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Growth and production performance of Pacific white leg shrimp *Litopenaeus vannamei* (Boone, 1931) in low stocking short term farming in earthen pond conditions

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ABSTRACT

Higher input costs involved in intensive farming of *Litopenaeus vannamei* drive back the small and marginal farmers from venturing into shrimp farming. The production potential and performance of the species was evaluated in low stocking short term farming in earthen pond conditions. Details from five crops with varying stocking densities, crop period and seasons were analysed to evaluate performance of the species. At higher stocking rates the shrimp yielded better production. The present report indicates better performance of the species in summer season. Interestingly all the observations point towards the fact that final harvest size depends on stocking density (SD), as well as days of culture (DOC) and it was observed that the minimum DOC to get a size of 20 g is around 80 days at SDs below 30 m^{-2}. The economic returns increased with increase in SD and DOC. Overall results imply that at any given SD, the economic returns per kg will be minimal till 80 DOC (approximately 20 g harvestable size) at stocking density less than 30 m^{-2}. The study confirms that for small and marginal farmers, *L. vannamei* farming can be made profitable at a shorter culture period (up to 80 days) adopting lower affordable stocking rates.

Keywords: *Litopenaeus vannamei,* Low intensive, Production, Short term farming

Introduction

Shrimp farming plays a pivotal role in the socio-economic condition of the coastal population of India by way of contributing to foreign exchange earnings and livelihood options. Recently there was a marked shift from farming of indigenous black tiger shrimp, *Penaeus monodon* to the culture of exotic white leg shrimp, *Litopenaeus vannamei* in the shrimp farming sector in India, following the successful introduction of the later.

L. vannamei is the most widely cultured shrimp in the western hemisphere where the species contributes to about 90% of the total shrimp culture (Wurmann *et al.,* 2004). The species was introduced in India for the first time during 2008 (CAA, 2010) and then onwards the production of this species surpassed production of *P. monodon* owing to its faster growth, compatibility to higher stocking rate, less disease risk, euryhaline as well as eurythermic nature, lower dietary protein requirement and lower feed conversion ratio (FCR). Coastal Aquaculture Authority of India (CAA) recommended a stocking rate of up to 60 m^{-2} (CAA, 2010) and majority of the farmers are following such high stocking rates. But many of the marginal farmers in India are not able to afford such high stocking rate in shrimp farming due to the huge operational cost involved, since previously they were following only modified extensive (less than 10 SD) and semi-intensive (less than 20 SD) farming practices for *P. monodon* (Laureatte *et al.,* 2012). In this backdrop, the present study was undertaken to evaluate the growth and production performance of this exotic species under low stocking, short term farming in order to check its viability so that it can be adopted by marginal farmers.

Materials and methods

Experimental details

The study was carried out at the brackishwater fish farm of Central Institute of Fisheries Education, Kakinada Centre, Kakinada. Five crops of varying stocking densities (SD) with shorter crop durations were undertaken during the period from March 2010 to December 2012 and the details of the crops are given in Table 1. All the crops were taken in uniform sized ponds (0.2 ha) with a water depth of 1.2 m.

Pond preparation

Pond preparation procedures explained in our previous report (Laureatte *et al*., 2012) were adopted for all the crops with slight modifications. Briefly, the ponds were dried for one month and the top soil was scraped and removed, ploughed and filled with pre-chlorinated (12 ppm available chlorine) water from a reservoir pond. The Coastal Aquaculture Authority of India (CAA) guidelines for bio-security measures (CAA, 2010) were adopted for all the five crops.

Specific pathogen free (SPF) post-larvae of *L. vannamei* (PL 10) were procured from CAA approved hatcheries and stocked in the ponds at varying SD (Table 1). Aerators were deployed in each pond according to the SD of the pond at the rate of one paddle wheel aerator (1 HP motor) for 1 lakh PL. A good quality (32% protein) commercial feed was provided 4 times (06.00 hrs, 11.00 hrs, 17.00 hrs, 22.00 hrs) by broadcasting from a boat as per the feeding schedule given by the feed manufacturer. Check trays were used to monitor feed consumption after 2 h of feed application. Zero water exchange was adopted in the farms and the evaporation losses were replenished with pre-chlorinated water from the reservoir ponds.

Water quality assessment

The physico-chemical parameters such as temperature (^{0}C), pH, dissolved oxygen (ppm) and salinity (ppt) were measured daily at 08.00 hrs in the morning and total alkalinity was analysed at weekly intervals following standard methods (APHA, 1998). Nitrite (NO_2^-) and ammonia nitrogen (NH_3-N) levels were analysed spectrophotometrically at 10 days intervals (Thermo Spectra, USA) following standard procedures (APHA, 1998).

Analysis of growth performance

To evaluate the growth performance, 50 shrimps were sampled weekly from each pond starting from 30th day of culture (DOC) using a cast net. Weight of the shrimps was measured using a top loading balance with an accuracy of 0.1 g.

The ponds were completely drained out and the shrimps were harvested after the desired DOCs. Total production, survival rate and final harvest size in each pond were assessed at the time of harvest. Total feed consumed and the FCR were calculated based on the feeding rates. Statistical analysis (paired t- test) was performed using the statistical software SPSS version 16.

Economic analysis was done following Balasubramanian *et al.* (2004). For this, fixed cost was calculated based on the lease amount prevailing in Andhra Pradesh, for 1 ha pond. A uniform price of ₹0.4 per seed was assigned for calculating the seed cost and the feed was costing ₹40 per kg. Manpower requirement was calculated based on the fact that ₹100 per day was spent for daily monitoring and ₹2000 was employed to harvest 1 ha pond. An approximate cost of ₹20 was assigned as cost of electricity and diesel for producing 1 kg of shrimp. The values were then converted into US dollar by assigning a value of ₹46 for 1 US dollar.

Table 1. Harvest details of different crops of *L. vannamei*

Crop	Duration (Season)	Stocking (PL m^{-2})	n	DOC	Harvest size (g)	Production (t ha^{-1})	Survival (%)	FCR
1	March – May 2010 (summer)	10	2	73	17.4*	1.42 ± 0.18*	81 ± 2*	1.4*
		20	2	74	17.1*^{a}	2.87 ± 0.35*^{a}	84 ± 0.1*^{a}	1.32*^{a}
2	August – October 2010 (post-summer)	20	2	81	19.75^a	3.68 ± 0.19^a	93 ±2.5^a	1.2^a
3	May –July 2011 (summer)	30	2	78	19.0	5.54 ± 0.25	97 ± 0.3	1.15
		30	1	83	19.23	5.66	98	1.3
		30	1	88	20	5.89	98	1.3
4	October- December 2011 (winter)	30	1	58	9.4	2.70	95	1.3
5	September-December 2012 (winter)	25	2	92	20	4.93	98.5	1.19

Values bearing same superscripts within a column differ significantly ($p<0.05$) in the paired t-test. (* and ^{a} indicate differet pairs)

Table 2. Physico-chemical parameters of water during different crops

Parameter	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5
Temperature (^{0}C)	24 -35	22 – 31.5	24 – 34	22 – 30.5	23 -31
pH	8.1 – 8.5	8.1 – 8.5	8 – 8.5	8.3 – 8.5	8.1 -8.5
Dissolved oxygen (ppm)	3.6 – 6.2	3.8 – 6	3.6 – 5.6	3.8 – 5.8	3.6 – 5.0
Salinity (ppt)	22 - 30	11 - 18	10 - 16	7 – 11	8 - 13
Total alkalinity (ppm)	188 - 212	186 - 220	180 - 300	166 - 206	184 - 234
Nitrite – N (ppm)	0.016 –0.028	0.01 – 0.32	0.01 – 0.35	0.013 – 0.18	0.01-0.24
Ammonia – N (ppm)	0.01 – 0.04	0.01 – 0.16	0.01 -0.48	0.01 – 0.40	0.01-0.26

Results and discussion

Physico-chemical parameters of water recorded during different crops are given in Table 2. All the parameters were within the favourable range required for white leg shrimp farming except temperature. Temperature fluctuated considerably in different seasons from 22^{0}C to 35^{0}C. pH of the pond water was always within the optimum range (6.6 - 8.5) recommended for shrimp farming (Tsai, 1990). Dissolved oxygen values were well above the minimum requirement (3.5 ppm) for shrimp farming (Boyd and Arlow, 1992; Gicos, 1993). The alkalinity levels were above the requirement given by Boyd *et al.* (2002). Variation in salinity in the present study appears to play only minimal role in the growth and survival of *L. vannamei*, as Araneda *et al.* (2008) reported successful production of *L. vannamei* even in freshwater systems. Nitrite–N level in water was well below the toxic limits reported for this species by Lin and Chen (2003). Ammonia-N was also within the tolerance limit reported by Lin and Chen (2001). Altogether the water quality parameters were not varying substantially during the entire study period nullifying their influence on the performance of the species except in the case of temperature which varied from season to season.

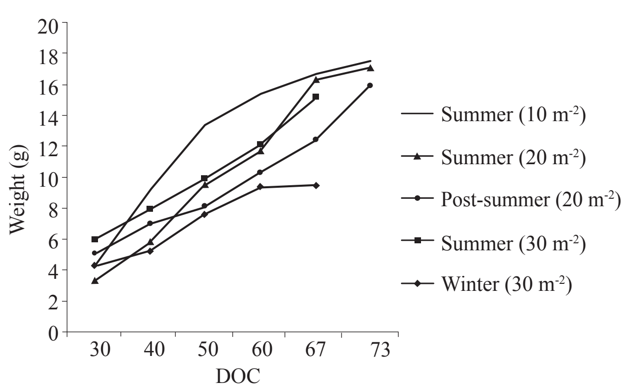

Fig 1. Growth performance of the shrimps at different seasons and stocking densities

Growth pattern of *L. vannamei* at different SD and seasons are given in Fig. 1. It is obvious that lower stocking rates gave better growth. Previous studies also indicated that as the stocking density increases the individual growth of white leg shrimp decreases (Appelbaum *et al.,* 2002; Samocha *et al.,* 2004; Araneda *et al.,* 2008).

Temperature plays a major role in the growth performance of penaeid shrimps especially in *L. vannamei* (Wyban *et al.,* 1995; Araneda *et al.,* 2008). *L. vannamei* grows at slower rate at temperatures below 22^{0}C (Araneda *et al.,* 2008). Wyban *et al.* (1995) reported that the growth rate increases with increase in temperature as they assessed the growth at 23, 27 and 30^{0}C. Growth performance of the shrimp at two differnt seasons such as summer (March – May; temperature 22 to 31.5^{0}C) and post-summer (August to October; temperature 24 to 35^{0}C) at a stocking density of 20 m^{-2} were drawn from the first and second crops, where the growth rate was only marginally higher in the summer season. Shrimps reached a body weight of 17 g at 73 DOC during summer but in post-summer, shrimps attained only 15.8 g on 75 DOC. Similarly growth performance of shrimps during two differnt seasons *viz*., summer (May – July; temperature 24 to 34^{0}C) and winter (October – December; 22 to 30.5^{0}C) at a stocking density of 30 m^{-2} drawn from the third and fourth crops, indicated significantly ($p<0.05$) higher growth during the summer in comparison with the winter season. Shrimps reached 12 g at 54 DOC in summer when compared to 9.4 g in winter. The present results clearly indicate better performance of white leg shrimp in summer compared to winter and post-summer crops under tropical earthen pond conditions.

Harvest details (Table 2) of different crops of *L. vannamei* cannot be compared as a whole since the stocking density and DOC varies considerably. However the results can be compared among different crops. During the first crop, SD of 20 m^{-2} showed significantly higher ($p<0.05$) production and FCR compared to the SD of

10 m^{-2}. Final harvest size increased significantly ($p<0.05$) at lower SD. Production details of the first crop indicate that the higher stocking densities yield higher production. Previous studies also indicate that as the stocking density increases the shrimp production also increase accordingly (Appelbaum *et al.,* 2002; Samocha *et al.,* 2004; Araneda *et al.,* 2008).

Final harvest size increased significantly ($p<0.05$) when the DOC increased from 74 days in the first crop to 81 days in the second crop at SD of 20 m^{-2}. The final weight of shrimp was directly related to duration of cultivation and inversely related to stocking density (Ruiz-Velazco *et al.,* 2010). But, during the third crop (at 30 m^{-2}) the harvest size did not increase considerably among the different harvests when the shrimps were harvested at 5 days interval from 78 DOC. During the fourth crop (winter crop) at an SD of 30 m^{-2}, only 9.4 g size could be achieved at 58 DOC and it affected the total production. These results combined with the growth rates indicate that *L. vannamei* after attaining a particular size (around 19 g) undergoes slower growth rates. These results are further confirmed in the fifth crop wherein the shrimps grew only up to 20 g even after 92 DOC at a SD of 25 m^{-2}. All these observations point towards the fact that the final harvest size depends on SD as well as DOC and thus the harvestable size of 20 g can be achieved at a minimum DOC of around 80 days at SDs less than 30 m^{-2}. A harvest size of 17 to 19 g can be considered as the marketable size for *L. vannamei* (Green, 2008). In the present study, parameters such as survival, FCR and production varied considerably, because in pond condition these parameters depend on a number of environmental conditions including natural productivity and nutrient cycles. Sookying *et al.* (2011) also reported similar observations in *L. vannamei* farming trials in ponds.

Details of economic returns from various crops are given in Table 3. Economic evaluation in the present study is not an exclusive analysis even though majority of the fixed and variable costs are incorporated. During the first as well as second crop, SD of 20 m^{-2} gave almost 3 times higher return than 10 m^{-2} but the returns per kg production did not show much increase. During the third crop, shrimps were stocked at a SD of 30 m^{-2} and harvested at different DOC at five days intervals. Even though the highest return was obtained for higher DOC, the returns per kg did not vary considerably among different DOC. Sookying *et al.* (2011) also reported that there was no significant variation in partial returns at different SDs of *L. vannamei* in pond trials. Fourth crop suffered economic losses revealing that at lower SD for a shorter DOC the farming will not be profitable. Overall results implies that at any given SD, the economic returns will be minimal till 80 DOC (approximately 19 g harvest size) and even if the culture prolongs, the economic returns per kg will not vary considerably. This may be due to the fact that economics of shrimp farming mainly depends on the operational costs such as seed and feed (Griffin *et al.,* 1985). As DOC increseases, the operational costs towards feed, manpower and electricity increase rapidly, but the harvest size will not increase considerably. The study confirms that for small and marginal farmers *L. vannamei* farming can be made profitable at a shorter culture period of less than 80 days adopting even a lower affordable stocking rate of less than 30 m^{-2}.

Table 3. Partial evaluation of economic returns from different crops (Returns ha^{-1} crop^{-1} in US$)

Crop	SD	DOC	Fixed and variable costs						Total cost	Revenue	Net Return	Return kg^{-1}
			Fixed cost	Seed	Feed	Power + Diesel	Manpower	Others				
1	10	73	652	870	1729	617	202	391	4461	5557	1096	0.77
	20	74	652	1739	3294	1248	204	391	7529	11230	3701	1.29
2	20	81	652	1739	3840	1600	233	391	8455	17600	9145	2.48
3	30	78	652	2609	5540	2409	220	391	11820	26496	14676	2.65
	30	83	652	2609	6398	2461	215	391	12727	27070	14343	2.53
	30	88	652	2609	6658	2561	224	391	13095	28170	15075	2.56
4	30	57	652	2609	3052	1174	235	391	8113	7043	-1070	-0.4
5	25	92	652	2174	5101	2143	176	391	10638	23578	12940	2.62

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