At $PL_{20}$ stage all the larvae were collected using larval collection buckets (300 µm mesh) and transferred to 200 L capacity cylindroconical tank. Total larvae was estimated by taking three sub samples of 1000 ml and survival rate from Nauplius to $PL_{20}$ was estimated by following the given formula:

Survival rate (%) from Nauplius1 to $PL_{20}$ = Total number of $PL_{20}$/ Total number of nauplii x 100

All the larval rearing tanks were accommodated in the hatchery shed that was four sides open and with transparent roof. During larval rearing photoperiod was natural. Sea water that was settled and filtered through gravity sand bed filter was used for entire hatchery operation, and sea water was again filtered (5µm filter bags) before entering larval rearing tanks. Sea water temperature ranged between 25-27° C and salinity 31-32 ppt.

*2.5 Grow-out culture*

*2.5.1 Objective of research*

The objective of the study is to evaluate the growth performance of shrimp, survival rate, FCR, spawner wise, in grow-out culture under three stocking densities (5/$m^2$, 6/$m^2$ and 10/$m^2$), and to establish correlations between hatchery parameters such as hatching rate and post larval survival rate and grow-out parameters such as survival rate, FCR, production rate and harvested size of shrimp.

*2.5.2 Pond management*

Grow-out culture was carried out for a period of 145 days in three consecutive years during November to April. Three similar rectangular earthen ponds (0.25 ha area each) with slope and drain –out facility were used for the farming and same were used for three years. Each year, ponds were stocked post larvae produced in such a manner that larvae of one spawner to one pond. Water supply was through 6" PVC pipeline that was pumped by two 10 HP capacity pump sets (one electrical and the other diesel pump set). Each pond was having an inlet with control valve and to prevent predators the inlet was attached with 300 µm size nylon filter bag. Water depth in all three ponds was maintained at 1 m level. About 30 % water exchange was provided after 30, 45, 60, 75, 90, 105, 120 and 135 days. During third year of culture (10/$m^2$ density trial) daily aeration was provided to each pond for 8 hrs (20.00 hrs to 06.00 hrs) from 60$^{th}$ day onwards, using paddle wheel aerator (1 HP capacity) to enhance dissolved oxygen.

Pond preparation was initiated one month before stocking; pond bottom of all three ponds was tilled and kept for drying. Prior filling with sea water lime was applied on the bottom at the rate of 400 kg / ha. About 15 days before stocking, pond water was fertilized with urea and super phosphate at the rate of 135 kg/ha and 67 kg/ha respectively to boost the production of phyto plankton and subsequently the zooplankton.

*2.5.3 Stocking seed and Feeding*

Seed ($PL_{20}$) were stocked in all the three ponds at a stocking density of 5/ $m^2$, 6/$m^2$ and 10 /$m^2$ during first, second and third year respectively. Shrimps were fed with shrimp feeds No. 1-6 of C.P. Aquaculture Private Ltd. India, gradually increasing the size of the feed with the growth of the shrimp. Shrimps were fed @ 20% of biomass during first 15 days; 10% of biomass during 16-30 days; 8% of biomass during 31-45 days, 5% of biomass during 46-60 days; 4% of biomass during 61-90 days; 3.5% of biomass during 91-120 days; 2.5% of biomass during 121-135 days; and 2.0% of biomass during 136-145 days. Two Check trays, 2'X2' frame with nylon webbing, were placed in each pond in opposite direction to observe the feed consumption from 60 th day on wards. During feeding about 2-3 % feed was placed in equal quantity in two check trays and after one hour feed consumption was assessed and accordingly feeding rate was adjusted on the following day. Total quantity of feed / day was divided in to different rations during the culture period: two times during first 45 days, three times during 46-120 days; and four times during 121 -145 days. Feeding schedule and details are given in table 2.5.3.1. In all the ponds sampling for growth was carried out in 15 days interval from day30 onwards ie 30, 45, 60, 75, 90, 105, 120 and 135. Based on the sampling, biomass of shrimp stock in each pond was estimated for finalizing the feeding rate at different culture periods, by taking mean weight of shrimp from periodical sampling and number of shrimp survived in the pond. In each pond shrimp survival (no of shrimp/$m^2$) at different periods of culture was estimated by operating cast net randomly at five places and computing average number of survived shrimp/$m^2$. After 145 days water in all ponds drained out and harvested all the shrimps and recorded total weight of shrimps pond wise. Growth in total length and weight, both sex wise and pond wise measured. Sex ratio pond wise also recorded. Total feed used during 145 days culture period was summed up to estimate the FCR. FCR was calculated by following the formula:

FCR = Total feed consumed by the shrimp (kg)/ Total weight of shrimp harvested (Kg)

Ambient water parameters such as temperature (°C), salinity (ppt), dissolved oxygen (ml/L) and pH were measured fortnightly in all three ponds every culture year.

**Table 2.5.3.1:** Feed and feeding schedule adopted during grow-out culture of *P. semisulcatus*

| Duration of culture (days) | Feed No. | Feed type and size (mm) | Feeding rate ( % of bio mass) | Feeding frequency/ day |
|---|---|---|---|---|
| 0-15 | 1 | Fine crumble (0.42 ) | 20 | 2 |
| 16-30 | 1 | Fine crumble (0.42 ) | 10 | 2 |
| 31-45 | 2 | Crumble (0.89) | 8 | 2 |
| 46-60 | 3 | Crumble (1.41) | 5 | 3 |

| | | | | |
|---|---|---|---|---|
| 61-75 | 3 | Crumble (1.41) | 4 | 3 |
| 76-90 | 4s | Pellet (1.8X3.5 ) | 4 | 3 |
| 91-105 | 4 | Pellet (2.3X3.5 ) | 3.5 | 3 |
| 106-120 | 5 | Pellet (2.3X4.0) | 3.5 | 3 |
| 121-135 | 5 | Pellet (2.3X4.0) | 2.5 | 4 |
| 136-145 | 6 | Pellet (2.3X4.5) | 2 | 4 |

*2.6 Statistical analysis*

ANOVA single factor analysis was carried out to find out the variation in water parameters such as salinity, dissolved oxygen, temperature and pH between three density trials and within each density trial. Similarly ANOVA single factor analysis was performed to find out the inter and intra variation in terms of growth such as total length and weight. In grow-out culture, to find out the variation in survival rate, production rate and FCR between three densities, ANOVA single factor analysis was used. Correlations were drawn between mean total length of shrimp and duration of culture and between mean weight and duration of culture by using spss13. Using spss13 partial correlations were also checked, within hatchery parameters, within grow-out parameters and in between hatchery parameters and grow-out parameters.

## 3. Results

*3.1 Reproductive performance*

Spawner wise egg production rate, nauplius production rate, hatching rate and post larval survival rate are presented in table 3.1.1. Total weight of spawners ranged between 18 to 62 g. Egg production rate and nauplius production rate ranged between 2806 to 8800/ g. body wt. and 1984 to 8033 / g. body wt. respectively. Hatching percent ranged from 68.6 to 91.3%. Larval survival rate from Nauplius1 to Post Larva$_{20}$ (PL$_{20}$) ranged from 25.5 to 36.1 %.

**Table 3.1.1:** Details of larval rearing of green tiger shrimp *Penaeus semisulcatus*

| Year | Spawner wt. (g) | Egg production rate (eggs/g.body wt.) | Nauplius production rate (nauplii / g. body wt.) | Hatching rate (%) | Nauplii stocking rate (nauplii/t) | PL$_{20}$ recovered | PL Survival rate (%) |
|---|---|---|---|---|---|---|---|
| 1 st year | | | | | | | |
| Larval rearing-1 | 32 | 5936 | 4531 | 76.3 | 100000 | 31000 | 31.0 |
| Larval rearing -2 | 32 | 5725 | 4313 | 75.3 | 100000 | 29500 | 29.5 |
| Larval rearing -3 | 32 | 4969 | 3406 | 68.6 | 100000 | 27500 | 27.5 |
| 2nd year | | | | | | | |
| Larval rearing -1 | 30 | 8800 | 8033 | 91.3 | 100000 | 36100 | 36.1 |
| Larval rearing -2 | 62 | 2806 | 1984 | 70.7 | 100000 | 25700 | 25.7 |
| Larval rearing -3 | 18 | 8000 | 5833 | 72.9 | 100000 | 29900 | 29.9 |
| 3 rd year | | | | | | | |
| Larval rearing -1 | 50 | 2912 | 2296 | 78.8 | 100000 | 25500 | 25.5 |
| Larval rearing -2 | 40 | 3120 | 2840 | 91.0 | 100000 | 34600 | 34.6 |
| Larval rearing -3 | 30 | 4167 | 3333 | 80.0 | 100000 | 34900 | 34.9 |

**Table 3.2.1.1:** Mean Salinity ± S.D, Mean Dissolved oxygen ± SD, Mean Temperature ± SD and Mean pH ± SD of pond water during grow-out culture of three consecutive culture years

| Year& Pond | Salinity (ppt) | Dissolved oxygen (ml/L) | Temperature °C | pH |
|---|---|---|---|---|
| 1 st year | | | | |
| Pond-1 | 33.10 ± 1.76 | 7.38 ± 0.97 | 31.67 ± 1.65 | 8.53 ± 0.18 |
| Pond-2 | 33.5 ± 1.62 | 7.65 ± 1.07 | 31.70 ± 1.7 | 8.44 ± 0. 19 |
| Pond-3 | 32.80 ± 1.85 | 8.02 ± 1.03 | 31.74 ± 1.92 | 8.52 ± 0.18 |
| 2 nd year | | | | |
| Pond-1 | 26.65 ± 4.1 | 6.14 ± 0.67 | 31.60 ± 2.08 | 8.66 ± 0.3 |
| Pond-2 | 27.6 ± 4.0 | 6.09 ± 0.63 | 31.57 ± 1.99 | 8.56 ± 0 .22 |
| Pond-3 | 25.45 ± 5.5 | 6.21 ± 0.82 | 31.61 ± 2.05 | 8.54 ± 0.2 |

| | | | | |
|---|---|---|---|---|
| 3 rd year | | | | |
| Pond-1 | 30.39 ± 2.8 | 4.15 ± 0.07 | 31.29 ± 2.09 | 8.47 ± 0.24 |
| Pond-2 | 30.36 ± 2.7 | 4.38 ± 0.15 | 31.27 ± 2.13 | 8.41 ± 0.28 |
| Pond-3 | 29.92 ± 2.9 | 4.47 ± 0.25 | 31.36 ± 2.04 | 8.45 ± 0.2 |
| P value (between densities) | 0.023024624 | 0.572901191 | 2.96851E-48 | 9.1373E-10 |
| P value within densities | | | | |
| Density-1 (5/$m^2$) | 2.75246E-07 | 0.000490408 | 1.32179E-17 | 2.886E-07 |
| Density -2 (6/$m^2$) | 9.71704E-11 | 1.42386E-10 | 1.56498E-22 | 7.7272E-08 |
| Density-3 (10/$m^2$) | 2.18304E-14 | 0.37984711 | 2.61585E-24 | 4.8966E-07 |

*3.2 Grow-out culture*

*3.2.1 Water parameters*

Mean values of water parameters such as temperature, salinity, dissolved oxygen and pH, pond wise for three culture years are presented in table, 3.2.1.1. Temperature ranged from 31.27 to 31.74° C and salinity ranged from 25.45 to 33. 5 ppt. Salinity was low during second year culture period than that of first and third culture years. Both temperature and salinity have significantly varied between density trials as well as within density trial of each year.

Dissolved oxygen during culture period varied from 4.15 to 8.02 ml/L. Dissolved oxygen was low at higher density than that of lower density, but not significantly varied. Intra variation in dissolved oxygen within density-1 (5/$m^2$) and density-2 (6/ $m^2$) was significant. pH ranged from 8.41 to 8.66. pH also significantly varied between density trials as well as within density of each trial.

*3.2.2 Evaluation of green tiger shrimp performance in grow-out culture*

Details of grow-out culture, spawner wise and density wise, number of post larvae stocked, number of shrimp harvested, survival rate and harvested size of shrimp from each pond are presented in table, 3.2.2.1.

Survival rate after 145 days of grow-out culture ranged from 46.4 to 98.5%. Production rate ranged from 436 to 1069 Kg/ha and FCR ranged from 1.9 to 2.6. Wide range in harvested size of shrimp was recorded, ranging from 102.4mmTL/ 10.2 g wt. to 129.46 mm TL/ 18.78 g.

Survival rate as well as production rate have not significantly varied between densities whereas FCR has significantly varied (*P*=2.87122E-05) resulting low conversion rate at higher stocking density.

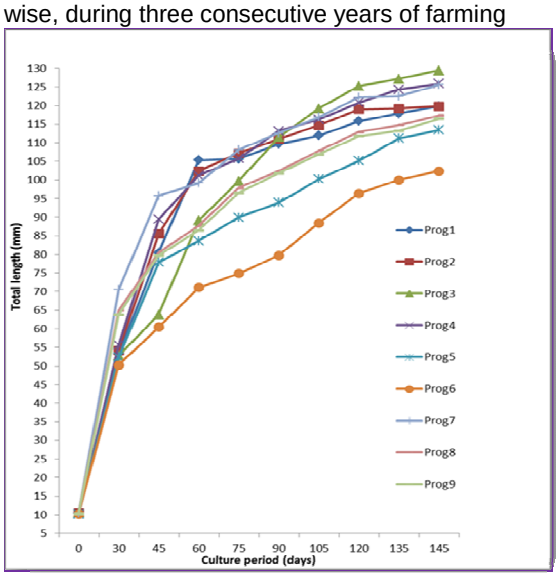
Growth in terms of total length (*P*=2.68253E-42) and weight (*P*=1.1465E-27) has significantly varied between densities. Significant intra variation in growth, in each density trial, was observed. Total length has significantly varied in density-1 (*P*=1.01E-14), density-2 (*P*= 5.91E-08) and density-3 (*P*= 1.33E-14). Similarly weight also has significantly varied in densit-1 (*P*=2.31832E-11), density-2 (*P*=0.000167), and density-3 (*P*=1.06E-08).

**Table 3.2.2.1:** Details of grow-out culture of green tiger shrimp *Penaeus semisulcatus* during three culture years

| Year &Pond | Spawner weight (g) | Pond area (ha) | No of $PL_{f\ PL20}$ stocked | Stocking rate ($PL_{20}$ /$m^2$) | No. of shrimp harvested | Survival rate (%) | Harvested shrimpproduction (kg) | Production rate (kg/ha) | FCR | Mean harvested size of shrimp (TLin mm) | Mean harvested size of shrimp (wt. in g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 st year | | | | | | | | | | | |
| Pond-1 | 32 | 0.25 | 12500 | 5 | 9188 | 69.0 | 131.2 | 524.8 | 1.97 | 119.83 | 14.28 |
| Pond-2 | 32 | 0.25 | 12500 | 5 | 12120 | 96.97 | 175.5 | 702.0 | 2.0 | 119.84 | 14.48 |
| Pond-3 | 32 | 0.25 | 12500 | 5 | 5804 | 46.4 | 109.0 | 436.0 | 1.9 | 129.46 | 18.78 |
| 2 nd year | | | | | | | | | | | |
| Pond-1 | 30 | 0.25 | 15000 | 6 | 12750 | 85.0 | 223.1 | 892.4 | 2.01 | 125.87 | 17.5 |
| Pond-2 | 62 | 0.25 | 15000 | 6 | 14775 | 98.5 | 192.37 | 769.48 | 1.96 | 113.4 | 13.02 |
| Pond-3 | 18 | 0.25 | 15000 | 6 | 14700 | 98.0 | 149.94 | 599.76 | 2.01 | 102.41 | 10.2 |
| 3 rd year | | | | | | | | | | | |
| Pond-1 | 50 | 0.25 | 25000 | 10 | 15125 | 60.5 | 267.3 | 1069.2 | 2.45 | 122.4 | 17.6 |
| Pond-2 | 40 | 0.25 | 25000 | 10 | 14600 | 58.4 | 200.01 | 800.04 | 2.6 | 117.32 | 13.7 |
| Pond-3 | 30 | 0.25 | 25000 | 10 | 15625 | 62.5 | 206.25 | 825.0 | 2.5 | 116.4 | 13.2 |

Progeny that produced from each spawner performed growth independently indicating growth is spawner dependent. Growth performance of each progeny, in terms of total length and weight is shown in Figs. 3.2.2.1 & 3.2.2.2.

**Figure 3.2.2.1:** Growth performance of green tiger shrimp *P. semisulcatus* by total length, progeny-wise, during three consecutive years of farming




*3.2.3 Growth correlations with duration of culture*

Correlations between duration of culture period and total length and between culture period and weight, density wise and progeny wise are presented in table, 3.2.3.1. Both total length and weight of all nine progenies significantly correlated with duration of culture period. Values of correlations ($r^2$ values) differed from progeny to progeny.

**Figure 3.2.2.2:** Progeny wise growth performance (by weight) of green tiger shrimp *P. semisulcatus* during three consecutive years of farming

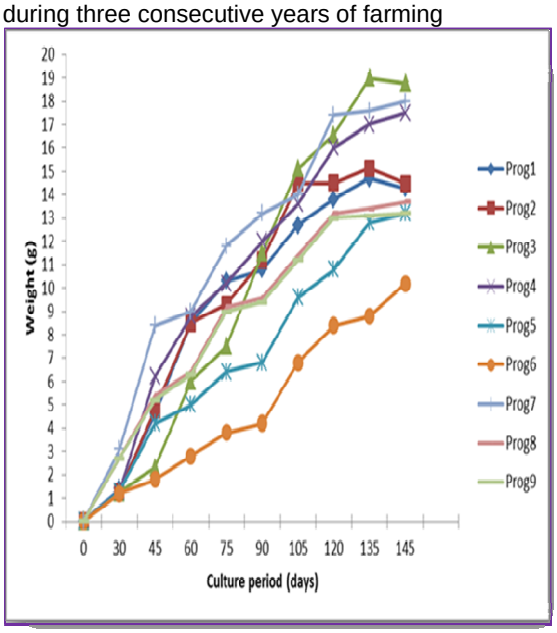



**Table 3.2.3.1:** Correlations between duration of culture& total length and between duration of culture & weight of nine progenies of *P. semisulcatus*

| | | Density-1 | | | Density-2 | | | Density-3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Progeny-1 | Progeny-2 | Progeny-3 | Progeny-4 | Progeny-5 | Progeny-6 | Progeny-7 | Progeny-8 | Progeny-9 |
| Total length (mm) | | | | | | | | | | |
| Duration | Pearson Correlation | 0.885 | 0.886 | 0.960 | 0.932 | 0.928 | 0.958 | 0.879 | 0.911 | 0.913 |
| | Sig. (2-tailed) | 0.0007** | 0.0006** | 1E-05** | 0.0003** | 0.0001** | 1E-05** | 0.0008** | 0.0002** | 0.0002** |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Weight (g) | | | | | | | | | | |
| Duration | Pearson Correlation | 0.967 | 0.963 | 0.981 | 0.985 | 0.99 | 0.979 | 0.981 | 0.987 | 0.986 |
| | Sig. (2-tailed) | 5E-06** | 8E-06** | 5E-07** | 2E-07** | 3E-081** | 9E-07** | 6E-07** | 1E-07** | 2E-07** |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| | **= Correlation is significant at 1% level (P< 0.01) | | | | | | | | | |

*3.3 Correlations*

*3.3.1*

Intra and inter correlations of hatchery and grow-out parameters controlling pond water parameters such as salinity, dissolved oxygen, temperature and pH are shown in table,

**Table 3.3.1.1:** Intra and inter co relations of hatchery parameters and grow-out parameters controlling pond water parameters of grow-out culture

| Control variables | Parameter number | | Spawner weight (1) | Egg production rate (2) | Nauplius production rate(3) | Hatching rate (4) | PL survival rate (5) | Stocking density in pond (6) | Survival rate in grow-out culture (7) | Production rate /ha (8) | FCR (9) | Total length of harvested shrimp (10) | Weight of harvested shrimp (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dissolved and pH Salinity, oxygen, | 1 | Correlation | 1 | -0.921 | -0.874 | -0.633 | -0.73 | -0.504 | 0.462 | 0.363 | -0.851 | -0.144 | -0.056 |
| | | Significance (2-tailed) | . | 0.026* | 0.050* | 0.251 | 0.162 | 0.386 | 0.433 | 0.548 | 0.068 | 0.817 | 0.928 |
| | 2 | Correlation | -0.921 | 1 | 0.984 | 0.795 | 0.712 | 0.215 | -0.1 | -0.023 | 0.756 | 0.07 | 0 |
| | | Significance (2-tailed) | 0.026* | . | 0.002* | 0.108 | 0.177 | 0.729 | 0.873 | 0.97 | 0.139 | 0.91 | 0.999 |
| | 3 | Correlation | -0.874 | 0.984 | 1 | 0.889 | 0.783 | 0.188 | 0 | 0.063 | 0.794 | 0.12 | -0.014 |
| | | Significance (2-tailed) | 0.050* | 0.002* | . | 0.044* | 0.118 | 0.761 | 0.999 | 0.919 | 0.109 | 0.848 | 0.982 |
| | 4 | Correlation | -0.633 | 0.795 | 0.889 | 1 | 0.88 | 0.051 | 0.263 | 0.202 | 0.773 | 0.13 | -0.158 |
| | | Significance (2-tailed) | 0.251 | 0.108 | 0.044* | . | 0.049 * | 0.936 | 0.67 | 0.744 | 0.125 | 0.835 | 0.799 |
| | 5 | Correlation | -0.73 | 0.712 | 0.783 | 0.88 | 1 | 0.31 | -0.094 | -0.259 | 0.915 | 0.091 | -0.269 |
| | | Significance (2-tailed) | 0.162 | 0.177 | 0.118 | 0.049* | . | 0.612 | 0.881 | 0.673 | 0.029* | 0.884 | 0.662 |
| | 6 | Correlation | -0.504 | 0.215 | 0.188 | 0.051 | 0.31 | 1 | -0.873 | -0.423 | 0.635 | 0.741 | 0.622 |
| | | Significance (2-tailed) | 0.386 | 0.729 | 0.761 | 0.936 | 0.612 | . | 0.050* | 0.478 | 0.249 | 0.152 | 0.263 |
| | 7 | Correlation | 0.462 | -0.1 | 0 | 0.263 | -0.094 | -0.873 | 1 | 0.719 | -0.399 | -0.382 | -0.404 |
| | | Significance (2-tailed) | 0.433 | 0.873 | 0.999 | 0.67 | 0.881 | 0.050* | . | 0.171 | 0.506 | 0.526 | 0.5 |
| | 8 | Correlation | 0.363 | -0.023 | 0.063 | 0.202 | -0.259 | -0.423 | 0.719 | 1 | -0.289 | 0.278 | 0.34 |
| | | Significance (2-tailed) | 0.548 | 0.97 | 0.919 | 0.744 | 0.673 | 0.478 | 0.171 | . | 0.637 | 0.651 | 0.575 |
| | 9 | Correlation | -0.851 | 0.756 | 0.794 | 0.773 | 0.915 | 0.635 | -0.399 | -0.289 | 1 | 0.399 | 0.101 |
| | | Significance (2-tailed) | 0.068 | 0.139 | 0.109 | 0.125 | 0.029 * | 0.249 | 0.506 | 0.637 | . | 0.506 | 0.872 |
| | 10 | Correlation | -0.144 | 0.07 | 0.12 | 0.13 | 0.091 | 0.741 | -0.382 | 0.278 | 0.399 | 1 | 0.894 |
| | | Significance (2-tailed) | 0.817 | 0.91 | 0.848 | 0.835 | 0.884 | 0.152 | 0.526 | 0.651 | 0.506 | . | 0.041* |
| | 11 | Correlation | -0.056 | 0 | -0.014 | -0.158 | -0.269 | 0.622 | -0.404 | 0.34 | 0.101 | 0.894 | 1 |
| | | Significance (2-tailed) | 0.928 | 0.999 | 0.982 | 0.799 | 0.662 | 0.263 | 0.5 | 0.575 | 0.872 | 0.041* | . |
| | *=Correlation is significant at 5% level (P < 0.05); In column 2 parameter number is corresponding to that of parameter given in first row | | | | | | | | | | | | |

**Table 3.3.2.1:** Intra correlations of grow-out parameters controlling hatchery parameters

| Control variables | Parameter number | | Stocking density in pond (1) | Survival rate in grow-out culture (2) | Production rate /ha (3) | FCR (4) | Total length of harvested shrimp (5) | Weight of harvested s hrimp (6) | Salinity (7) | Dissolved oxygen (8) | Temperature (9) | pH (10) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spawner weight, egg production rate, nauplius production rate, hatching rate &PL survival rate | 1 | Correlation | 1 | 0.360 | 0.827 | 0.981 | -0.955 | -0.873 | -0.887 | -1.000 | -0.998 | 0.299 |
| | | Significance (2-tailed) | . | 0.640 | 0.173 | 0.019* | 0.045* | 0.127 | 0.113 | 0.000* | 0.002* | 0.701 |
| | 2 | Correlation | 0.360 | 1 | 0.793 | 0.498 | -0.617 | -0.759 | -0.230 | -0.353 | -0.325 | -0.740 |
| | | Significance (2-tailed) | 0.640 | . | 0.207 | 0.502 | 0.383 | 0.241 | 0.770 | 0.647 | 0.675 | 0.260 |
| | 3 | Correlation | 0.827 | 0.793 | 1 | 0.915 | -0.937 | -0.994 | -0.599 | -0.823 | -0.815 | -0.288 |
| | | Significance (2-tailed) | 0.173 | 0.207 | . | 0.085 | 0.063 | 0.006 | 0.401 | 0.177 | 0.185 | 0.712 |
| | 4 | Correlation | 0.981 | 0.498 | 0.915 | 1 | -0.976 | -0.942 | -0.802 | -0.980 | -0.979 | 0.120 |
| | | Significance (2-tailed) | 0.019* | 0.502 | 0.085 | . | 0.023* | 0.058 | 0.198 | 0.020* | 0.021* | 0.880 |
| | 5 | Correlation | -0.955 | -0.617 | -0.937 | -0.977 | 1 | 0.968 | 0.840 | 0.953 | 0.940 | -0.034 |
| | | Significance (2-tailed) | 0.045* | 0.383 | 0.063 | 0.023* | . | 0.032* | 0.160 | 0.047* | 0.060 | 0.966 |
| | 6 | Correlation | -0.873 | -0.759 | -0.994 | -0.942 | 0.967* | 1 | 0.681 | 0.869 | 0.858 | 0.203 |
| | | Significance (2-tailed) | 0.127 | 0.241 | 0.006* | 0.058 | 0.032* | . | 0.319 | 0.131 | 0.142 | 0.797 |
| | 7 | Correlation | -0.887 | -0.230 | -0.599 | -0.802 | 0.840 | 0.681 | 1 | 0.889 | 0.866 | -0.483 |
| | | Significance (2-tailed) | 0.113 | 0.770 | 0.401 | 0.198 | 0.160 | 0.319 | . | 0.111 | 0.134 | 0.517 |
| | 8 | Correlation | -1.000 | -0.353 | -0.823 | -0.980 | 0.953 | 0.869 | 0.889 | 1 | 0.998 | -0.307 |
| | | Significance (2-tailed) | 0.000* | 0.647 | 0.177 | 0.020* | 0.047* | 0.131 | 0.111 | . | 0.002* | 0.693 |
| | 9 | Correlation | -0.998 | -0.325 | -0.815 | -0.979 | 0.940 | 0.858 | 0.866 | 0.998* | 1 | -0.319 |
| | | Significance (2-tailed) | 0.002* | 0.675 | 0.185 | 0.021* | 0.060 | 0.142 | 0.134 | 0.002* | . | 0.681 |
| | 10 | Correlation | 0.299 | -0.740 | -0.288 | 0.120 | -0.034 | 0.203 | -0.483 | -0.307 | -0.319 | 1 |
| | | Significance (2-tailed) | 0.701 | 0.260 | 0.712 | 0.880 | 0.966 | 0.797 | 0.517 | 0.693 | 0.681 | . |
| | *=Correlation is significant at 5% level (P < 0.05); In column 2 parameter number is corresponding to that of parameter given in first row | | | | | | | | | | | |

*3.3.1.1. Results show the following correlations*

1. Spawner weight inversely correlated with egg production rate and nauplius production rate.
2. Egg production rate positively correlated with nauplius production rate.
3. Nauplius production rate positively correlated with hatching rate.
4. Hatching rate positively correlated with PL survival rate.
5. Stocking rate negatively correlated with survival rate in grow-out culture.
6. Total length positively correlated with weight and vice versa.

*3.3.2*

Intra correlations of grow-out parameters controlling hatchery parameters such as spawner weight, egg production rate, nauplius production rate, hatching rate and PL survival rate are shown in table, 3.3.2.1. Results show the following intra correlations of grow-out parameters.

1. Stocking density positively correlated with FCR and inversely correlated with dissolved oxygen and total length.
2. Total length positively correlated with weight and dissolved oxygen.
3. Weight inversely correlated with production rate.
4. Dissolved oxygen correlated with temperature.

## 4. Discussion

*4.1 Hatchery*

*4.1.1 Egg production rate and nauplius production rate*

4.1.1.1

In the present study wide range in egg production rate as well as nauplius production rate was recorded and these two parameters are negatively correlated with spawner weight, indicating that small size spawners are yielding high egg production rate as well as nauplius production rate rather than big sized spawners. Manickam et al. (1997) while analyzing spawning performance and subsequent larval rearing results of 106 spawners of *P. semisulcatus*, reported that medium sized spawners (151-170 mm TL) performed better than large sized spawners (191-210 mm TL).

*4.1.1.2*

Egg production and nauplius production rates are positively correlated, revealing that high egg production rate lead to high naupllus production rate. Nauplius production rate positively correlated with hatching rate & PL survival rate, and hatching rate positively correlated with nauplius production rate and PL survival rate, revealing that high production rate of nauplius will lead to good hatching rate and further good larval survival in the hatchery (table, 3.1.1). Spawning frequency and egg production rate are spawner dependent and heritable from parent. Maheswarudu et al. (1996) studied the reproductive performance of *P. indicus* in a recirculation system for prolonged period, and reported that spawning frequency, egg production rate and nauplius production rate are spawner dependent, and reproductive performance varies from spawner to spawner. Similar results were also reported in *P. semisulcatus* (Radhakrishnan et al., 2000; Vineetha, 2001).

*4.1.1.3*

Ibarra et al. (2007) suggested that the multiple spawning capacity of a female penaeid shrimp is a trait which is measured as reproductive indicator (Emmerson, 1980; Bray et al., 1990; Palacios et al., 1999). Multiple spawning trait inherits to off spring from parents, hence reproductive performance varies from spawner to spawner. Arcos et al. (2004) estimated heritabilities for egg diameter and egg number in *P. vannamei* and suggested that these traits can be selected through selective breeding programme to improve reproductive out come from female shrimps. Multiple spawning capacity, production of egg number and egg diameter together associated with one trait or independently heritable as different traits is not known. However, reproductive performance in penaeid shrimps is a trait and it is heritable. In the present study, variation in egg production and nauplius production rates, found to be spawner dependent, suggests that it is necessary to develop captive brood stock of commercially important species of penaeid shrimps with high reproductive performance as a trait, to achieve multiple spawnings from same batch of brood stock and to produce more number of eggs and subsequent nauplii which in turn reduce the expenditure on procurement of less productive brood stock.

*4.1.1.4*

Egg production rate, nauplius production rate, hatching rate and PL survival rate are successively correlated, indicating that high egg production rate leads high PL survival rate. This is suggesting that eggs that are spawned with high production rate only can be selected for further larval rearing in the hatchery to achieve high PL survival.

*4.2 Grow-out culture*

*4.2.1 Water parameters*

In the present study, pond water salinity ranged from 25.45±5.5 to 33.5±1.62 ppt during the three years of farming. Raj and Raj (1982) conducted experiments on survival and growth of *P. semisulacatus* at different salinities and reported that optimum salinity was from 15 to 25 ppt in Indian waters. Whereas Soyel and Kumlu (2003) reported that optimum salinity for *P. semisulcatus* was 40 ppt at 28° C in Mediterrean waters, suggesting difference in optimum salinity between Indian strain and Medeterrean strain of *P. semisulcatus* is strain specific. Both of these two experiments were conducted in small containers during nursery rearing. Maheswarudu et al., 1997 conducted nursery rearing of *P. semisulcatus* in grow out ponds (400 $m^2$) at two different stocking densities, ie, 40,000/ha and 50,000/ha for 110 days and found growth was low in the salinities less than 12 ppt. The salinity range of present study is above 25 ppt, a little above the optimum salinity (Raj and Raj, 1982).

*4.2.2 Production rate, survival rate and FCR*

*4.2.2.1*

In Turkey, for *P. semisulcatus*, high production (2880 kg/ha) was reported at high stocking density (20/$m^2$) with 77% survival after 150 days of culture period. The harvested size was at 18.72 g with 2.26 FCR (Turkmen, 2007). The culture operation was conducted with provision of paddle aerators and daily water exchange at 5-20%. In the present study though the shrimp attained similar size at harvest, production is low due to low density culture as well as low survival at 10/$m^2$ stocking density. The FCR reported by Turkmen (2007) is similar to the FCR of present study at 10/$m^2$ density. Turkmen (2007) stocked the pond using post larvae from different spawners whereas in the present study each pond was stocked with post larvae from same progeny. In grow-out culture production and FCR are dependent on the growth performance of the seed. It is evident from the table, 3.2.2.1 that growth is spawner dependent and production is varied accordingly.

*4.2.2.2*

After 145 days in grow-out culture survival rate has negatively correlated with stocking density, revealing that low density culture yielded higher survival rate and high density culture yielded low survival rate. Survival in grow-out culture is dependent on availability of dissolved oxygen and also affected by the accumulation of ammonia and nitrite in the pond water caused by the fecal matter deposition of shrimp. Low survival at high stocking density may be attributed to water quality. Because same rate of water exchange was provided at both densities (5-6/$m^2$ and 10/$m^2$) except provision of paddle wheel aerator at 10/$m^2$ density. Williams et al. (1996) conducted culture trials at different densities in a closed recirculation system for *P. vannamei* and *P. setiferus* and reported inverse relation between stocking density and survival for both species. Araneda et al. (2008) also reported in verse relation between stocking density and survival in *P. vannamei*.

*4.2.2.3*

In grow-out culture stocking density positively correlated with FCR and inversely correlated with dissolved oxygen and total length. High stocking density resulted in high values of FCR (low conversion of food) due to low survival at high stocking density that lead to low conversion of food. Stocking density inversely correlated with total length is due to low growth at high stocking density. Stocking density inversely correlated with dissolved oxygen is due to high biomass of shrimp at high stocking density that demand more dissolved oxygen.

*4.2.2.4*

In grow-out culture weight of harvested shrimp inversely correlated with production rate. Production rate is dependent on growth performance of shrimp and poor growth yield low production rate.

*4.2.3 Growth*

*4.2.3.1*

In grow –out culture total length and weight of all nine progenies significantly correlated with duration of culture period, suggesting that growth of all progenies has progressed during 145 days of farming. Similar correlations were reported earlier for *P. semisulcatus* (Seidman and Issar, 1988). However, correlations (r2 value) vary from progeny to progeny, suggesting existence of growth variation between progenies.

*4.2.3.2*

In grow-out culture growth in terms of total length and weight did not correlate with hatchery parameters, but total length inversely correlated with stocking density. However, significant intra variation in growth performance was recorded in each density trial, which is indicating that growth in shrimp is spawner dependent. Each progeny performed growth differently, indicating that

**Table 4.2.4.1:** Comparision of grow-out culture details of present study with those of Israel and Turkey

| Parameter/ Country with reference | Israel (*Samocha and Lewinshon, 1977*) | Israel (*Samocha and Lewinshon, 1977*) | Israel (*Seidman and Issar, 1988*) | Israel (*Seidman and Issar, 1988*) | Israel (*Seidman and Issar, 1988*) | Israel (*Seidman and Issar, 1988*) | Israel (*Seidman and Issar, 1988*) | Israel (*Seidman and Issar, 1988*) | Israel (*Seidman and Issar, 1988*) | Israel (*Seidman and Issar, 1988*) | Turkey (*Turkmen,2007a*) | Turkey (*Turkmen,2007*) | India (*present study*) | India (*present study*) | India (*present study*) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Pond area (ha) | 0.15 | 0.15 | 0.15, 0.19 & 0.45 | 0.15, 0.19 & 0.45 | 0.15, 0.19 & 0.45 | 0.15, 0.19 & 0.45 | 0.15, 0.19 & 0.45 | 0.15, 0.19 & 0.45 | 0.15, 0.19 & 0.45 | 0.15, 0.19 & 0.45 | 0.1 | 0.2 | 0.25 | 0.25 | 0.25 |
| 2.Stocking density (No/$m^2$) | 3 | 0.5 | 17 | 21 | 22 | 31 | 16 | 30 | 31 | 31 | 15 | 20 | 5 | 6 | 10 |
| 3. Stocking seed size (g) | 0.01 | 0.01 | 2.72 | 9.45 | 1.52 | 2.52 | 8.58 | 8 | 8.7 | 7.1 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| 4. Survival rate (%) | ------ | ------ | 107 | 81 | 59 | 41 | 87 | 97 | 109 | 92 | 79 | 77 | 69.0-96.9 | 85.0-98.5 | 58.4-62.5 |
| 5. Duration of culture (days) | 100 | 164 | 43 | 95 | 92 | 91 | 105 | 140 | 135 | 134 | 150 | 150 | 145 | 145 | 145 |
| 6. Harvested weight of shrimp (g) | Male-6.5; Female-11.7 | Male ,8.8-25.8; Female, 10.4-47.7 | 9.45 | 21.5 | 8.79 | 8.44 | 21.5 | 25.6 | 22.1 | 24.2 | 16.46 | 18.72 | 14.28-18.78 | 10.2-17.5 | 13.2-17.6 |
| 7. Production rate (kg/ha) | ---- | ----- | 1615 | 3943 | 1755 | 2413 | 3000 | 7439 | 7451 | 7034 | 1950 | 2880 | 436-702 | 599-892 | 800-1069 |
| 8. FCR | Without feed | Without feed | 2.3 | 4.2 | 3.5 | 3.4 | 4 | 3.1 | 3 | 3.3 | 2.42 | 2.26 | 1.9-2.0 | 1.96-2.01 | 2.45-2.6 |

growth is a trait and it is heritable from parent stocks. Browdy (1998), in his review, suggested that growth in shrimp and prawn has been shown to be heritable (Malecha et al., 1990; Lester and Lawson, 1990; Wyban, 1992; Gjedrem and Fimland, 1995; Benzie, 1995). In shrimp culture, farmers are frequently encountering stunted growth and the present study revealed that stunted growth is related to growth trait acquired from spawner. Thus the present study is recommending that stunted growth in grow-out culture can be solved by developing captive brood stock of penaeid shrimp with superior growth as a trait.

*4.2.4 Comparisons of results of present study with those of Israel and Turkey*

Different parameters and findings of the present study are compared with those of grow-out cultures of Israeli and Turkey and presented in table 4.2.4.1. Samocha and lewinshon (1977) has reported that low density culture (0.5/$m^2$) in Israel has produced larger harvested size while Seidman and Issar (1988) in the same country reported that high density culture yielded larger harvested size and high production rate by stocking larger juveniles in grow –out culture. Stocking size of seed and duration of culture of present study are similar to those of Turkey (Turkmen, 2007; 2007a). Survival rate, harvested size and FCR are comparable between these two studies.

*4.2.5. Comparison of grow-out performance with P. monodon and P. vannamei*

In the present study the production rate at 10/$m^2$ density ranged from 800 to 1069 kg/ha with survival rate ranging from 58.4 to 62.5% and the harvested size varied from 13.2 to 17.6 g. The FCR ranged from 2.45 to 2.6. In other culture trial with *P. monodon*, carried out in a similar pond with same stocking density in the same farm the production rate was 3.5 t/ha with 95% survival. The harvested weight of shrimp was 37.0 g. and FCR was 1.8 (un published data). Valdes et al. (2012) reported production rate for *P. vannamei* as 1.35 t/ha after 90 days of culture period at a stocking density of 15/$m^2$ with 90% survival and the harvested size was 9.5g. with 2.71 FCR.

In *P. semisulcatus* FCR was low to that of *P. monodon* due to fast growth in *P. monodon*. Economics in grow-out culture are dependent on FCR and size of harvested shrimp as more than half of the production cost is for feed and larger sized shrimp fetches high price than small sized one. Though FCR of *P. semisulcatus* is comparable to that of *P. vannamei*, latter fetches high survival and faster growth at high stocking density, compared to former. Because of all these farmers prefer *P. vannamei* and *P. monodon* for grow-out culture. However, advantage of *P. semisulcatus* over other two species is that, it is less vulnerable to WSSV (Maheswarudu and Josileen jose, 2008). *P. semisulcatus* being small in size and more sturdy, compared to *P. monodon*, is also suitable for live shrimp trade. Of late, demand is increasing for live fish trade especially for major carps in India. Green tiger shrimp is most suitable for live shrimp trade in domestic markets/ export which fetch high price than that of frozen product. More studies are required on these lines to standardize the methods for the live shrimp trade of *P. semisulcatus*.

**Limitations**

Though the present study is aimed to establish correlations between hatchery parameters (such as hatching rate and PL survival rate) and grow-out culture parameters (such as survival rate and FCR), in view of selecting appropriate seed in the hatchery for successful grow-out culture, it has not yielded as expected, revealing that hatching rate and PL survival rate have no effect on grow-out parameters such as survival rate and FCR. However, further studies are required to explore possibilities to establish correlations between hatchery parameters and grow-out parameters.

**Recommendations**

1. High egg production rate lead to high PL survival rate passing successively through high nauplius production rate and high hatching rate, suggesting that nauplii that hatches out from high egg production rate can be selected to achieve high PL survival rate that enhance profits in the hatchery.

2. The present study suggests that egg production rate, nauplius production rate are spawner dependent and this trait can be selected in selective breeding programme to produce captive brood stock of penaeid shrimps to reduce expenditure on less productive brood stock.

3. The present study also suggests that growth in grow-out culture is spawner dependent and this trait can be selected in selective breeding programmes of penaeid shrimps for development of captive brood stock with superior growth as a trait and this issue

addresses the stunted growth in grow-out culture, which farmers are frequently being encountered, to improve economics.

4. *P. semisulcatus* is less vulnerable to white spot syndrome virus, less compatible to high density culture, small in size and more sturdy, compare to *P. monodon* and *P. vannamei*. As growth of *P. semisulcatus* has not much progressed after 120 days, grow-out culture can be restricted to 120 days where salinity prevails above 25 ppt and economics can be improved by encouraging live trade of shrimp in local market/export.

## Conclusion

In conclusion the present study reveals the following results.

1. In the hatchery small sized spawners are performing in terms of egg production rate better than large sized spawners.

2. High egg production rate lead to high PL survival rate passing successively through high nauplius production rate and high hatching rate.

3. In grow –out culture total length and weight of all nine progenies significantly correlated with duration of culture period, suggesting that growth has progressed during culture period.

4. In grow-out culture high stocking density yielded low survival rate and high FCR values (Low Food Conversion Ratio).

5. In grow-out culture growth in terms of total length and weight significantly varied between densities and within each density trial, indicating that growth is spawner dependent and each progeny performed differently irrespective of stocking density.

6. The present study suggests that egg production rate, nauplius production rate are spawner dependent.

7. The present study also suggests that growth in grow-out culture is spawner dependent.

## Acknowledgement

The authors are grateful to Dr. M. Devaraj, former Director, CMFRI for providing facilities and guidance at appropriate time. The authors also thankful to Dr. A. Gopalakrishnan, present Director of CMFRI for encouragement. We extend our thanks to technical assistance rendered by A. Ramakrishanan and A. Vairamani during the present study.

## Author's Contribution and Competing Interests

The Corresponding author (G.M1) has designed the work plan and carried out the work in the hatchery as well in the grow-out ponds. The contributing authors (J.J. 2, S.M. 3 and M.R.A.4) have associated with the corresponding author in the hatchery as well as in the grow-out culture. Data analysis and manuscript preparation was done by the corresponding author (G.M1). The contributing author (J.J.2) has reviewed the manuscript. The authors are not competing for financial interest.

## References

Ameeri A.A.Al., Cruz E.M., 2006. Production and yield of *Penaeus semisulcatus* (de Haan) cultured at different densities. Aquaculture Research, 37, 1499-1506.

Araneda M., Perez E.P., Leyva E.G., 2008. White shrimp *Penaeus vannamei* culture in fresh water at three densities: condition state based on length and weight. Aquaculture, 283, 13-18.

Arcos G.F., Racotta I.S., Ibarra A.M., 2004. Genetic parameter estimates for reproductive traits and egg composition in Pacific white shrimp *Litopenaeus vannamei*. Aquaculture, 236, 151-165.

Benzie J.A.H., 1995. Genetics in the domestication of the giant tiger prawn *Penaeus monodon* in Australia. Book of Abstracts, Aquaculture '95. World Aquaculture Society, Baton Rouge, LA, USA, p.61.

Bray W.A., Lawrence A.L., Lester L.J., 1990. Reproduction of eyestalk-ablated *Penaeus stylirostris* fed various levels of total dietry lipids. Journal of World Aquaculture Society, 21, 41-52.

Browdy C.L., 1998. Recent developments in penaeid broodstock and seed production technologies: improving the outlook for superior captive stocks. Aquaculture, 164, 3-21.

Emmerson W.D., 1980. Induced maturation of prawn *Penaeus indicus*. Marine Ecology Progress Series, 2,121-131.

FAO, 2012. The state of world fisheries and aquaculture (SOFIA).

FAO, 2012 a. Cultured aquatic species information programme. In: FAO Fisheries and Aquaculture Department.

http://www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en. [Cited on 18 August 2012].

Gjedrem T., Fimland E., 1995. Potential benefits from high health and genetically improved stocks. In: Browdy C.L., Hopkins J.S., (Eds.), Swimming through trouble water, Proceedings of the special session on shrimp farming, World Aquaculture Society, Baton Rouge, LA, USA, pp.60-65.

Holthuis L.B., 1980. FAO Species Catalogue. Shrimp and prawns of the world. Annotated catalogue of species of interest to fisheries. FAO Fish Symposium, Vol, 1, No. 125, FAO, via delle Terme diCaracalla, Rome 00100, Italy.

Ibarra A.M., Racotta I.S., Arcos F.G., Palacios E., 2007. Progress on the genetics of reproductive performance in penaeid shrimp. Aquaculture, 268, 23-43.

Lester L.J., Lawson K.S., 1990. Inheritance of size as estimated by principal component analysis at two temperatures in Penaeus vannamei. Aquaculture, 85, 323.

Maheswarudu G. Sampson Manickam P.E., Rao P.V., Arputharaj M.R., Muniyandi K., 1994. Some aspects of biology and exploitation of the green tiger prawn, *Penaeus (Penaeus) semisulcatus* de Haan from Mandapam (Palk Bay) and Pamban (Gulf of Mannar), southeast coast of India. Indian Journal of Fisheries, 41(2) 55-64.

Maheswarudu G., Radhakrishnan E. V., Pillai N. N., Arputharaj M. R., Ramakrishnan A., Mohan S., Vairamani A. 1995. *Penaeus semisulcatus:* A potential species for commercial culture along Tamilnadu coast. Fishing Chimes, 15(1) 81-83.

Maheswarudu G., Radhakrishnan E. V., Pillai N. N., Mohan S., Arputharaj M. R., Ramakrishnan A., Vairamani A. 1996. Repetitive spawning of *Penaeus indicus* without eyestalk ablation, hatching rate and growth upto juveniles. Fishing Chimes, 16(3) 21-23.

Maheswarudu G., Radhakrishnan E. V., Pillai N. N., Arputharaj M.R., Ramakrishnan A., Mohan S., Vairamani A., 1997. Observations on the growth of *Penaeus semisulcatus* in the nursery ponds. Journal of the Marine Biological Association of India, 38(1 & 2) 63-67.

Maheswarudu G., Jose J., 2008. A preliminary trial on polyculture of three Indian penaeid shrimps. Journal of the Marine Biological Association of India, 50(1) 38-42.

Malecha S.R., Masuno S., Onizuka D., 1990. The feasibility measuring the heritability of growth pattern variation in juvenile fresh water prawns *Macrobrachium rosenbergii* (De Man). Aquaculture, 38, 347-363.

Manickam P.E.S., Maheswarudu G., Pillai N.N., Arputharaj M.R., Rao P.V., 1997. Observations on complete and partial spawning and related seed production in *Penaeus semisulcatus*. Journal of the Marine Biological Association of India, 38 (1 & 2), 97-100.

Nandakumar G., 1982. Experimental prawn culture in coastal ponds at Mandapam camp. In: Proceedings of the Symposium on Coastal Aquaculture, Part 1, MBAI, 12-18 January 1980, Cochin, India,103-111.

Palacios E., Racotta I.S., APSA., 1999. Spawning frequency analysis of wild and pond reared shrimp *Penaeus vannamei* brood stock under large-scale hatchery conditions. Journal of World Aquaculture Society, 30, 180-191.

Radhakrishnan E.V., Maheswarudu G., Arputharaj M.R., Ramakrishnan A., 2000. Repetitive maturation and spawning of the green tiger prawn *Penaeus semisulcatus* by environmental regulation in closed seawater recirculation systems. Journal of the Marine Biological Association of India, 42 (1 & 2) 91-100.

Raj P.R., Raj P.J.S., 1982. Effect of salinity on growth and survival of three species of penaeid prawns. Proceedings of Symposium on Coastal Aquaculture, 1, 236-243.

Rao G., Subramanian T.V., Rajamani M., Sampson Manickam P.E., Maheswarudu G., 1993. Stock assessment of *Penaeus* spp. off the east coast of India. Indian Journal of Fisheries, 40(1&2) 1-19.

Samocha T., Lewinsohn C., 1977. A Preliminary report on rearing penaeid shrimps in Israel. Aquaculture, 10, 291-292.

Scordella G., Zecca P., 2002. Shrimp farming in Italy: Status and Perspectives. Global Aquaculture Advocate, August, 51-52.

Siedman E.R., Issar G., 1988. The culture of *Penaeus semisulcatus* in Israel. Journal of World Aquaculture Society, 19: 237-245.

Soyel H.I., Kumlu M., 2003. The effect of salinity on postlarval growth and survival of *Penaeus semisulcatus* (Decapoda: Penaeidae). Turkish Journal of Zoology, 27, 221-225.

Turkmen G., 2007. Field report, Experimental commercial grow-out of *Penaeus semisulcatus* (Decapoda: penaeidae). The Israeli Journal of Aquaculture-Bamidgeh 59(1) 52-57.

Turkmen G., 2007a. Pond culture of *Penaeus semisulcatus* and *Marsupenaeus japonicas* (Decapoda, Penaeidae) on the west coast of Turkey. Turkish Journal of Fisheries and Aquatic Sciences 7, 7-11.

Valdes R.C., Arjona E., Bueno G., 2012. Feeding rate and stocking density in semi-intensive Lito *penaeus vannamei* culture with moderate periodic

fertilization. ARPN Journal of Agricultural and Biological Science, 7(11) 899-904.

Vineetha A., 2001. An evaluation of the intertidal oligochaete Pontodrilus bermudensis Beddard as dietary supplement for stimulation of reproduction in *Penaeus semisulcatus* De Haan. Ph. D. Thesis, Central Institute of Fisheries Education, Mumbai, India, 156 pp.

Williams A.S., Davis D.A., Arnold C.R., 1996. Density-dependent growth and survival of *Penaeus setiferus* and *Penaeus vannamei* in a recirculation system. Journal of World Aquaculture Society, 27(1), 107-112.

Wyaban J.A., 1992. Selective breeding and specific pathogen free (SPF) shrimp for high health and increased growth. In: Fulks, W., Main, K.L. (Eds.). Diseases of cultured penaeid shrimp in Asia and the United States. Oceanic Institute, Honolulu, HI, USA, 257-268.