

Growth performance of *Macrobrachium rosenbergii* in nursery and growout systems

Thesis submitted in part fulfilment of the requirements for the Degree of Doctor of Philosophy in Aquaculture to the Tamil Nadu Veterinary and Animal Sciences University, Chennai.

By

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CERTIFICATE

This is to certify that the thesis entitled “**Growth performance of *Macrobrachium rosenbergii* in nursery and growout systems**” submitted in part fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** (Fisheries Science) in Aquaculture to the Tamil Nadu Veterinary and Animal Sciences University, Chennai, is a record of bonafide research work carried out by **Tmt. S. Balasundari**, M.F.Sc., DPF01002 (AQC) under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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***Dedicated to
My family and my teachers***

ABSTRACT

Balasundari, S., 2006. Growth performance of *Macrobrachium rosenbergii* in nursery and growout systems. Ph.D., (Dr. M.J. Prince Jeyaseelan).

The farming of giant freshwater prawn, *Macrobrachium rosenbergii* is attracting considerable attention from farmers in India and many South East Asian countries owing to its profitability and its suitability for both monoculture and polyculture. Uneven growth is the main problem and this phenomenon is observed in the larval stage itself. The onset and completion of metamorphosis of larvae to postlarvae takes more than a week and those prawns that metamorphose first continue to grow faster in the postlarval, juvenile and adult stages and dominate in the hierarchy. Based on this viewpoint, the majority of early metamorphosed postlarvae could be males. However, this work has not been done elsewhere and the published information pertaining to this aspect is also lacking in the global scenario. The aim of this study was to determine whether age at metamorphosis could serve as a criterion for the separation of prawns according to high or low growth potential. The effect of age at metamorphosis on growth of prawns grown under monoculture conditions in earthen ponds is here with reported in the present study.

In the first experiment, early settled postlarvae and late settled postlarvae from larger sized berried prawns, early settled postlarvae and late settled postlarvae from smaller sized berried prawns and mixed group of postlarvae from large and smaller sized berried prawns were collected. All the 5 groups were reared separately in nursery for 60 days at a stocking density of 200 PL/m². The growout experiment for all the above five groups were carried out separately in earthen ponds for 120 days at a stocking density of 4 Nos./m². After the growout period, the growth performance and sex ratio were studied for each group. Based on the results of the present study, by stocking the early settled PL obtained from larger sized berried prawns the prawn farming community could increased the present yield by 70.92%.

In the second experiment, the growth rates of blue clawed males, orange clawed males and runts (small males) were studied individually and in combination. The conversion of small male to orange clawed male and orange clawed male to blue clawed male was observed. The conversion of orange clawed males was as high as 90% when orange clawed males were reared in combination with runts. When orange clawed male prawns alone were reared, 98.34% conversion of orange clawed males to blue clawed males was observed. The present finding emphasized the need for periodic culling of blue clawed males from culture system so as to enable the orange clawed males to metamorphose into the blue clawed prawns, thereby enhancing the yield potential.

In the third experiment, the profile of amino acid and fatty acid of runts and larger sized prawns after 120 days of culture was studied. The amino acid and fatty acid profiles of the commercial feed used were also studied. The level of palmitic acid, stearic acid, oleic acid, linoleic acid and arachidonic acid were found to be high in large sized prawns compared to runts. In the case of amino acids, the level of arginine was high in large sized prawns than in runts.

In the fourth experiment, based on these comparative studies, the nutrient requirements, especially the amino acids and fatty acids needed for the improvement of runts were identified. A quality test diet was prepared in a scientific way with 33 ingredients. The profile of amino acids and fatty acids of the experimental feed was also studied. The test diet contained 24.41% of n-6 fatty acid than commercial prawn feed (1.59%) due to the inclusion of safflower oil, which is rich in n-6 fatty acid – linoleic acid. The higher level of n-6 fatty acids than n-3 fatty acids, which is the primary need of freshwater prawn, has been fulfilled in the test diet prepared in the present study.

Feed trials were conducted to evaluate the test diet both in nursery and growout for 60 and 120 days respectively with the mixed group of PL. In the feed trial, performance of the above said experimental feed was compared

with commercial prawn feed. The protein, fat and calorific value of the test diet were 34.31%, 9.38% and 4683.32 calories / g respectively at a moisture level of 4.46%. The survival, FCR and percentage of runts of experimental groups fed with commercial feed and experimental feed was studied. The percentage of runt was relatively less ($9.40 \pm 0.1412\%$) in the case of experimental group fed with test diet prepared in the present study, whereas the experimental group fed with the commercial feed showed relatively higher percentage of runts ($18.25 \pm 1.0605\%$). Hence, the objective of designing the feed to improve the growth of runts was fulfilled and the feed gave good results in the production of larger sized prawns in higher numbers. In addition, in the growout culture, the experimental feed designed in the present study yielded 13.29% higher net prawn production (827.31kg/ha/year) than the internationally renowned commercial feed (730.28kg/ha/year) by improving the growth performance of runts and other morphotypes. The current cost of production of the experimental feed (farm made) was worked out to Rs.34/kg, whereas the market leading prawn feed was available at a cost of Rs.37/kg in the local market. The FCR of experimental feed was 2.43, whereas the value for the commercial feed was 2.55.

INTRODUCTION

The giant freshwater prawn *Macrobrachium rosenbergii* (De Man, 1879) is now in a key position in the aquaculture scenario of the world in general and India in particular. This species now claims the title of most popular crustacean cultured in freshwater, and is second only to the black tiger shrimp, *Penaeus monodon*. Freshwater prawn farming is now a significant and valuable sector of global aquaculture. New (2003) reported that the average annual expansion rate of freshwater prawn farming between 1992 and 2001 was over 29%. Between 1999 and 2001, the global expansion rate was even more rapid (48%). In both periods, freshwater prawn farming was expanding, from a lower base line, very much faster than marine shrimp farming globally. As reported by Sakthivel (2003), out of 44 countries involved in production of scampi in the global arena, India has taken the lead to produce through farming for export and has made substantial progress within the last five years.

Many *Macrobrachium* species have been transferred from their natural habitats to other parts of the world, initially for research purposes. *M. rosenbergii* remains the species most sought after for commercial farming in freshwater and consequently is the one which has been introduced to many countries. Following its import into Hawaii from Malaysia during 1965, the pioneer work of Ling (1969) was translated into a method for the mass production of postlarvae (PL) by Fujimura and Okamoto (1972). Then onwards, it has been introduced into almost every continent for farming purposes. *M. rosenbergii* is now farmed in many

countries; the major producers (>200 tonnes) are Bangladesh, Brazil, China, Ecuador, India, Malaysia, Taiwan and Thailand (FAO 2002). More than thirty other countries reported production of this species during the year 2000. Vietnam is also a major producer, according to New (2000). In addition, there are also valuable capture fisheries for *M. rosenbergii* in Bangladesh, India, and several countries in Southeast Asia.

As per the FAO statistics, global scampi production from aquaculture during 2000 was 1,18,501 tonnes worth US\$ 410 million. This did not include production from countries like India, Vietnam, etc. Scampi production in India crossed 16,600 tonnes in 2000, while Vietnam production crossed 25,000 tonnes in 1998 itself. In other words, the global production of scampi is much more than the 118,501 tonnes recorded by FAO. China is way ahead of other countries in scampi production, with 97,420 tonnes, accounting for 83% of Asian and 82% of global scampi production. Thailand and Taiwan registered decline in production during the second half of 90's, while countries like India, Vietnam and Bangladesh recorded increased production (Bojan and Viswakumar, 2003). As per FAO (2003) statistics the global production of *M. rosenbergii* was 1,80,221 tonnes worth US\$ 6,43,234 and the production in India was 30,500 tonnes worth US\$ 35,870 for the year 2002-2003.

Bojan (2003) reported that the giant freshwater prawn is being sourced through capture and culture fisheries from all coastal states and some inland states of India. It is presently cultured in 34,630 ha area in the country. The average production per hectare is 880 kg with the productivity

ranging from 65 kg in the reservoirs of Maharashtra to 1,250 kg in the highly productive aquafarms of Nellore. It is of interest to note that around 62% of the scampi culture operation have been in Andhra Pradesh, and the Nellore district alone accounted for about 90% of the culture area of the state. In India, scampi production through aquaculture in the last four years increased from 7,140 tonnes in 1999-2000 to 30,500 tonnes in 2002-03. The increase also reflected in the export of scampi from the country, i.e. from 2,676 tonnes of scampi worth Rs. 123 crores to 10,379 tonnes worth Rs. 447 crores during the corresponding period. The development of freshwater prawn farming also promoted the establishment of hatcheries and feed market on a large scale. Initially the production of scampi seeds was restricted to a few hatcheries in Kerala. However, presently 71 hatcheries are operating in various states supplying 1.83 billion scampi seeds to the farmers in India. Similarly, exclusive feed for scampi are produced and marketed by leading manufacturers. The development of scampi aquaculture is not just confined to the coastal states, but made inroads to inland states as well. Scampi culture has now spread to more than 10 districts of Haryana, 2 districts of Bihar, and a district each in Madhya Pradesh, Uttar Pradesh and Punjab. The high cost of seed and feed was a problem in scampi farming. Moreover, the seeds produced from farm reared brooders tend to grow smaller. Supply of good quality seeds with bias towards males, quality feed at low cost, etc. has now increased the optimism among farmers in scampi culture. The future for freshwater prawn farming in India is very bright, in view of the vast resources available in the country and the support extended by various

agencies for its popularization to meet both the domestic and international market demands.

Bojan and Viswakumar (2003) reported that a number of factors favour the development of freshwater prawn farming. Brackishwater shrimp culture has been reeling under the persistent threat of disease outbreaks and resultant crop losses. Freshwater prawn is relatively less disease-prone. Not many diseases have been reported globally in scampi culture, more specifically in its growout stage. It can be successfully cultured in polyculture systems, which provide an opportunity for the fish farmers to increase their production and profit with a little extra cost and at no cost to environment. Possibility of easy sourcing of dedicated brooders from the farms itself, adds one more feather to the factors favouring the development of its culture. Besides, the export potential always works as a driving force for development of scampi culture. They further reported that India is blessed with vast natural resource for scampi culture viz. about 5.4 million ha of freshwater areas including reservoirs (big and small), tanks, ponds and 1,71,334 km of rivers and canals. However, despite excellent prospects, in India scampi culture has not shown considerable progress compared to shrimp farming. This difference in growth is due to some perceived constraints of the prawn compared to the shrimp. The major constraints perceived by the investors are that it does not show uniform growth in growout, as compared to marine shrimps. This causes high variability in production and returns in monoculture practices. Research on

management of morphotypes in commercial growout farms is yet to come out with a practical package to help the farmers.

The authors also added that, in order to build up the investor confidence and induce them to utilize the opportunities offered by this sector, it is essential to transfer the technology to tackle the problems of differential growth rate and low survival rates that are considered as bottlenecks in growouts. New concepts of nursery management, grading while stocking in growout and production system management, etc., need to be inculcated. Along with the improvement in technology and its transfer to the farmers it is also essential to inculcate the concepts of Good Management Practices (GMP) in hatcheries and farms. GMPs are the instruments for ensuring longterm sustainability of the enterprise without any environmental costs.

Prawns are sexually dimorphic as far as growth is concerned. Males grow faster than females. Uneven growth is more prominent among males than in females. This uneven growth phenomenon is seen in the larval stage itself. Onset and completion of metamorphosis of larvae to postlarvae takes more than a week and those prawns that metamorphose first continue to grow faster in the PL, juvenile and adult stages and dominate in the hierarchy (Murthy, 1998).

In *M. rosenbergii* the phenomenon of metamorphosis, i.e. the transition from the free-swimming zoea larvae to a crawling adult-like postlarvae (PL), takes place over a period of 15 days under controlled conditions (Ling, 1969). The aim of this study was to determine whether age at metamorphosis could serve as a criterion for the separation of prawns according to high or low growth potential. Two laboratory studies, which tested the effect of age at metamorphosis on growth of *M. rosenbergii*, generated contradictory results.

Sandifer and Smith (1979) found no difference in the growth of early and late metamorphosing PL raised in containers for a period of 5 months to a mean size of 50 mm in USA. Howlader and Kiortsis (1978) reported that early and late metamorphosed prawns differed in both growth potential and sex ratio. Both studies were carried out in the laboratory on juvenile prawns only, which did not fully express their growth potential. Karplus and Hulata (1990) reported about the effects of age at metamorphosis on population structure and production of *M. rosenbergii* in polyculture ponds. The influence of age at metamorphosis on growth of prawns grown under monoculture conditions in earthen ponds is herewith reported in the present study.

From the commercial point of view of scampi farming, males have a negative effect on females. Under intensive monosex culture of scampi, females grew much better (37%) than the females of a mixed sex population (27%). At the same time, the portion of berried females was 45% in the mixed sex population while in the monosex population the portion was only 13% (Cohen *et al.*, 1981). Similar observations were reported by Sagi *et al.* (1986). Under identical culture conditions, the all male population yielded up to 80% more compared with the mixed sex population. The all female population had doubled the growth in comparison with mixed sex population.

Ahmed and Ramesh (2001) reported that Heterogeneous Individual Growth (HIG) rate is the most prominent characteristic of prawns. For the individuals of the same age, a group of prawns with a mean weight of 20 g will commonly have individuals ranging from 2g to 40g. Within a pond stocked with a single batch of postlarvae, some prawns have been observed to grow 15 to 20 times faster than others. In a typical growout example, after six months of growing, prawns reached an average size of 47.8g, yet ranged from 10 g to 100 g. Since purchase prices of crustaceans are a function of their size, this growth pattern is the most economically important biological characteristic.

In the males, a few morphotypes are seen. Small males (SM) become orange clawed (OC), which are the fastest growing group and the largest OC become blue clawed (BC). BC males cease to grow, but become sexually

aggressive and exhibit territorial behaviour. Hence a lot of variation is seen in the same batch of prawns, which leads to reduced yield at harvest. Discarding the lower fraction after secondary nursing is not profitable due to the high cost of nursing. However, discarding prawns with a low growth potential at an earlier stage may increase profitability that requires tracing at an earlier stage.

To overcome the above mentioned problems, this research work was designed with the following objectives.

Objectives

1. To study the growth performance of early settled and late settled postlarvae obtained from broodstock of two varying sizes in nursery and growout systems;
2. To study the growth of blue clawed males, orange clawed males and runts (small males) individually and in combination to understand the associated behavioural aspects;
3. To study the amino acid profile of runts and large sized prawns after 120 days of culture;
4. To study the fatty acid profile and $n_6:n_3$ ratio of runts and large sized giant freshwater prawns and
5. To formulate and evaluate a feed to find out its suitability for the production of large sized prawns in higher numbers.

REVIEW OF LITERATURE

2.1 BroodStock

2.1.1 Source

In the tropics, berried females of *Macrobrachium rosenbergii* can be obtained round the year from farm ponds containing adult animals and they can also be obtained seasonally from rivers, canals and lakes where they are indigenous. Sureshkumar and Kurup (1998) studied the breeding migration of *M. rosenbergii* in Vembanad Lake and the impact of salinity barrier on migration. They concluded that the differential migration could be discernible with males predominant in the population from April to July and henceforth dominance of females. Occurrence of berried prawns was observed in the lake from June to January with a peak in October.

Mohanta (1999) indicated that healthy broodstock can be developed within six months and can be used for hatchery purpose for two seasons. According to him for dedicated and farm raised broodstock, broodstock development in separate ponds is highly essential in order to choose of large sized berried prawns round the year.

2.1.2 Morphotypic differentiation

Harikrishnan *et al.* (1996) reported the differentiation of various morphotypes in female population of *M. rosenbergii* identical with their male counterparts from the Vembanad lake on the basis of colour pattern. They have reported orange clawed females (OF) and Blue clawed females (BF) that are easily distinguished by the presence of orange and blue colours respectively on merus, carpus and propodus.

2.1.3 Performance of broodstock

Yaakob (1992) observed the growth of *M. rosenbergii* larvae from two sources of breeders, namely pond grown breeders and river breeders. The pond grown breeders might have gone through inbreeding for several generations. The observations were made on 4 cycles of larviculture or both the source of breeders. The culture period (larval cycle) of larvae from pond grown breeders was between 33-35 days compared to larvae from river

breeders, which were observed to be between 40-45 days. The average metamorphosis percentage and number of postlarvae produced per litre was high for river breeders compared to pond grown breeders. The average length and weight of postlarvae produced from pond grown breeders were 9.4mm and 0.009g while the corresponding values for river breeder were 11.9 mm and 0.012g respectively.

Bart and Yen (2003) compared the performance of larvae of giant freshwater prawn from Thailand and Vietnam. Thai broods were collected from a farm and Vietnamese broods were collected from a river. Larvae from these two sources were raised in identical environment, and their rates of development and survival as well as their ability to withstand environmental stresses were assessed. The first postlarval stage was observed in both strains on day 22. All the larvae (100%) from Thai farm broods completed metamorphosis by day 36, but only 89% of the Vietnam river strain completed metamorphosis by day 45. No clear difference was found in brood size and fecundity between the two groups. No difference in survival was observed between the two groups of larvae challenged with salinity, oxygen or formalin. Differential development rates of larvae in the same batch would naturally create conditions favourable for cannibalism and impaired ability to capture food. The earlier and more uniform rate of development and subsequent higher rate of survival of Thai farm stock compared with the Vietnamese wild stock was attributed to inadvertent selection in the domesticated stock.

2.2 Larval rearing

2.2.1 Tank Colouration

Yasharian *et al.* (2005) evaluated the effect of culture tank colouration on survival, metamorphosis rate, weight and time required to reach the postlarval (PL) stage. Newly hatched prawn larvae were stocked in plastic culture tanks at a density of 30/litre. Tank colours evaluated were red, black, white, blue, green and yellow. Larval prawns were fed with brine shrimp nauplii and a supplemental diet. Data indicated that larval tank colour had no significant impact on the final PL size or days required in reaching PL stage. However, total survival was significantly higher in red and green coloured

tanks (84% and 78% respectively) than in white and blue coloured tanks (56% and 44% respectively).

2.2.2. Metamorphosis of larvae

New and Singholka (1982) reported that the time taken for a larval batch to metamorphose varies according to feeding and environmental conditions particularly temperature. According to them, in a healthy, well fed batch, which was maintained within the optimum temperature range (26-31° C), the first few postlarvae should be observed during day 16-18. Most of the larvae should have metamorphosed into postlarvae by day 25-28 and it was seldom economic to maintain the batch longer than 28 days to wait for the last few larvae to metamorphose. They also added that metamorphosis of postlarvae was characterized by a radical change in behaviour and appearance. They resemble adult prawns and instead of swimming freely in the water, many crawl or cling to the tank surfaces.

2.3 Nursery Rearing

2.3.1 Stocking Density

Ling (1969) suggested the use of nursery ponds nearly 4 decades ago. Wulff (1982) obtained a nursery survival of 70% when PL were stocked in nursery ponds at a density of 1000/m² and grown for two and half months.

In USA, Smith *et al.* (1983) reported that prawns grew from 0.01g to 0.2-0.4g at densities of 1,194-1,663 Nos./m² in nursery rearing (for 67-105 days) and the survival was 90% after 12 weeks of culture; whereas on the other trial with stocking size varied from 0.09-0.70 g and density from 538-904Nos./m², prawns attained a weight of 0.9 – 2.1 g during 42-64 days of culture and the survival was 84% after 8 weeks.

Ra'anan and Cohen (1984a) assessed the distribution of body size among juvenile prawns. Prawns reared in a group showed a relative excess of size variation, primarily associated with the appearance of two size classes which failed to appear among juveniles raised in isolation. They are exceptionally fast growing individuals, termed “jumpers” and severely growth – repressed individuals termed “laggards”. The results suggested that the

variation in attained sizes of juveniles in a population was more influenced by interactions within the prawn group than by genetic differences in growth potential of the individual prawns.

Ra'anan and Cohen (1984b) examined the development of the size distribution curve in postlarval populations of *M.rosenbergii*, reared under various stocking densities. It was found that newly metamorphosed PL demonstrated a lognormal size distribution, which with time becomes positively skewed. Individuals within the "leading tail" – jumpers, exhibit a higher growth rate than the bulk of the population and its appearance was enhanced under low stocking densities. It is suggested that the appearance of jumpers is not a result of competition alone, but also of intrinsic factors associated with the population development, such as genetic or social in nature.

Mulla and Rouse (1986) reported nursery rearing of PL (average weight 0.04 g) stocked at 40Nos. /m² in circular plastic nursery pools with a surface area of 7.3m² and water depth of 0.5m for a period of 35 days. They evaluated the use of fertilizers in place of feeds, pretreatment of fertilized ponds with trichlorfon to reduce predacious insects and / or competitors and use of additional substrate. The results suggested the prawn growth and survival improved with feeds, while improvement from a trichlorfon pretreatment or additional substrate were not substantial.

New (1990) indicated 1-3 months nursery phase with stocking densities varying from 350 Nos./ m² to 1500 Nos./m² in his review on nursery rearing technology of *M. rosenbergii*.

Reddy *et al.* (1996) studied the optimum stocking rate for better nursery management. They did experiments with postlarvae of *M.rosenbergii* at densities of 500, 1000, 1500, 2000, 2500, 3000 and 4000 Nos./m² in different tanks and found that stocking densities up to 3000 Nos./m² was suitable for postlarval rearing.

Eight to 10 day old postlarvae (PL 8 to PL 10) of *M.rosenbergii* were reared for 6 weeks in cement cisterns of 20 m² area under different stocking densities viz. 50, 100, 150, 200 and 250 PL/m² and the highest final mean

body weight (0.079g) and survival (89-96%) were recorded in the experimental group with stocking density of 50 PL/m² in Indian condition (Vasudevappa *et al.*,1997).

Coyle *et al.* (2003a) evaluated the effects of stocking density on growth and survival of prawns during nursery production. Postlarvae (0.01 g) were stocked in 1900 litres tanks with 20.5m² artificial substrate in the form of black plastic mesh (10mm dimension). The tanks were stocked with 215, 430 and 860 Nos.PL/m² of substrate and reared for 60 days. After 60 days, there was no significant difference in average weight of juvenile prawns stocked at the three densities averaging 0.58 g, overall. Survival was significantly lower in prawns stocked at the higher density of 860Nos./ m² (62%). Differences in survival of prawns were 94% when stocked at 215Nos. PL/m² and 78% when stocked at 430Nos. /m².

Tidwell *et al.* (2003) studied the effects of size grading and length of nursery period on growth and population structure of freshwater prawns stocked in temperate zone ponds with added substrates. All ponds were stocked at 59,280Nos. / ha and were provided with artificial substrate in the form of polyethylene fence oriented vertically at a rate sufficient to increase the available surface area in the ponds by 50%. According to them, compared to control ponds (61-day ungraded), grading of 61-day juveniles significantly increased total production with 2549Kg and 2945 kg / ha respectively. The authors also observed that extending the nursery period and thereby increasing the average stocking weight did not significantly improve the total production or average individual weight. Feed conversion ratios were significantly higher for 133-day juveniles compared to controls (2.8 vs. 2.3).

2.3.2 Feed

2.3.2.1 Protein

Koshio *et al.* (1992) compared the nutritive value of Soybean Protein (SBP) with Crab Protein Concentrate (CPC) for the juvenile prawn. The protein contents of the test diets ranged from 30 to 55% with an interval of about 7 and the dietary energy was kept constant (4.3kcal/g) by adjusting carbohydrate contents (alpha starch and dextrin). No statistical significance was detected between SBP and CPC diet groups in the weight gain but the

food conversion efficiency (FCE) and protein efficiency ratio (PER) of SBP diet groups were better than those of CPC diet groups in each protein level except for prawns fed on the second highest protein level of 47%.

Behanan *et al.* (1998) reported the changes in digestive protease in hepatopancreas of *M.rosenbergii* fed on diets containing 10, 20, 30, 35 and 45% protein levels for 15, 30, 60 and 90 days. They concluded that a protein level of 30-35% in the diet was found ideal for the growth.

Pezzato *et al.* (1995) evaluated the influence of three protein levels in the diet (30, 40 and 50% crude protein) of *M.rosenbergii*. The diet with 40% of crude protein showed a lower mortality rate and higher weight gain after 20 weeks.

2.3.2.2 Live and inert feed

Indulkar and Belsare (2004) reported on live and inert foods for postlarvae of *M.rosenbergii*. Five live or inert food organisms (adult Artemia, Moina, Tubifex worms, clam meat and poultry egg custard) were evaluated as feed for postlarvae of *M.rosenbergii*. The postlarvae (avg. 5.2 mg and 7.2 mm size) were reared in plastic pools stocked at one postlarva per litre for 30 days. The live Moina were superior to other feeds with a significantly higher weight gain, length gain and improved specific growth rate. The higher protein (66.16% on dry weight basis) and n-3 HUFA (10.2%) levels in Moina could explain these results.

2.3.2.3 Feed composition

Indulkar and Belsare (2001) studied twelve diet combinations consisting of indigenous plant and animal materials such as fish meal, Acetes, prawn shells, poultry egg, wheat flour, ground nut oil cake and ricebran by feeding the PL-5 of *M.rosenbergii* for 15 days in 30 litres plastic tubs at a stocking density of 1PL/ litre. They found that, weight gain, specific growth rate, protein efficiency ratio, food conversion ratio and survival rate of prawn at the end of experiment were significantly higher in diet containing fish meal (20%) + Acetes (20%) + prawn shells (20%) + wheat flour (10%) + rice brain (10%) + ground nut oil cake (10%) and poultry egg (10%).

2.3.2.4 Additives

2.3.2.4.1 Vitamins and minerals

Dietary requirements of vitamin C were determined by D'-Abramo *et al.* (1994) for the juvenile freshwater prawn using two water stable sources of ascorbic acid, ascorbyl 2 monophosphate, and ascorbyl 6-palmitate by conducting a feed trial for 90 days. A quantitative requirement equivalent to 104 mg of vitamin C/kg of diet was estimated by a quadratic surface analysis, using survival as the measured response to the different dietary level. They also observed high mortality in vitamin C deficient diets (50mg/kg) within 21 days after initiation of feeding trial due to the lack of successful extrication from the old exoskeleton.

Radull (1995) conducted two feeding experiments to evaluate the effects of vitamin C and highly unsaturated fatty acids, docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) ratio on the growth, development and vitality of the larvae of the freshwater prawn. In the second experiment Artemia enriched with three experimental emulsions with DHA/EPA ratios 0.6, 2.6 and 4.6 were fed to the larvae. A pre-tested emulsion of ratio 0.6 was used as the control. The incorporation of both EPA and DHA corresponded positively to their ratios in the diet. Increasing the ratio of DHA to EPA in the diets had no significant effects on the growth, survival, or stress resistance of the larvae. There was, however, significantly better development (metamorphosis and larval stage index) of larvae fed diets of low DHA/EPA ratio. The results indicated that under suboptimal conditions (e.g. stress), supplementation of high levels of vitamin C in diets could improve larval production characteristics.

Vitamin C requirements of *M.rosenbergii* were studied by Hari and Kurup (2002) by incorporating graded levels of ascorbyl 2 polyphosphate (ApP) in semi purified diets to provide 50, 100, 150, 250 and 500 mg ascorbic acid equivalent (AAE) kg⁻¹ diet in growth experiment of 49 days. The results indicated that 135 mg (AAE) kg⁻¹ diet was required for normal growth and survival of juvenile prawns.

The effects of vitamin C (ascorbic acid, AA) and vitamin E (tocopherol) on the maternal performance and offspring quality of the freshwater prawn *M. rosenbergii* were investigated by Cavalli *et al.* (2003). Prawn females were fed with four diets containing different levels of 2-ascorbyl-1-polyphosphate (ApP) and α -tocopherol acetate (α -TA) during 155 days. The results suggested that broodstock diets containing around 60 μ g AA/g dry weight and 300 μ g α -TA/g dry weight are sufficient to ensure proper reproduction and offspring viability. However, feeding *M. rosenbergii* females with higher dietary levels of both AA and α -TA (each around 900 μ g/g DW) might increase larval quality, as demonstrated in this study by the higher tolerance to the exposure to ammonia.

2.3.2.4.2 Beef liver

Garces and Heinen (1993) evaluated frozen beef liver fed at dietary levels of 5, 10, 15, 20 and 25% (dry weight) to postlarval *M. rosenbergii* as a supplemental to Purina Trout chow No.2. Diet. Among the levels tried, 15% beef liver incorporated showed good results. They also tested the suitability of 47 fresh and frozen fruits and vegetables as dietary supplements. Fourteen fruits and vegetables were readily consumed by prawns, and seven (fresh orange, sweet potato, frozen banana, carrot tops, butternut squash, yellow squash and turnip greens) were tested as supplements (10% dry weight of the total ration) to trout chow and 15% beef liver. Pigmentation of prawns fed carrot tops or turnip greens was enhanced. Diets with 15 and 20% levels of banana showed significantly higher food conversion ratio than other levels (0 and 5%).

2.3.2.4.3 Cod liver oil and corn oil

Sheen and D'-Abramo (1991) conducted two separate experiments to determine the level of a dietary cod liver oil / corn oil (2:1, w/w) mixture needed for maximum weight gain of juvenile freshwater prawns, *M. rosenbergii*. They found that the juvenile freshwater prawn do not require a specific level of dietary lipid. Rather, the optimal amount of dietary lipid depends upon the amount and quality of protein, the level of available lipid energy and satisfaction of specific fatty acid requirements.

A feeding trial was conducted to determine the effect of replacing costly cod liver oil with corn oil as a source of dietary lipid on the growth and fatty acid composition of the larval freshwater prawn (Kamarudin and Roustaian, 2002). Prawn larvae were weaned to artificial diets containing cod liver oil and corn oil either in single or in various combinations (2:1, 1:1, 1:2w/w). The reference group was reared solely on *Artemia nauplii* during the entire experiment. Incorporation of corn oil at 33-67% of dietary supplemental oil did not have significant effects on the postlarval production. Palmitic (16:0) and oleic/vaccenic (18:1) acids were the dominant saturated and monounsaturated fatty acids in larval tissues, respectively, whereas the polyunsaturated fraction was dominated by eicosapentaenoic (20:5n-3) acid. N-3 fatty acids rather than n-6 fatty acids dominated the polyunsaturated fatty acid composition. The fatty acid composition of the prawn, in general reflected that of the diet. Larvae on diets containing higher concentrations of corn oil rich in linoleic (18:2n-6) acid showed a higher concentration of this acid in their tissues. No evidence of *de novo* synthesis of linoleic (18:2n-6) acid was found. Higher levels of stearic (18:0), arachidonic (20:4n-6) and eicosapentaenoic (20:5n-3) acids found in larvae as compared with those fed *Artemia* and artificial diets strongly indicated the larval ability in chain elongation and desaturation of palmitic (16:0), linoleic (18:2n-6) or linolenic (18:3n-3) acids, respectively. Despite a large variation of n-3 to n-6 ratios of the live and artificial diets, larval n-3 to n-6 ratios were relatively stable among different dietary treatments.

2.3.2.4.4 Cholesterol and lecithin

Briggs *et al.* (1988) examined the effects of dietary cholesterol and lecithin on growth, survival and moulting frequency of juvenile freshwater prawns, *M. rosenbergii* using semi-purified diets in a laboratory recirculated water system. The results suggested that there was no advantage in supplementing cholesterol and/or lecithin at any of the levels tested to the basal diet (containing 0.12% endogenous cholesterol and 0.048% total phospholipid) formulated for this species.

When postlarvae were reared for 12 weeks at 27°C in a recirculated aquatic system on semi purified diet supplemented with 0 and 10% lecithin

Hilton *et al.*, (1983) found out no significant differences in either the weight gain or mortality rates of the prawn reared on different test diets and no sign of moult death syndrome was observed in any of the prawn.

2.3.2.4.5 Soylecithin

Srivastava and Parihar (1997) incorporated soylecithin to the postlarval diet of *M.rosenbergii* at a level of 20g/kg of feed and studied the effect for 56 days. Growth, survival and carcass composition were found better than that of control. Tiwari and Sahu (1999) tested the level of inclusion of soylecithin (0-6%) by replacing equal amount of cod liver oil and groundnut oil mixture (1:1). The trial was conducted for 60 days with PL 30. The crude protein and total lipid contents of the diets were found to be 35 and 11%, respectively. Maximum weight gain (164%) was obtained where soytecithin was included at 5% along with 1% cod liver oil and groundnut oil mixture.

2.3.2.4.6 Antibiotics

Optimum level of oxytetracycline was evaluated as growth promoter in *M.rosenbergii* postlarvae (Ignatius and Jose, 1999) at four concentrations i.e., 5, 10, 20 and 40mg/100g diet. Oxytetracycline at 10mg/100g was found optimal which gave maximum growth increment and specific growth rate of postlarvae.

2.3.4 Fish meal replacement

A study was conducted by Tidwell *et al.* (1993) to evaluate the effect of partially or completely replacing fish meal with soybean meal and distillers' dried grains with solubles (DDGS) in diets for pond-raised freshwater prawns. Juvenile prawns averaging 0.51 g were stocked in 0.02 ha earthen ponds at 39,520 Nos./ha. Three isonitrogenous diets (32% crude protein) containing 15, 7.5 or 0% fish meal were fed to prawns. A variable percentage of soybean meal and a fixed percentage (40%) of DDGS replaced fish meal. Average yield, survival, individual weight, and feed conversion did not differ significantly among prawns fed the three diets. Results indicated that fish meal could be partially or totally replaced with soybean meal and distillers' by-products in diets for pond production of freshwater prawns in temperate areas.

Three experimental diets containing either fish meal, acid silage or fermented fish silage were fed to postlarvae of *M.rosenbergii* and changes in amylolytic and proteolytic activity along with biochemical composition of tissue were studied as indicator parameters to evaluate the acceptability of silage based diet (Ali *et al.*, 2000). Postlarvae fed on silage based diets registered higher weight gain with no adverse effect on survivability, establishing silage based diet as a possible alternative to fish meal.

Du and Niu (2003) studied the effects of dietary substitution of soy bean meal (SBM) for fish meal on consumption, growth and metabolism of juvenile giant freshwater prawn. Feed intake was significantly affected by inclusion of SBM, while the growth rate and conversion efficiency decreased with increasing dietary SBM. Standard metabolic rate was also affected by dietary soya bean level. SBM inclusion without supplementation of amino acids was not suitable as a major protein source in prawn diets.

The study of Rajan (2000) dealt with the partial replacement of costly fishmeal by hide flesh in the feed formulation of *M.rosenbergii*. Four different isonitrogenous (30% CP) diets were prepared by replacing 0, 25, 50 and 75% of fishmeal by hide flesh. The other ingredients used were prawn meal, groundnut oil cake, sesame oil cake, wheatflour, rice bran, tapioca, fish oil, sunflower oil, vitamin mix and sodium chloride. Growth studies were conducted for a period of 30 days. The results showed that 50% replacement of fishmeal by hide flesh was best for feed conversion efficiency, growth, relative growth rate and gross growth efficiency of *M.rosenbergii*.

Ali and Sahu (2002) studied the response of *M.rosenbergii* (De Man) juveniles to fish silages as substitute for fishmeal in dry diets. A feeding trial was conducted for 60 days to study the use of fish silage as substitutes for fishmeal in the juveniles' diets of *M.rosenbergii*. Three different isocaloric (estimated digestible energy 290 kcal 100 g⁻¹) and isonitrogenous diets were prepared with either fishmeal (FM) or acid fish silage (AFS) or fermented fish silage (FFS) keeping crude protein (CP) level of the diets at 35%, in which 15% CP was contributed by FM, AFS or FFS. The prawns fed diets containing FFS showed no statistically significant, but better weight gain (72.68%),

specific growth rate (0.91% day⁻¹), feed conversion ratio (3.46), and protein efficiency ratio (0.85) than those fed FM and AFS. Carcass composition and survival of the juveniles were not affected by the diets.

2.3.5 Feeding

Heinen and Mensi (1991) reported that PL with initial weights ranging from 9 to 15mg showed higher weight gain and survival rates when fed only a single daily ration. However, in some nurseries, food is supplied *ad libitum* and quantities were adjusted according to the amount of uneaten foods from the previous feeding.

2.4 Growout rearing

2.4.1 Table 1: Stocking density of *M.rosenbergii* in various growout systems

Sl. No.	Country	Culture unit	Stocking densities tried (Nos/m ²)	Stocking density recommended	Duration of the study (days)	Production achieved (kg/ha)	Source
1.	USA	Earthen ponds	5, 10&20	20/m ²	168	2,786	Willis and Berrigan (1977)
2.	USA	Concrete tanks	32 & 83	32/ m ²	110-138	3,828	Sandifer <i>et al.</i> (1982)
3.	Israel	Earthen ponds	1,2,3,& 4	2/m ²	NA	NA	Karplus <i>et al.</i> (1986a)
4.	USA	Earthen ponds	4 & 6	4	150	1409	D' – Abramo <i>et al.</i> (1989)
5.	Italy	Earthen ponds	2.8 & 7	2.8/m ²	120	1,682	Melotti <i>et al.</i> (1989)
6.	India	Earthen ponds	2 & 3	3/m ²	180–210	600	Thangadurai(1991)
7.	Saudi Arabia	Concrete tanks	2,4,8 & 16	2/m ²	175	NA	Siddiqui and Al-Hinty (1993)
8.	Brazil	Earthen ponds	4,8,12,16&20	4/m ²	180	NA	Valenti <i>et al.</i> (1993)
9.	USA	Earthen ponds	3.95,5.93&7.91	3.95/m ²	131–134	1,041	Daniels <i>et al.</i> (1995)
10.	Saudi Arabia	Concrete tanks	5,10,15 & 20	5/m ²	168	1,350	Siddiqui <i>et al.</i> (1997)
11.	India	Cement tanks	5 & 10	5/m ²	180	984	Nagarathinam <i>et al.</i> (2000)
12.	India	Earthen ponds	4.5 – 6 & 7.5 – 12	4.5 – 6 /m ²	NA	800 - 2825	Singh <i>et al.</i> (2005)
13.	India	Earthen ponds	2, 3, & 5	3/m ²	164	339	Somdutt <i>et al.</i> (2005)

NA – Not Available

2.4.2 Feed

2.4.2.1 Protein

Boonyaratpalin and New (1982) tested pelleted diets with three protein levels (15, 25 and 35%) for freshwater prawn in concrete ponds in Thailand. They found that there was no significant difference among diets with different protein levels.

El-Sayed (1997) tested the effects of varying dietary protein and energy levels on the growth, feed utilization efficiency and body composition of *M. rosenbergii* fed diets containing 5 protein levels (20, 25, 30, 35 or 40%) each at 2 energy levels (350 or 450 kcal Gross Energy (GE) /100g diet) fed *ad libitum*, once a day for 90 days. These results revealed that optimum growth of *M. rosenbergii* was obtained at 35% protein and 350 kcal GE/100g diet, with a protein-to-energy ratio of 100mg protein / kcal GE.

Nair *et al.* (1998) evaluated the growth, survival and production of *M. rosenbergii* with an indigenous feed developed at CIFT. The feed with 40% protein contained only cheap indigenous animal and plant protein ingredients gave good results when they conducted experiment in freshwater ponds.

Wu-Ruiquan *et al.* (2000a) conducted experiment to determine the optional dietary protein content of feed for *M. rosenbergii*. The protein content of the feed varied from 13.28 to 62.45%. It was recommended that 37.02% as the optimal feed protein content by linear regression based on growth rate, feed conversion ratio and protein efficiency.

2.4.2.2 Protein Source

Comparative evaluation of dietary protein levels and plant-animal protein ratios in *M. rosenbergii* was studied by Hari and Kurup (2003a). Better feed conversion ratio was recorded for the group having a plant to animal protein ratio of 1:1 (2.02) followed by 1:1.5 (2.66), however, there was no significant difference between them. Based on this study it is possible to replace animal protein by low cost plant protein in prawn feed. Better growth performance in juvenile *M. rosenbergii* could be achieved by the incorporation of equal portions of plant and animal protein (A:P = 1) in the diet.

2.4.2.3 Lipid

Wu-Ruiquan *et al.* (2000b) determined the optimum lipid level of feed for growing *M.rosenbergii*. The experimental diets were isonitrogenous (37% protein) and isoenergetic (11.9MJ / kg of diet) with casein, fish meal, dextrin and cellulose as main ingredients. Dietary lipid levels ranged from 1.2 to 11.1% with a mixture of marine fish oil and soybean oil (1:1) as lipid sources. Prawns, which received diets with lipid levels of 5.1 to 9.0%, had best growth rate, feed conversion and protein efficiency. When considering feed cost, it was found to be reasonable to keep the lipid at 5% level in feed for *M.rosenbergii*.

2.4.2.4 Lipid Source

Querijero *et al.* (1997a) conducted experiments on the utilization of monounsaturated fatty acid (18:1n-9, oleic acid) by freshwater prawn, *M.rosenbergii* juveniles. The effects of oleic acid and/or dietary soyabean lecithin (SBL) concentrations on the growth and survival, lipid class and fatty acid composition of *M.rosenbergii* juveniles (mean weight 0.26 g) were examined in a feeding experiment. Inclusion of SBL 20 g/kg had no significant effect on growth and survival, nor was there any interactive effect between dietary SBL and oleic acid levels. Body fatty acid profile of prawns reflected dietary fatty acid quantity. The fatty acid composition of prawns fed on diets containing oleic acid at 80 g/kg had tremendously high proportions of oleic acid. Prawns fed on SBL had higher PC content. Oleic acid was metabolized for energy by *M.rosenbergii* juveniles at the same rate regardless of dietary level of SBL and/or oleic acid.

The effects of dietary stearic acid (SA) and crude protein (CP) levels on the utilization of SA as an energy source by freshwater prawn were determined (Querijero *et al.*, 1997b) by feeding and tracer experiments. Feeding experiments showed that juveniles fed diet with 2% SA and 35% CP gave significantly higher weight gain, feed conversion efficiency (FCE), and protein efficiency ratio (PER) than those fed diet with 7% SA and 50% CP. The higher weight gain of prawns fed diet with 2% SA compared with diet with 0% SA indicated the positive contribution of SA as an energy source.

Significantly higher SA and oleic acid levels were observed in prawns fed diets with 7% SA than those fed with 2% SA, indicating the SA affected body fatty acid profile. Prawns fed diets containing 35% CP had significantly higher PER than those fed 50% CP diets. Tracer experiments showed that *M.rosenbergii* juveniles utilized SA as an energy source.

The utilization of stearic acid (SA) and corn starch (CS) or dextrin (DX) as energy sources for juveniles, and the effect of increasing dietary SA and digestible energy levels on weight gain, survival, lipid class and fatty acid profiles of the whole body of prawns were determined by Querijero *et al.* (1997c) in a 60-day feeding experiment. The diets contained fixed amounts of carbohydrate (30%) and protein (35%), and increasing levels of SA (0, 2 and 7%). Regardless of carbohydrate sources, increase in dietary amount of SA resulted in significantly higher content of SA and 18:1n-(9 + 11) fatty acids in the body of prawns, both in the neutral and polar lipid fractions. The result showed that *M.rosenbergii* juveniles utilized SA as an energy source but the contribution of SA as energy source was lower than that of carbohydrates.

2.4.2.5 Carbohydrate

Gomez and Nakagawa (1990) evaluated various dietary carbohydrate sources for juvenile prawn according to weight gain and body composition. Different carbohydrate sources, alpha-potato starch, soluble starch, dextrin, sucrose, glucose and glycogen were separately included in a purified diet. After 60 days, higher weight gain was achieved in the groups fed potato starch or soluble starch. The group received glucose as the carbohydrate source had low weight gain.

2.4.2.6 Calcium

The influence of water hardness on spawning, egg production, hatching rate, broodstock growth and survival of freshwater prawn, *M.rosenbergii* was investigated in indoor tanks during a 132 day study (Sukadi, 1991). An evaluation was also carried out to determine the influence of water hardness and dietary calcium on growth and survival of postlarval and juvenile prawns in an eighteen-week study. Water hardness levels of 18,

35, 150 and 300 mg/l as CaCO₃ and dietary calcium levels of 0.25, 2.00 and 4.00% were used as treatment levels. There was no evidence that number of spawns, spawning frequency of individual prawns, survival of brood stock, number of eggs per gram of female, final weight of postlarvae and juvenile prawns or survival of juveniles were influenced by water hardness.

Zimmermann *et al.* (1993) tested two levels of calcium in diets (1.8% and 3.0%) and three levels of calcium in water (23±4, 51±3, 74±3.5mg/l CaCO₃) on the growth of *M.rosenbergii* postlarvae. The study was conducted for 8 weeks in plastic tanks with a stocking density of 1.53PL/l. Results of this experiment confirmed the narrow relation between calcium from the diet and dissolved calcium from the rearing water, showing the need of dosing the calcium in diet as function of the alkalinity of the culture water.

2.4.2.7 Zinc

Rath and Dube (1994) reported that best growth, survival, FCR, SGR and condition factor were obtained with diet containing 90mg Zn/kg of diet for freshwater prawn.

2.4.2.8 Vitamin E

Dandapat *et al.* (2000) determined the effect of supplementary vitamin E (200, 400 and 600 mg/kg feed) on lipid peroxidation (LPX) and antioxidant defence system in gills and hepatopancreas of *M.rosenbergii*. The findings suggest that dietary vitamin E is capable of reducing LPX level and can modulate antioxidant defence system in gills and hepatopancreas nevertheless, the response is highly tissue specific. It is further observed that highest dose of vitamin E (600mg/kg feed) could not render much additional protection in both the tissues.

2.4.3 Additives

2.4.3.1 Attractants

Chemoreception in adult freshwater prawn *M.rosenbergii* was investigated (Harpaz *et al.*, 1987). Of the 28 different substances tested, the amino acids taurine, glycine, arginine and betaine, as well as trimethylamine, elicited a positive behavioural response in 50% of the test animals, when applied at a threshold concentration of 10⁻⁵ - 10⁻⁸M. Harpaz (1997) conducted

a feed experiment with juvenile prawns in which betaine was added as a feed attractant. He found 17% increase in growth with feed which had chemoattractant augmentation following actual feeding. The chemoattractant was added to the water, in an aqueous concentrated solution of 10^{-3} M and induced a burst of food searching behaviour leading to further consumption.

A feeding experiment was conducted by Felix and Sudharsan (2004) to determine the effect of the feeding attractant, glycine betaine (betaine hydrochloride) on the growth and feed conversion of juveniles of *M. rosenbergii*. Among the glycine betaine-added diets, prawn fed glycine betaine at 5 g kg⁻¹ level showed highest weight gain by registering 61.5% increase in growth over control and also higher feed intake and good FCR.

Pavadi and Murthy (2005) studied the enhancement of growth, survival and feed utilization in *M. rosenbergii* through use of feed attractant. The study was taken up to evaluate the effect of feed attractants which contain natural flavour extracts (Choline chloride and BHT), amino acids (Alanine, Valine, Glycine, Proline, Serine and Histidine) and natural attractants (Glutamic acid, Tyrosine and Betaine) and named as 'Aqua savor'. The feed attractant was incorporated at 1, 1.5 and 2% levels in the diets and fed for a period of 120 days in cement cisterns of 25m². It was concluded that feed attractants are effective in promoting growth, survival and feed utilization in freshwater prawn, *M. rosenbergii* and a level of 10g/kg diet was found optimum in field condition.

2.4.3.2 Barley

Ashmore *et al.* (1986) carried out a growth and digestibility trial to evaluate the nutritive merit of 4 cereal grains (corn, milo, wheat and barley) in diet formulated for *M. rosenbergii*. Their results showed that feed consumption and apparent digestible energy contributed to the growth response and at the 30% dietary protein level, barley appears to have been more efficiently utilized than wheat, effectively reducing the level of required dietary protein.

2.4.3.3 Rice hay

Miltner *et al.* (1983) conducted a pilot study to evaluate air dried rice hay as a detrital feeding substrate for culture of *M. rosenbergii*. They

concluded that rice hay or similar agricultural by-products could have promise as detrital forage to supplement pelletized rations in prawn culture ponds, but further research needed to quantify optimum feeding rates, nutritional contribution and effects on water quality.

2.4.3.4 Leaves

Harpaz and Schmalbach (1986) conducted a 12 month long laboratory trial on supplementation of dry artificial feed with fresh leaves of *Ailanthus altissima* (Simaroubaceae) and *Malva parviflora* (Malvaceae). The results indicated elimination of moult death syndrome and a considerable reduction of black spot disease incidence in *M.rosenbergii* adults. An additional effect of this supplement was the shortening of intermolt intervals as well as increased average body weight.

The study of Vasudevappa *et al.* (1996) indicated that incorporation of suitable plant material in the feed enhanced the growth of giant freshwater prawn, when they conducted experiment in small earthen ponds for a period of 6 months. The control feed consisted of fish meal, oilcakes, binding agent, vitamins and minerals. In addition to these ingredients the experimental feeds consisted groundnut leaf powder and mulberry leaf powder each at 17 percent. The results indicated that the prawn growth and survival were far better when fed with the feed supplemented with groundnut leaf powder than control and feed supplemented with mulberry leaf powder.

2.4.4 Water Stability

Stanley and Moore (1983) evaluated the effect of water stability of different quality feeds namely bound and water stable, unbound and less water stable. There was no difference in growth of prawns fed with bound or unbound diets.

2.4.5 Feed Composition

Labao *et al.* (1995) compared eight different kinds of diets for the development of *M.rosenbergii*. The trial was conducted for 21 weeks in indoor tanks. From the results, it was evident that the diet containing fish meal (34.8%), soy meal (34.8%), corn meal (17.9%), shrimp carapace meal (5%) soybean oil (5%), binder (2%), attractive stimulant (0.2%) and vitamin C

(0.3%), provided the best development with weight gain and feed conversion ratio (2.86: 1).

An experiment was conducted by Hossain *et al.* (2000) for 105 days in earthen mini ponds of each 30m² size. Five different experimental diets containing 32% protein were formulated and prepared using fishmeal, shrimp meal, soybean meal, mustard oil cake, sesame meal, wheat bran and rice bran. A commercial shrimp diet was used as the control. Prawns (*M.rosenbergii*) were stocked at the rate of 2.5 PL/m² and fed twice daily at the rate of 10% at the beginning and reduced to 8% for the last two months. The result of the study showed that diet containing 30% fishmeal, 5% shrimp meal, 5% soybean meal, 10% mustard oil cake, 10% sesame meal, 20% wheat bran, 18% rice bran, 1% oyster shell and 1% vitamin premix could be recommended for monoculture of *M.rosenbergii*.

2.4.6 Feeding strategy

Fair and Fortner (1981) studied the role of formula feeds and natural productivity in culture of the prawn, *M.rosenbergii*. They compared the growth of prawn population fed with formula feed alone, formula feed and fertilization, prawns cultured on natural productivity induced by fertilization with manure and no formula feed and no fertilization. They found that formula pelleted diets contributed directly to growth in the pond culture of *M.rosenbergii*.

This study Correia *et al.* (2003) evaluated growth of freshwater prawn *M.rosenbergii* under three feeding regimes, where supplemental feed was reduced and natural productivity of the ponds was increased by a fertilization programme that included the addition of lime, phosphorus and nitrogen. According to the authours, under the local conditions of semi-arid and warm water temperatures (24.0-33.5° C), increasing natural productivity of ponds significantly improved feed conversion ratio, which was reflected in feed cost savings and potential savings of the farm operating cost.

Coyle *et al.* (2003b) compared two feeding technologies in freshwater prawns, raised at high biomass densities in temperate ponds. This study was conducted to compare the current recommended technology of phase feeding of different quality feedstuffs to prawns of different sizes with the feeding of a

high quality penaeid diet throughout the production season. Two treatments were evaluated: one was phase feeding (current technology-control) where prawns were fed unpelleted distillers' grains with solubles (DDGS) for the first four weeks, then a 28%-protein prawn diet for weeks 5-12, and finally a 40%-protein penaeid diet for weeks 13-16, whereas, the other prawn groups were fed 40%protein penaeid diet throughout the entire production period in 0.04ha ponds. Feeding rates in both treatments were based upon a feeding table. All ponds were stocked at 59,280 juveniles/ha and were provided with artificial substrate in the form of a polyethylene "safety fence" oriented vertically to increase available surface area by 50%. After 106 culture days, no significant differences were observed between treatments in terms of yield, average individual weight, food conversion ratio (FCR), or survival, which averaged (overall value) 2,575 kg/ha, 46 g, 2.3 and 94%, respectively.

2.4.7 Farm made feed

A feeding trial was conducted by Hari and Kurup (2003b) in *M.rosenbergii* to compare efficiency of the farm made feed (FMF) with commercial feeds such as CP feed, Higashi feed, and Rosen feed. Dried clam meat was used as the control feed. Water stability of FMF was found well comparable with the above feeds. Higher specific growth rate and higher survival were recorded in FMF. Results of the study revealed the growth, survival and feed conversion ratio of *M.rosenbergii* fed with farm made feed prepared from the locally available feed ingredients were comparable with those of commercial scampi feeds. As the farm made feed preparation was found very cost effective, it could be recommended to the scampi farmers to make farming more economically viable.

2.5 Size grading

Ra'anan and Cohen (1983) studied the production of freshwater prawn in Israel by selective stocking of size populations. Selective stocking of separated juvenile size sub populations in the production ponds in the first growing season, stocking separated large sized juveniles as opposed to stocking a whole mixed population in intensive monoculture improved yields, average weight and the percentage of large market size prawns.

The effects of size grading on morphotype differentiation, population structure and yield characteristics were analyzed by Karplus *et al.* (1986b). Juvenile prawns were size graded into an upper (1/3 of the population) and a lower (2/3) fraction prior to stocking at a density of 2 Nos./m² in the earthen ponds for a growout period of 105 days. Three graded and recombined control groups were included in this study. One control was of the same origin as the graded groups. The other two control groups consisted of larger and smaller prawns, similar in size to the graded upper and lower fractions. The results of this study indicated that the relative position of juvenile prawn within the population was more important than absolute size in determining further growth rate and yield.

Karplus *et al.* (1987) studied the effect of size grading juvenile *M.rosenbergii* to three fractions prior to stocking on their population, structure and production in polyculture. Juvenile prawns were graded into upper, middle and lower fractions. The graded fractions and the graded and recombined control were stocked in 400m² earthen ponds at a density of 2 Nos./m² and grown for 97 days in polyculture with tilapia, silver carp, common carp and grass carp. The proportion of females was higher than that of males in all of the groups except the lower fraction in which males predominated. The fractions differed in the portions of the male and female morphotypes. Survival was 88% in all the groups. The three graded groups differed significantly in mean weight with the largest prawns occurring in the upper fraction.

Daniels and D'-Abramo (1994) also studied the effect of stocking size graded juveniles on pond production characteristics. Nursery reared population of 50 day old PL averaging 0.16 g was divided into three groups. Prawns passing through the 0.64cm mesh were proportionately graded into two size groups, viz. 30% upper (0.40 g) group and 70% lower (0.15 g) group. Average yield for the 30% upper and 70% upper treatments (1106 and 884kg/ha respectively) were significantly greater than that of the ungraded treatment (775kg/ha).

Tidwell *et al.* (2004) compared the growth of lower grade fraction with the upper grade fraction and an ungraded fraction of the same population within a temperature constrained growing season of 100-120 days. Prawn juveniles that had been nursed 60 days were separated into three groups. Approximately 50% of the population was maintained ungraded with full range of size variation. The other 50% was separated into two fractions (large=upper grade; small=lower grade) using a # 13 bar grader (0.5 cm spacing) in earthen ponds. All ponds were stocked at 59,280 Nos./ha. Artificial substrate was added to ponds at a rate to increase available surface area by 50%. In summary, stocking of the upper graded fraction increased total production, average weights, and marketable production. There was no difference in lower graded and ungraded animal production variables.

2.6 Water Quality

2.6.1 Oxygen

Oxygen consumption of postlarvae of *M.rosenbergii* was studied by Stephenson and Knight (1980) at 20, 27 and 34°C and at four levels of salinity (0,7,14 and 28 ppt). Differences in oxygen consumption among salinity treatments were not significant except in which oxygen consumption decreased as salinity increased and oxygen consumption increased with temperature.

2.6.2 Temperature

Postlarval *M.rosenbergii* acclimated to 27, 22 or 16°C and 5,8 or 14ppt were temperature shocked to 16°C or 13/16°C for one week. Survival was significantly better in animals acclimated to 22°C or below. Salinity had no significant effect on survival (Silverthorn and Reese, 1978). This study indicated that postlarvae stocked in cool ponds from warm hatcheries might benefit from pre acclimation to lower temperatures. Exposure to cold did not adversely affect later growth of prawns.

Herrera *et al.* (1998) determined the critical therma maxima (CT Max) and minima (CT Min) for postlarvae and juveniles of *M.rosenbergii* acclimated at 20, 23, 26, 29 and 32 ± 1°C. There was no significant difference in the CT

Max and CT Min of the PL and juveniles. They recommend a favourable temperature range of 16-42° C.

Magallon and Salas (2005) studied the growth of postlarval *M.rosenbergii* at two temperatures. Postlarvae of the giant Malaysian prawn *M.rosenbergii* were reared for a 120 days period under laboratory conditions at 20°C and 33°C. The growth of the prawn was significantly greater at 33°C than at 20°C.

2.6.3 Water Volume

D'-Abramo *et al.* (1996) studied the effect of water volume and surface area of culture containers on weight gain of juvenile freshwater prawns when they were held individually in containers under conditions of different volume, surface area and flow rate (turnover rate). Reduced volume or reduced area was associated with a significant reduction in weight gain of prawn after 60 days and no significant effect was observed with regard to turn over rates.

D'-Abramo *et al.* (2000) studied the effects of combinations of water volume, bottom surface area and water replacement rate on weight gain of juvenile freshwater prawn in two experiments. After 60 days, the weight gain of juvenile prawns was significantly greater (232%) under conditions of both greater volume and bottom surface area. Higher water replacement did not compensate for lower volume. There was significantly more weight gain (149%) with greater bottom surface area at the lower rate of water replacement. However, at the higher rate of water replacement, greater bottom surface area did not result in a significant increase in weight gain.

2.6.4 Hydrogen sulphide

Jayamanne (1986) determined the mean lethal concentration (LC₅₀) of hydrogen sulphide toxicity on juveniles of *M.rosenbergii* performing static bioassays for 96 hour period. The safe concentration of hydrogen sulphide determined for juveniles was 0.26mg/litre.

2.6.5 Photo period

Tidwell *et al.* (2001) evaluated the effects of three different photoperiods on growth and survival of *M.rosenbergii* during nursery

production. The PL were stocked in nursery tanks at 2.3 PL/ litre with artificial substrate added to each tank at a rate to achieve a density of 430 PL/m² of substrate. Tanks were randomly assigned to one of the following photoperiod regimens: 24 hours darkness, 12 hours light: 12 hours darkness or 24 hours light for 60 days. This study indicated that continual light conditions have a positive impact on survival of juveniles during the nursery phase.

2.6.6 Hardness

Bartlett and Enkerlin (1983) conducted experiment on *M.rosenbergii* in which the prawns were grown for 158 days in 25 m² ponds with earth and asbestos asphalt bottom. The total hardness was 1000 ppm and animals were fed on a diet with 14% protein content. Production was in the range of 660 – 1270 kg / ha with 97% of final biomass in marketable size (17-70g). The results were comparable with other temperate region studies and suggested that water high in calcium but low in carbonates did not inhibit growth in *M.rosenbergii*.

Vasquez *et al.* (1989) reported the effects of low to moderate levels of water hardness on the growth of *M.rosenbergii*. High levels of hardness were found to depress prawn growth rates. However, extremely soft water was also not very conducive to optimum growth. Results indicated that optimal prawn growth could be expected at hardness levels between 20 and 200 mg/ litre.

2.6.7 Culture of prawn in brackishwater

In India, Nair *et al.* (1977) conducted experiments to determine the optimum salinity and the effect of its sudden increase or decrease on the survival and growth of the larvae of *M.rosenbergii*. In the first experiment, larvae were transferred to salinities ranging from 5 to 35‰ after prior acclimatization in each range. In the second experiment, the larvae were acclimatized to a salinity of 20‰ and then suddenly transferred to lower salinities (0 to 15‰). It was noticed that salinity had a marked influence on the survival and growth of the early larval stages and 15‰ was the optimum salinity at which maximum growth and survival occurred. A sudden increase or decrease to the extreme high or low salinities had adverse effect on survival and growth.

The study of Perry and Tarver (1981) and Perry *et al.* (1982) described culture of *M.rosenbergii* in brackishwater ponds in Louisiana. Survival and average size increased with decreasing stocking densities. Production ranged from 159 kg/ha to 832 kg/ha for 140 – 163 days of culture with stocking densities 1.25, 2.5, 4.9 and 7.4/ m².

Popper and Davidson (1982) also conducted preliminary experiments in 1979 to rear *M.rosenbergii* in brackishwater (PL 14, 2.5 Nos./ m²) and the results indicated that prawn grows best in salinities of 10 to 15 ppt. The results of this observation suggested a good potential for the culture of *M.rosenbergii* in brackish water.

During 1975 – 1979, Smith *et al.* (1982) conducted five non-replicated rearing trials to examine the effect of various salinities (range similar to 5 – 15 ppt) on growth and survival of *M.rosenbergii*. Prawns reared at higher salinities (13.0, 15.3 ppt) also exhibited growth and survival rates, which appeared similar to those observed in freshwater ponds.

Sadek and El-Gayar (1995) studied the effect of using agricultural drainage water with salinity ranging from 4 to 6 ppt, total hardness 900 to 1500 ppm and total alkalinity 115 to 130 ppm on the growth rate of *M.rosenbergii* in earthen ponds. Different stocking levels (1 and 2 prawns/ m²) were used in earthen ponds and the daily individual weight increment of prawns was determined after 155 days. There was no significant difference in growth among the prawns stocked at both densities.

2.7 Substrates

Smith and Sandifer (1979) examined the spatial and temporal behaviour of juvenile *M.rosenbergii* in a variety of habitat configurations and materials in intensive nursery system. Of the configurations tested a layered habitat design was preferred. A significant preference for edge or perimeter areas of solid layer habitat units was displayed by the prawns. No temporal movements were observed on the habitats during daylight hours but the prawns generally exhibited a preference for darkened tank and habitual areas.

Ra'anan *et al.* (1984) compared the performance of prawn in ponds with and without substrates by stocking nursed juveniles (0.5g) at a density of 15Nos./m² for a growout period of 184 days. Yields of marketable size prawns were 24% higher in ponds with substrates and survival also increased by about 10%.

Cannibalistic habit of *M.rosenbergii* in intensive culture was studied by Nair *et al.* (1999) in a semi – recycled freshwater system under varying environmental conditions. They observed on moulting rate, mortality rate, tube occupancy and substrate preference under different light intensities and their inter and intra relations were studied. The morphometry of the animals was studied to understand the damage or loss of appendages due to cannibalism and its trend of variation in relation to number of tubes as hideouts in intensive culture. Cannibalism appeared to be independent of the physical surroundings and the animals were found more susceptible to cannibalism soon after the moult. This could be guarded by suitable hideouts. Dried commercial feed alternated with fresh animal tissues was found to reduce cannibalism up to 70%.

The response of freshwater prawns to increasing amounts of artificial substrate was evaluated in ponds by Tidwell *et al.* (2000). Juvenile prawns were stocked at 74,000Nos. /ha (7.4/m²). Artificial substrate in the form of horizontal strips of polyethylene “constructed fence” was added to ponds to produce 40% or 80% increase in available surface area. Increasing availability of surface area produced a direct linear increase in total production with no significant change in average weight. There was an inverse linear relationship between available surface area and feed conversion ratios likely indicating increased availability of natural foods or reduced stress among animals.

Tidwell *et al.* (2001) conducted a series of studies for five years and evaluated the effects of added substrate on prawns stocked at different densities, effects of varying amount of substrate and the impact of substrate orientation. In this series of studies production rates have been increased from an average of 1,000kg/ha at the beginning in ponds with no substrate to

average production rates in excess of 2,500kg/ha with larger average sizes and improved FCR in ponds with added substrate.

Previous studies of Tidwell *et al.* (2000) demonstrated a direct linear relationship between production intensity (kg/ha) and amount of added substrate. However increase in substrate greater than 80% have not been practicable with multiple layers of substrate installed in horizontal orientation. Vertical orientation could allow higher inclusion rates, but might not be useable by prawns, which had recently moulted.

Tidwell *et al.* (2002) compared the effectiveness of substrates (in the form of polyethylene fencing) oriented horizontally or vertically and evaluated the impact of increasing amounts of vertical substrate (0,50 and 100%) on prawn production. Juvenile prawns were stocked in ponds at 65,000/ha (6.5/m²) reared for 106 days. The data indicated that orientation does not impact substrate effectiveness in ponds and that increasing amounts of added substrate continue to increase prawn production up to at least an increase of 100% in available surface area.

2.7.1 Effects of substrates on population structure

Tidwell *et al.* (1998) studied the effects of added substrate on the production and population characteristics of prawns in ponds. Juvenile prawns were stocked at a density of 59,280 Nos./ha and artificial substrate consisted of PVC frames with horizontal plastic mesh and vertical suspended seines was added to increase available surface area approximately by 20%. At harvest average individual weight, daily yield and total yield were significantly higher in ponds with added substrate (37g, 12kg/ha daily and 1268 kg/ha respectively). In ponds without substrate, the number of small males (SM) was significantly higher and the number of orange clawed males (OC) was significantly lower than in ponds with added substrate.

Tidwell *et al.* (1999) evaluated the effects and interactions of added artificial substrate with different stocking densities of prawns at 60,000 and 1,20,000 Nos./ha. Added substrate consisted of horizontal plastic mesh and strips of oyster netting sufficient to increase available surface area by about

80%. Increasing stocking density produced an increase in total production (18%) but a significant decrease in average prawn size and production of marketable size prawns (>20g-27%; >30g-56%). However, average prawn size was not decreased and production of marketable prawns was increased (>20g -25%; >30g -19%) when the stocking density was 60,000/ha. The inclusion rates for added substrate should be based on desired levels of total production, stocking rates and optimum market sizes.

2.8 Shelters

To understand how social behaviour affected resource utilization by *M.rosenbergii*, Peebles (1979) conducted three experiments in which shelter was the limiting resource and relative size and prior residence were measured as variables. The results indicated that when prawns competed for shelter at least three factors, viz. relative size, prior residence and length of time contestants are paired, play important roles in determining who occupies a shelter. In a closed system the prior resident effect breaks down into simple size related dominance. These results offer a behavioural explanation for the known and recognized bull effect in culture ponds. Larger animals had preferential access to food and shelter, two important resources, which were often dispersed in a clumped or patchy fashion.

Chand (1999) studied the effect of hideouts on survival and production rate of *M.rosenbergii* in ponds for 9 months. Old PVC pipes of 3 inch diameter and 1.5 foot length were used as hideouts. The study comprised of four treatments with varying numbers of hide out, no hideout (T₁), 300 hideouts (T₂), 600 hideouts (T₃) and 900 hideouts (T₄). At the end of culture period, survival rate of prawns among treatments varied between 46-59% and mean weight was between 58.2 and 61.0g. It is estimated that a density of 2000 hide outs/ ha is optimal for commercial farming.

2.9 Pond aging

Most farmed prawns are cultured in earthen ponds in semi –intensive systems with added feed. Newly dug ponds have low biomass and diversity of microbial and macro invertebrate populations and therefore require adequate

fertilization programmes to improve the ponds natural productivity. Once established, ponds contain microbial and invertebrate populations that are of high nutritional value to the prawns. This study was conducted by Correia *et al.* (2002) to examine the effect of pond aging on natural food production and its availability and its influence on the growth performance of the prawn *M.rosenbergii*. Experiments were conducted in 50m² earthen ponds, which were treated with hydrated lime, followed by organic and inorganic fertilization to obtain adequate natural productivity level. PL were stocked in new ponds (age: 1-3 months) and in old ponds (ponds age: 8-10 months) at a stocking density of 80 and 72 animals /m² respectively. The improved growth in the old ponds was correlated with an increase in the density and diversity of benthic macro invertebrate, as evidenced by the increased numbers of zoobenthos and greater diversity of food items found in the stomach contents of the prawns. This work demonstrates a clear advantage of pond aging as applied to the culture of *M.rosenbergii* in earthen ponds.

2.10 Natural food

In a study by Tidwell *et al.* (1997a), forage organisms were identified as important natural foods for prawns in ponds, under controlled conditions. Juvenile prawns were stocked in 37.5litre aquaria at a density of 10 prawns per tank. The six dietary treatments tested were: unfed (negative control); commercially prepared diet (positive control); oligochaetes; chironomids; zooplankton and a combination of the latter three. There were no significant differences between the growth rate and survival among prawns in the five feed treatments. Selective retention of arachidonic acid (20: 4n-6), eicosapentanoic acid (22: 5 n-3) and docosahexanoic acid (22: 6n-3) in unfed prawns likely indicated the relative nutritional importance of these fatty acids. Comparisons of whole body fatty acid and amino acid concentrations of prawns and food organisms indicated that zooplankton and oligochaetes may have the most appropriate biochemical compositions as prawn food sources.

Tidwell *et al.* (1997b) evaluated prawn production rates in unfed, organically fertilized and fed pond systems. Population of benthic macro invertebrates that potentially served as forage organisms in these systems were also evaluated and compared with ponds without prawns and received

no nutrient input, to evaluate forage preferences. Juvenile prawns (0.36 g) were stocked into 0.04ha earthen ponds at a density of 39,520 Nos./ha. Average prawn yields in fed, fertilized and unfed ponds (1261,1056,426 kg/ha respectively) were all significantly different.

Walters *et al.* (2001) investigated the use of natural foods by freshwater prawns. Artificial as well as natural substrate, such as rooted aquatic grasses support the growth of attached algae and associated invertebrate organisms. Such organisms served as a natural food source for prawns. In this study, natural foods were collected from ponds during culture period in each of four culture treatments including a bare mud control pond (unstocked); a vegetated mud control pond (unstocked); a bare mud prawn pond and a vegetated mud prawn pond. Several major groups of natural foods were available in ponds, with chironomid midge larvae and oligochaete worms being the most abundant. The consumption of natural foods by freshwater prawns was indirectly assessed by comparing natural food assemblages found in ponds stocked with and without prawns.

2.11 Harvesting methods

Siddiqui *et al.* (1995) evaluated the effect of harvesting methods (cull and batch) on population structure, growth and yield of *M. rosenbergii*, cultured at two densities (5/m² and 10/m²) for 196 days. Females (67.4%) were more abundant than males (32.6%) but there was no effect on harvesting methods and stocking rates on sex ratio. They concluded that harvesting method had no effect on yield at any density.

Two culture strategies viz. single stocking with drain harvest and single stocking with cull harvest were evaluated in the culture of *M. rosenbergii* by Jose *et al.* (2003) to assess the response in terms of growth, survival and production. The trials were conducted in manured earthen ponds of water depth 75-90cm over a period of 6 months at a stocking density of 4 Nos./m². In the cull harvest trial 11.42% (21.7cm/38.5g) and 14.25% (22.5cm /42g) of stocked prawns were culled on day 90 and 120 respectively, the remaining stock being reared further, till the end of culture period 6 months. Gross production was worked out to 903 kg/ha/6 months and 1360 kg/ha/6 months in the drain harvest and cull harvest trials respectively with the corresponding

overall survival rates being 60.92% and 70% respectively. The results clearly indicated the feasibility of cull harvest over drain harvest strategy in reducing size heterogeneity and eliciting enhanced production rates.

2.12 Economics

Liao and Smith (1983) conducted a survey in South Carolina, USA during 1982 to evaluate the economic potential of small-scale prawn farming. Based on survey data, total costs were estimated to be \$1,883.78 and total gross returns were \$2,041.69 per 0.4ha pond, thereby producing a net return of \$157.91/0.4ha. They also conducted a consumer survey and the majority of consumers indicated the preference for the headless form in the 57-110 tail count/kg size category.

Liao (1996) conducted a survey to evaluate the economic aspect of freshwater prawn farming in southern Taiwan. Based on survey data, larger farms were more profitable than smaller farms. Farm size, capital and management were significant factors affecting production of prawn. The results indicated that there existed a potential for achieving high productivity of prawn aquaculture through the adjustment of various resources and the adoption of improved practices.

Valenti and Sampaio (1996) quantitatively analyzed the culture of *M. rosenbergii* to determine the best productivity in biomass and profit. A 0.02ha earthen pond was stocked with 300 PL at a density of 1.5/m² and reared for 8 months. The estimated maximum biomass and profit were 402.5kg/ha and US\$912/ha, respectively.

An economic appraisal of freshwater prawn farming was made by Senthilathiban *et al.* (2001) by conducting a field survey from January to April 2000, among 25 randomly selected freshwater prawn farmers in Thanjavur district of Tamilnadu. The economic estimates indicated economic feasibility of freshwater prawn farming. The net returns per ha per crop were found to be Rs. 47,378 and the rate of return to investment was 45.34%.

2.13 Sex ratio

Tidwell *et al.* (1994) studied the population structure and weight distribution of *M.rosenbergii* raised in monoculture and fed diets containing different protein sources in earthen ponds under cool water conditions. Prawns weighing $0.5 \pm 0.3\text{g}$ were stocked in 0.02 ha ponds at 4 Nos./m² and reared for 110 days. At harvest, percentage distribution by number and weight of three male morphotypes (blue claw, orange claw and small male) and two of the three female morphotypes (berried and open) were not significantly influenced by diet. The percent contribution of virgin females by weight was significantly higher in prawns fed diet containing 7.5% fish meal. The male / female ratio ranged from 2.5 to 5.3 among treatments and averaged 3.0 overall. Combined data collected from all 9 ponds indicate percentage contribution of biomass by small males was low (1.1%) and by orange claw males was high (71.0%). Among harvested prawns, >88% exceeded 30g and 96% exceeded 20g wet weight.

2.14 Culture systems

2.14.1 Intensive monoculture

Ra'anan *et al.* (1985) conducted experiment in earthen ponds stocked with juvenile prawns averaging 1.5 to 2g size at a density of 10/m². The ponds included substrates in the form of horizontally hung plastic nets along the banks and aerators (1/3hp), which were activated only at night. Selective harvesting of marketable size prawns was initiated 57 days after stocking and were carried out at two week intervals. Altogether seven harvests were made prior to the final drainage of the ponds. By the end of 176 days, pond yielded 2,064 kg/ha prawns, averaging 33.4g.

2.14.2 Sewage fed wet lands

Ali *et al.* (1993) attempted the culture of *M.rosenbergii* in primary and secondary oxidation ponds to explore the feasibility of domestic waste stabilization ponds for prawn culture along with fish. The results indicated that biologically treated domestic sewage due to its highly rich food web, offered excellent opportunities for culture of the prawn without any supplementary feeding.

Ghosh *et al.* (2002) reported *M.rosenbergii* as a possible candidate species for rearing in sewage fed wet lands. This species demonstrated relatively high adaptability and can be regarded as a candidate for introduction into sewage fed wet lands.

2.14.3 Temperate culture

An over view of recent research and development in temperate culture of the freshwater prawn *M.rosenbergii* in the South Central United States was given by Tidwell *et al.* (2005). Culture of *Macrobrachium* in temperate zones offered positive opportunities, despite the inability to culture year-round. Recent research in the South and Central USA was directed towards intensifying production (kg/ha) without decreasing average harvest sizes or deteriorating water quality. Particular areas of research include evaluating and maximizing the relative contributions of natural foods, effects of artificial substrates on growth and prawn population structure and grading of animals before pond stocking to reduce heterogeneous individual growth and aggressive interactions.

2.15 Reproductive potential of male morphotypes

Sureshkumar and Kurup (1998b) conducted a comparative study on the reproductive potential of male morphotypes in broodstock rearing and larval production. This study was aimed at delineating the reproductive activity of three male morphotypes and also at optimizing the sex ratio in broodstock rearing. Best result was obtained in respect of oviposition, hatchability of eggs and survival of larvae in trials conducted with BC males when the ratio was maintained at 1 BC male: 4 females.

2.16 Fatty acids composition

Nutrition with polyunsaturated fatty acids was studied in juvenile freshwater prawn by D'-Abramo (1993). Weight gain and survival responses and analyses of fatty acid composition of tissue were used to investigate the nutritional value of C18 and C greater than or equal to 20 polyunsaturated fatty acids (PUFA) and provided to juveniles of *M.rosenbergii* in a purified diet. All diets were formulated so as to have 6% lipid.

2.17 Comparison of prawn and shrimp in fatty acid and amino acid requirement

The nutritional requirements of the freshwater prawn *M.rosenbergii* were reviewed and compared with those reported for several species of marine shrimp (D'-Abramo, 1998). Most of the information has been derived from experiments with juveniles. A comparison of essential amino acid proportions between *M.rosenbergii* and penaeid species suggested only minor, if any, differences in requirements of essential amino acids. Qualitative and quantitative fatty acids requirements of the freshwater prawn were reflective of the lower n-3/n-6 polyunsaturated fatty acid (PUFA) ratio found in the body tissue. In contrast to marine shrimp, both classes of n-6 and n-3 PUFAs with more than 20 carbon atoms [$>20C$] were found to be equally effective in producing maximum weight gain responses in *M. rosenbergii*. Absence of dietary n-3 or n-6 PUFAs did not affect growth of prawn, but associated with a reduction in the weight of the midgut gland expressed as a percent of whole body weight.

2.18 Proximate composition

Labao *et al.* (1988) studied the meat yield and proximate composition in *M.rosenbergii*. The rate of the moisture, protein and ashes did not show significant changes on different size categories, showing average values of 76.24%, 20.26% and 1.22% respectively.

MATERIALS AND METHODS

The present experimental study was conducted at the Fisheries unit of Livestock Research station, TANUVAS, Kattupakkam, Kancheepuram District of Tamil Nadu.

3.1 Source of broodstock

The broodstock of *Macrobrachium rosenbergii* collected from Vembanad Lake, Kerala were used for the study. The animals weighing 65-125g were considered as small sized and those weighing 150-250g were considered as large sized brooder. The postlarvae produced from each size groups of brooders were collected for this study. The average body weight of smaller sized broodstock was 95g and the large sized brood stock was 200g.

From each group of brooders, the larvae settled on the first day and the seventh day were harvested and reared separately. The early settled post larvae and the late settled post larvae thus obtained from the hatchery were used for this study.

3.2 Experiment -I

3.2.1 Nursery rearing

The prawn seeds produced from hatcheries using wild brood stock were collected. The post larvae (PL) weighing 0.0196g to 0.054g were used for the present study. The PL were stocked in outdoor circular cement tanks of size 3.05 m diameter and 0.92 m height (area – 7.86m²). The stocking density of PL was maintained at 200 numbers/m². The details of experiment conducted are presented in Table1.

Table 2. Details of experiment on nursery rearing

Category of brooder	Category of Post Larvae	Stocking density (Nos./m ²)	Feed given	Codes used
Larger size berried female prawn	Early Settled Post Larvae	200	Commercial feed	LSES
	Late Settled Post larvae	200	"	LSLS
Smaller size berried female prawn	Early Settled Post Larvae	200	"	SSES
	Late Settled Post larvae	200	"	SSLS
Mixed Group of Post Larvae		200	"	MGPL

The depth of the water was maintained at 65cm $\pm$ 5cm. The initial body weight was recorded for each group of PL. The five groups of PL were reared separately. Duplicate tanks were maintained for each group. Commercially available freshwater prawn feed with 32% protein (Starter) was given twice daily at 8am and 4pm *ad libitum*. PVC pipes of 15cm in length & 3cm in diameter were used as shelters. These shelters were placed at the bottom of all tanks uniformly. The nursery rearing was conducted for 60 days with fortnightly sampling to assess growth rate. The freshwater obtained from the open well was used for the nursery rearing. The water quality parameters of the culture tank were analyzed using standard (APHA, 1980) procedures and the quality of water at the beginning of the experiment is given in Table 2.

Table 3. Water quality during nursery rearing

Sl. No.	Parameters	Value
1	pH	8.0
2	Electrical conductivity	0.99ms/cm
3	Total alkalinity	297.52ppm
4	Total hardness	97.84ppm
5	Chlorides	99.40ppm
6	Sulphates	52.32ppm
7	Sodium	91.08ppm
8	Potassium	0.78ppm
9	Sodium Absorption Ratio	2.2

The water quality parameters were recorded fortnightly during nursery rearing. Water exchange was done once in 10 days at 25% level. The proximate composition of the commercial feed used during the nursery rearing experiment is given below.

Parameters	Percentage
Crude Protein	32
Fat	3
Crude Fiber	12
Total Ash	18
Moisture	12
Nitrogen Free Extract	23

3.2.2 Grow out rearing

The nursery reared post larvae were stocked in earthen growout ponds. The five experimental groups were stocked separately with a stocking density of 4 numbers/ m². The area of the earthen ponds was 250 ± 15m². The hideouts were kept uniformly at the bottom of all the five ponds. The average body weight of juvenile prawns at the time of stocking was given below.

Experimental Groups	Average body weight (g)
LSES	3.07
LSLS	0.90
SSES	1.28
SSLS	0.74
MGPL	0.65

Water quality parameters such as dissolved oxygen, pH, temperature, total alkalinity and total hardness were recorded fortnightly during the culture period of four months. The quality of the pond water at the beginning of the experiment is given in Table 3.

Table 4. Water quality during growout rearing

Sl.No.	Parameters	Value
1	pH	7.7
2	Electrical conductivity	0.53ms/cm
3	Total alkalinity	148.84ppm
4	Total hardness	30.48ppm
5	Chlorides	103.66ppm
6	Sulphates	41.28ppm
7	Sodium	92.0ppm
8	Potassium	19.5ppm
9	Sodium Absorption Ratio	4.3

The analysis of the pond soil was carried out following the method of Tandon (2005) before the start of the experiment and after the growout rearing.

Commercially available freshwater prawn feed with the following proximate composition was used for the growout experiment.

Parameters	Grower	Finisher
Crude protein (%)	31.0	30
Fat (%)	3.5	3.0
Fiber (%)	8.0	8.0
Moisture (%)	12.0	12.0
Nitrogen Free Extract (%)	45.5	47.0

The prawns were fed twice daily at 8.00 hrs and 16.00hrs. Three feed trays were kept in each pond and the feed was supplied to the prawns in the feed trays.

Monthly samplings were done during the culture period using cast net and the growth of prawns was assessed. The body weight was measured using electronic balance with an accuracy of 0.01g. After 160 days of culture period, the prawns were harvested and the weight and sex ratio were recorded.

3.3 Experiment-II

The growth of blue clawed males, orange clawed males and runts (small males) was studied individually and in combination. The male prawns obtained from the experiment I were used for this study. The experiment was conducted in circular cement tanks of 7.86m² area each. The depth of water

was maintained at 70 ± 5 cm. The prawns were fed commercial freshwater prawn feed with 31% protein. The male prawns were stocked at the rate of 4 Nos./m² after recording their initial body weight. After a rearing period of 40 days, the conversion of male morphotypes and final weight were recorded.

Table 5. Average body weight of male morphotypes

Sl. No	Combinations of male morphotypes	Initial average body weight of experimental groups (g)
1.	Blue clawed males + Orange clawed males (BC + OC)	21.33 + 14.00
2.	Blue clawed males + Runts (BC + R)	13.00 + 3.67
3.	Orange clawed males + Runts (OC+ R)	8.33 + 3.33
4.	Blue clawed males + Orange clawed males + Runts (BC + OC+R)	14.50+10.00+4.50
5.	Blue clawed males alone	26.78
6.	Orange clawed males alone	22.47
7.	Runts alone	3.40

3.4 Experiment- III

The larger sized prawns and runts obtained from the first experiment were collected. The profile of amino acid and fatty acid of both the groups were studied. The commercial feed used for the first experiment was also analyzed for its fatty acid and amino acid profile.

3.4.1 Amino acid analysis

The amino acid profile of prawns and feed were analyzed at Central Institute for Brackishwater Aquaculture, Chennai.

The prawn tissue and feed sample were analyzed for amino acid composition by HPLC using SHIMADZU HPLC model LC-10A. The samples were hydrolyzed using 6N HCL under vacuum for 24 hrs at 110°C. At the end of hydrolysis, the acid was removed and samples were dried over NaOH in a desiccator. These samples were brought into the solution using the sample diluent, filtered through 0.4 micron membrane filter and used for injection. The qualitative and quantitative amino acids were determined against Sigma

amino acid standards by post column derivatization using orthophthalaldehyde (Yokotsuka and Kushida, 1983).

3.4.2 Fatty acid analysis

The fatty acids profile was analyzed by Gas Chromatography at Fisheries College & Research Institute, Thoothukudi.

The lipid was extracted from prawn muscle and feed by the method described by Folch *et al.* (1957). The extracted lipid was concentrated using rotary vacuum flash evaporator (Superfit, Model DB-3135, Mumbai) and 250mg of lipid was weighed and esterified into fatty acid methyl esters (FAME) using 5ml of BF₃ methanol (AOAC, 1995). Fatty acid composition was determined by gas chromatography technique following the method described by Candelda *et al.* (1996) with slight modifications.

Perkin-Elmer Autosystem XL Gas Chromatograph, USA, fitted with flame ionization detector (FID) and a fused silica capillary column (PE-225, 0.25mm ID and 30m length) was used for the separation and identification of fatty acids.

The operating conditions were injector temperature 250°C and detector temperature 300°C. A temperature gradient programme was followed with initial oven temperature set at 70°C for 1 min., which was then increased to 180°C at the rate of 3°C/min. and then to 220°C at the rate of 10°C/min. The carrier gas used was nitrogen at 20psi pressure. Peaks were identified by comparison of their retention times with those authentic fatty acid standard mixtures.

3.4.3 Proximate analysis

The moisture, crude protein, lipid, ash and crude fibre contents of test diets and the experimental animals (BC male and runt) were analyzed according to the standard procedures of Association of Official Analytical Chemists (AOAC, 1980).

Based on the results of fatty acid and amino acid analysis the nutrient requirement for the improvement of the runts was assessed. The feed

ingredients which possess those nutrients were identified. A quality test diet was formulated by using 33 ingredients. The composition of the test diet prepared was as follows:

Table 6. Composition of experimental feed

Sl. No	Ingredients	% of inclusion
1.	Soy flour	20.00
2.	Fish meal	20.60
3.	Crab meal	3.00
4.	Acetes meal	3.00
5.	Ragi	10.50
6.	Carrot	10.00
7.	Yellow pumpkin	5.00
8.	Cattle blood meal	2.50
9.	Poultry viscera meal	4.50
10.	Egg	7.50 (2Nos/Kg Feed)
11.	Barley	2.00
12.	Lime fruit	0.01 (1No./kg Feed)
13.	Ashwagantha powder	0.60
14.	<i>Cynodon dactylon</i> meal	1.00
15.	Virginiamycin	0.05
16.	Flavomycin	0.05
17.	Agar	0.10
18.	<i>Lactobacillus</i> powder	0.01
19.	Vitamin E and Selenium	0.50
20.	Turmeric powder	0.50
21.	Zeolite	0.20
22.	Soy lecithin	0.05
23.	Gum Arabic	1.00
24.	Vitamins and minerals mix	2.00
25.	Synthetic feed binder	2.00
26.	Safflower oil	2.50
27.	Olive oil	0.10
28.	Palm oil	0.10
29.	Coconut oil	0.10
30.	Sesame oil	0.10
31.	Garlic oil	0.10
32.	Beef tallow	0.05
33.	Cod liver oil	0.20

Table 7. Source of feed ingredients and purpose of their inclusion

Sl.No.	Ingredients	Source	Purpose
1.	Soy flour	Local shop	Plant protein source
2.	Fish meal	Poultry Research Station, Chennai	Animal Protein source
3.	Crab meal	Local shop	Animal protein source
4.	Acetes meal	Local shop	Animal protein source
5.	Ragi	Local shop	Carbohydrate source
6.	Carrot	Local shop	Vitamin A source
7.	Yellow pumpkin	Local shop	Pigmentation source
8.	Cattle blood meal	Local shop	Animal protein source
9.	Poultry viscera meal	Local shop	Animal protein source
10.	Egg	Local shop	Animal protein cum binder
11.	Barley	Poultry Research Station, Chennai	Beta glucan source
12.	Lime	Local shop	Vitamin C source
13.	Ashwagantha powder	Ayurvedic medical shop	Immune enhancer cum growth promoter and Protein source
14.	<i>Cynodon dactylon</i> meal	Ayurvedic medical shop	Growth promoter
15.	Virginiamycin	Pfizer Ltd, Mumbai,	Antibiotic growth promoter
16.	Flavomycin	Intervet	Antibiotic growth promoter
17.	Agar	S.D. Fine chemical Ltd, Mumbai	Binder
18.	<i>Lactobacillus</i> powder	Bushal Laboratories Pvt Ltd, Badlapur	Probiotic source
19.	Vitamin E and Selenium	Tetragon Pvt Ltd, Bangalore	Antioxidant and mineral source
20.	Turmeric powder	Local shop	Natural antibiotic source
21.	Zeolite	Local shop	Built-in metabolite remover
22.	Soy lecithin	Local shop	Lipid source
23.	Gum Arabic	Local shop	Binder
24.	Vitamins and minerals mix	Neospark, Hyderabad	Vitamins and minerals source
25.	Synthetic feed binder	Local shop	Binder
26.	Safflower oil	Local shop	Plant lipid source
27.	Olive oil	Local shop	Plant lipid source
28.	Palm oil	Local shop	Plant lipid source
29.	Coconut oil	Local shop	Plant lipid source
30.	Sesame oil	Local shop	Plant lipid source
31.	Garlic oil	Ranbaxy Ltd, Mumbai	Immunostimulant and herbal antimicrobial source
32.	Beef tallow	Local shop	Animal lipid source
33.	Cod liver oil	Vetcare shop	Animal lipid source

3.4 Experiment- IV

In the feed trial, the performance of experimental feed was compared with the commercial feed, which was used in the first experiment. This trial was conducted in outdoor circular cement tanks of 7.86m² each. The mixed group of postlarvae obtained from the mixed size group of wild broodstock were nursery reared for 60 days at a stocking density of 200 numbers /m². Water depth was maintained at 65 ± 10cm. Water exchange was carried out once in 20 days. The prawns were fed *ad libitum*, three times a day. PVC pipes (2 inches dia, 10 inches length) were placed as hideouts for prawns.

The growout rearing was carried for 120 days at a stocking density of 4 numbers /m² in outdoor cement tanks. The biogrowth parameters were recorded. The depth of water level was maintained at 65 ± 10cm level. The complete water exchange was given once in a month. The PVC pipes measuring 2 inch width and 10 inch length were placed at the bottom of the tanks as shelters. The prawns were fed *ad libitum* thrice a day. The daily feed input was apportioned into 25% (08.00 hrs), 25% (14.00hrs) and 50% (18.00hrs). In each growout tank three feed trays were provided with an area of 0.56 m² each. Feed was supplied to the prawns in the feed trays. The left over feed was removed and recorded.

3.4.1 Water quality analysis

Water temperature was measured using a thermometer with an accuracy of 0.1degree Celsius. The pH of the water sample was measured immediately after the collection using laboratory model Elico pH meter. Dissolved oxygen, water hardness and total alkalinity were determined following APHA (1980).

3.4.2 Biogrowth parameters

The following biogrowth parameters were calculated for evaluating the performance of experimental diet and commercial feed on the nursery and growout rearing of *M.rosenbergii*.

$$\text{Growth (\%)} \text{ or weight gain (\%)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100$$

$$\text{Food conversion ratio (FCR)} = \frac{\text{Feed given per prawn (g)}}{\text{Weight gain per prawn (g)}}$$

$$\text{Per day growth (g)} = \frac{\text{Mean weight gain (g)}}{\text{No. of days}}$$

$$\text{Specific growth rate (SGR)} = \frac{\text{Log}_e \text{ final weight} - \text{Log}_e \text{ initial weight}}{\text{Experiment days}} \times 100$$

$$\text{Survival (\%)} = \frac{\text{No. of prawns survived at the end of the experiment}}{\text{No. of prawns stocked at the start of the experiment}} \times 100$$

3.5 Statistical analysis

The data collected were subjected to one way analysis of variance (Completely Randomised Design) following the methods of Snedecor and Cochran (1980).

RESULTS

A total of four experiments were carried out on freshwater prawn *M. rosenbergii* in nursery and growout systems. The biogrowth parameters such as mean weight gain, percentage weight gain, specific growth rate, per day growth and survival were studied in nursery and growout experiments and the results are presented here.

4.1. Experiment I: Growth performance of early settled and late settled postlarvae obtained from broodstock of two varying size in nursery and growout systems.

4.1.1. Nursery rearing

The biogrowth parameters recorded in this experiment were presented in Table 8. There was an increase in mean weight gain and percentage weight gain during nursery rearing. Among the 5 groups, LSES (early settled postlarvae from larger sized broodstock) showed the best performance followed by SSES, LSLS, SSLS and MGPL. The attractive trend of growth performance of LSES was depicted in Fig.2. The ANOVA test indicated that there was significant variation at 1% level among the treatments in the weight gain (Table 9) whereas, there was no significant variation among the treatments in survival (Table 9a). The biomass produced (g/m^2) was higher in LSES group and very low for the SSLS (late settled postlarvae from small sized broodstock) group (Table 10). Fortnightly weight gain of prawns in nursery phase was given in Table 10.

4.1.2. Growout rearing

The growth performance of five experimental groups was given in Table 12 and 15 and Fig.3. The performance of LSES was best followed by LSLS (late settled postlarvae from large sized broodstock). The mean weight gain obtained by LSES was $18.46 \pm 16.57\text{g}$ where as for SSLS it was $10.98 \pm$

7.47g only. The survival was also high for the group LSES with 75.28 ± 0.39 . The biomass produced (kg/m^2) was also high for LSES. The ANOVA test showed that there is significant variation at 1% level among the treatments in weight gain and survival (Table 14). The sex ratio of all the five groups was studied after growout rearing and the results are given in Table 13 and Figure 4. The male population was high (87 ± 0.24) in LSES followed by LSLS (77.27 ± 1.23) and MGPL (77.08 ± 1.30). The ANOVA test indicated that there was significant variation at 1% level among the treatments in percentage of male population (Table 14). The water quality parameters recorded during the growout experiment is given in Table 16. The macro and micronutrients of soil from the experimental ponds were also studied before and after culture and the results are given in Table 17 and Fig. 5 and 6. A significant raise in the level of nitrogen, potash and micronutrients was observed after growout prawn culture. Monthly observation on the average body weight of prawns in growout phase is given in Table 15.

4.2. Experiment II: Growth studies of blue clawed males, orange clawed males and runts (small males) individually and in combination.

The percentage conversion of various male morphotypes grown individually and in combination were studied and the results were presented in Table 18. The conversion rate was high for orange clawed (OC) males when they were reared alone and in combination with runts (Fig.7). The conversion of orange clawed males was very less (10 ± 4.70) when they were grown in combination with blue clawed males.

4.2.1. Growth performance of Blue Clawed (BC) males

The growth performance of blue clawed males in combination with other male morphotypes were studied for a period of 40 days and the mean weight gain, percentage weight gain and SGR assessed were given in Table 19. The percentage weight gain of blue clawed males was high when they were grown in combination with orange clawed males and runts (Fig.8).

4.2.2. Growth performance of Orange Clawed (OC) males

The biogrowth parameters such as mean weight gain, percentage weight gain and SGR of orange clawed males were studied individually and in combination with other male morphotypes and the values are given in Table 20 and Fig. 9. The percentage weight gain of orange clawed males was high when they were reared alone (68.83 ± 1.25) and in combination with r₆₇ (69.54 ± 0.90).

4.2.3. Growth performance of runts (Small males)

Mean weight gain, percentage weight gain and SGR of runts were studied and the results were given in Table 21. The percentage weight gain of runts individually and in other combinations is given in Fig.10. Runts showed maximum weight gain when reared with orange clawed males than when reared exclusively as runts.

The overall mean weight gain of all the three male morphotypes when reared individually and in combination with other male morphotypes were presented in Table 22. The maximum overall mean weight gain percentage was observed in blue clawed males + runts combination followed by blue clawed males + orange clawed males + runts. The growth performance of runts reared in combination with orange clawed males was very high followed by blue clawed males + orange clawed males + runts.

4.3. Experiment III: Study on amino acid and fatty acid profile of large sized prawns, runts and the commercial feed used.

4.3.1. Study on amino acid profile of large sized prawns, runts and the commercial feed used

A total of 15 amino acids were detected in large sized prawns, runts and also in commercial feed used and the results are presented in Table 23. The pictorial representation is given in Fig.11. The result indicated that the commercial feed contained more amount of glutamic acid than the requirement of prawns. It was also observed that the feed contained relatively more quantity of almost all the amino acids than the prawns have. The pattern of amino acids of both large prawn and runts showed a very low degree of

variation. The percentage availability of amino acids in prawns and feed is given in Table 24.

4.3.2. Study on the fatty acid profile of large sized prawns, runts and commercial feed used

The fatty acids detected in the large prawns, runts and commercial feed used are shown in Table 25. There were also unknown fatty acids found in the samples and the corresponding values are given in Table 25a. The profile of known and unknown fatty acids of large prawns, runts and commercial feed are depicted in Figure 12, 13 and 14 respectively.

A comparative view of the fatty acids of all the three samples could be clearly observed from Figure 15. The significant difference in percentage availability of known and unknown fatty acids are given in Table 26 and 26a. There was a significant difference in the percentage availability of stearic acid, oleic acid, palmitic acid, linoleic acid, arachidonic acid and myristic acid between large prawns and runts. The commercial feed showed very high amount of palmitic acid and myristic acid than the requirement of prawns.

The proximate composition of blue clawed males, runts and commercial feed used are given in Table 27. The runts possessed a little more amount of protein and fat than blue clawed males.

4.4 Experiment IV: Formulation and evaluation of feed to find out its suitability for the production of large size prawns in higher numbers.

4.4.1 Formulation of feed

The level of palmitic acid, stearic acid, oleic acid, linoleic acid and arachidonic acid were found to be high in large sized prawns when compared to runts. Ingredients such as palmoil, beef tallow, olive oil, safflower oil and cod liver oil which are rich in these fatty acids respectively were incorporated in the formulated feed. In the case of amino acids the level of arginine was high in large sized prawns than in runts. Ingredients such as chicken egg and soy flour were incorporated in the test diet to promote adequate arginine.

Apart from these, the other ingredients needed for a basic and quality feed were also incorporated. The list of ingredients included in the experimental diet and their source is given Table 6 and 7.

4.4.2 Evaluation of experimental feed

4.4.2.1 Nutrient analysis

The amino acid profile of the experimental diet was tested and the results are given in Table 28. A comparative view of the amino acid profile of large prawns, runts and experimental feed is given in Figure 16. The experimental feed contained very high amount of leucine than the prawns required where as the commercial feed contained very high amount of glutamic acid (Fig.11) than the prawns required. The experimental feed possessed lesser amount of glycine, tyrosine and phenylalanine than the requirement of prawns.

The fatty acid profile of experimental feed was furnished in Table 29. The number of known and unknown fatty acids detected was 9 and 7 respectively. The profile of fatty acid of experimental feed is shown in Fig.17 and a comparative view of fatty acid profile of large prawns, runts and experimental feed is given in Fig.18. The test diet contained 24.41% of n-6 fatty acid than the commercial prawn feed (1.59%) due to inclusion of safflower oil that is rich in n-6 fatty acid – linoleic acid. The higher level of n-6 fatty acid than n-3 fatty acid, which is the primary need of freshwater prawn was fulfilled by the test diet prepared in the present study.

The calorific value of the experimental feed was 468.332 Kcal /100g. The proximate composition of the experimental feed was evaluated and the results is depicted in Table 29.

4.4.2.2 Feed trial

Trials were conducted to evaluate the formulated experimental diet both in nursery and growout rearing. The mean weight increment, SGR and biomass produced are furnished in Table 31. The average body weight recorded during the culture period is shown in Table 33 and the growth of prawns fed with commercial and experimental feed is depicted in Fig.19. The survival, FCR and percentage of runts of experimental groups fed with

commercial feed and experimental feed is presented in Table 34. The ANOVA test showed that there was no significant difference between both the diets in weight gain and FCR (Table 32). There was significant variation at 1% level among the treatments in the percentage of runt population and at 5% level among the treatments in SGR (Table 32a). The comparison of biogrowth parameters of prawns fed with both the diets is depicted in Fig.20. Though the prawns fed with test diet showed higher weight increment, statistically there was no significant variation between the treatments. The water quality parameters recorded during the feed trial is given in Table 35.

SUMMARY

The present study was designed with four experiments to assess the growth performance of Macrobrachium rosenbergii in nursery and growout systems.

The prawn seeds produced from hatcheries using wild broodstock were collected. The seeds thus collected represented five groups viz., early settled PL (Group 1 – settled on first day) and late settled PL (Group 2-settled on seventh day) from large sized berried female prawns (150g to 250g size), early settled PL (Group 3) and late settled PL (Group 4) from small sized berried female prawns (65g to 125g size) and mixed group of PL (Group 5- settled between 1st to 7th day) from berried female prawns of size varying from 65g to 250g. All the 5 groups were reared separately in nursery for 60 days at a stocking density of 200 PL/m². The growout experiment for all the above five groups was carried out separately in earthen ponds for 120 days at a stocking density of 4 Nos./m². An internationally reputed commercial feed meant for freshwater prawn farming was used for both nursery and growout rearing. After the growout period, the growth performance and sex ratio were studied for each group.

In the case of PL group obtained from small sized berried female prawns, the percentage of male population (assessed after six months of rearing) was 74.23 and 62.23 in early settled and late settled PL respectively. In large sized berried female prawns, the corresponding values were 87.27% and 77.27% in early settled and late settled PL respectively. For the mixed group of PL, the male population was 77.08%. At the end of the growout culture, the mean body weight of the prawn obtained from early settled and late settled PL were 12.91g and 11.72g for small sized berried female prawns and 21.53g and 18.3g for large sized berried female prawns. For the mixed group the mean body weight of prawn was 13.3g. Based on results of the present study, by stocking the early settled PL obtained from large sized berried female prawns, the prawn production could be increased to 70.92%. The prospective prawn farmers aiming at production maximization could

utilise this category of premium quality seeds for better returns. The hatchery owners should also produce and sell such “premium quality” seeds for better and mutual remuneration and for spurring up the demand for such ‘quality seeds’ (in the current scenario of poor demand for poor quality seeds). “Broiler prawn” concept could be mooted by capitalizing this finding in order to revive the prawn farming industry.

The growth rates of blue clawed males, orange clawed males and runts (small males) were studied individually and in combination. The conversion of small male to orange clawed male and orange clawed male to blue clawed male was observed. In the absence of blue clawed male, the conversion of orange clawed male to blue clawed male was found to be high. The conversion of orange clawed prawns to blue clawed prawns was 13.33% when the orange clawed prawns were reared in combination with blue clawed prawns. On the other hand, the conversion of orange clawed males was as high as 90% when orange clawed males were reared in combination with runts. *When orange clawed male prawns alone was reared, 100% conversion of orange clawed males to blue clawed males was observed. When the runts were reared exclusively, 10% of runts showed conversion to orange clawed males, in the absolute absence of hierarchical pressure from orange clawed males and blue clawed males. The present finding emphasized the need for periodic culling of blue clawed males from culture system, so as to enable the orange clawed males to metamorphose into the blue clawed prawns, thereby enhancing the yield potential.*

The profile of amino acid and fatty acid of runts and large sized prawns after 120 days of culture were comparatively studied. The amino acid and fatty acid profiles of the commercial feed used were also studied. Based on these comparative studies, the nutrient requirements especially amino acids and fatty acids needed for the improvement of runts were identified. The level of palmitic acid, stearic acid, oleic acid, linoleic acid and arachidonic acid were found to be high in large sized prawns when compared to runts. Ingredients such as palm oil, beef tallow, olive oil, safflower oil and cod liver oil that are rich in these fatty acids respectively were incorporated in the formulated feed.

In the case of amino acids the level of arginine was high in large sized prawns than in runts. The ingredients such as chicken egg and soy flour were incorporated in the test diet to meet out the arginine requirement of the runts. Apart from this, the other ingredients needed for a basic and quality feed were also incorporated. Thus a quality test diet was prepared in a scientific way with 33 ingredients. The profile of amino acids and fatty acids of the experimental feed was also studied. The experimental feed thus prepared showed 24.41% of linoleic acid (C18:2 n-6) of total fatty acids as against the commercial prawn feed with just of 1.59% of linoleic acid, due to the inclusion of safflower oil (which is rich in linoleic acid). The higher level of n-6 fatty acid than n-3 fatty acids, which is the primary need of freshwater prawn, has been fulfilled in the test diet prepared in the present study.

Trials were conducted to evaluate the test diet in the nursery for 60 days with the mixed group of PL from the mixed size group of broodstock. The nursery reared juveniles obtained from these groups were individually cultured in growout for 120 days. In the feed trial, performance of the above said experimental feed was compared with an internationally renowned commercial prawn feed available in the market. The protein, fat and calorific value of the test diet were 34.31%, 9.38% and 4683.32 calories/g respectively at a moisture level of 4.46%. The mean body weight was 11.1 g and 12.98g for the prawns fed with commercial feed and experimental feed respectively. The food conversion ratio (FCR) was 2.55 and 2.43 for prawns fed with the commercial feed and experimental feed respectively. The percentage of runt was relatively less (9.4%) in the case of prawn group fed with experimental feed whereas, the prawn group fed with the commercial feed produced relatively higher percentage of runts (18.25%). Hence the objective of designing a feed to improve the growth of runts was fulfilled and the feed gave good results in the production of large sized prawns in higher numbers.

In addition to the above benefits, the experimental feed designed in the present study gave 13.29% higher net prawn production in growout prawn culture (827.31 kg/ha/yr) when compared to market leading commercial prawn feed (730.28 kg/ha/yr). The cost of

production of the experimental feed designed in the present study was also found to be competitive / attractive even admixture usage of 33 valuable ingredients. The cost of experimental feed worked out to Rs.34/kg, as against Rs.37/kg for the commercial prawn feed available in the market. Future line of work to further improve the performance of test diet was also discussed.

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* Originals not referred.