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Comparison between kuruma shrimp, *Marsupenaeus japonicus*, Bate (1888) cultured in monoculture system and polyculture system with red tilapia *Oreochromis spp* fingerlings

Abstract

Post larvae of Kuruma shrimp, *Marsupenaeus japonicus* (PL25) were stocked at 10shrimp/m^2 (MC) in nine concrete ponds (4.0mx6.0mx1.25m, total area 24.0m^2) filled up with seawater at a salinity of 38ppt. Kuruma shrimp were stocked with Red tilapia *Oreochromis* spp fingerlings (4.0g±0.5) collected from the marine hatchery of MRC. Red tilapia were stocked at 0.25g (PC1) and 0.5g (PC2) fingerlings/m^2 in the polyculture treatment ponds with shrimp larvae. Results showed significantly differences ($P<0.5$) in body weight of *M.japonicus* cultured in MC system in comparison with PC1 and PC2 systems. The best food conversion ratio FCR (wait/gain) was for those shrimp cultured in MC. No significantly differences were observed in PER and PEP between shrimp cultured in the three evaluated systems. The juveniles cultured in MC system had significantly ($P>0.05$) higher survival values than juveniles cultured in PC1 and PC2. Final BW, weight gain WG and weekly growth rate WGR of Juveniles cultured in PC1 system were higher than Juveniles cultured in PC2 system. Survival rate of red tilapia cultured in PC system was 100% in both PC1 and PC2 systems.

Keywords: kuruma shrimp, red tilapia, polyculture system

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Introduction

Kuruma shrimp, *Marsupenaeus japonicus* Bate1 is one of the most important marine shrimp species.[1] its production technology began in japan and transferred to China, Southeast Asia, India and Latin America. Several factors have limited the growth and expansion of the marine shrimp *Marsupenaeus japonicus* farming industry .[2]

Shrimps consume detrital aggregates, including bacteria and meiofaun including protozoa, micro-algae, zooplankton, macrobenthos and other items.[3-5] The widely diverse feeding behaviors offer possibility to culture shrimp in polyculture as either the main species or a secondary species.

Tilapia are among very few domesticated finfish species that feed on natural foods of low trophic level, such as detritus and plankton, and they can grow in saline water after proper acclimation, so they appear to be the most appropriate choice for a shrimp–fish polyculture system. Akiyama and Anggawati[6] reported that yields of shrimp increased when red tilapia (*Oreochromis* spp.) were stocked into black tiger shrimp (*Penaeus monodon*) ponds. They believed that red tilapia might have assisted shrimp performance by improving and stabilizing water quality and by foraging and cleaning the pond bottom and by having a probiotic type effect in the pond environment.

Shrimp polyculture is an old practice and might have evolved from early extensive shrimp systems in which fish species such as tilapias (*Oreochromis* spp.)[7-9] and bivalves[9] were done with the purpose of increasing overall production and controlling water quality.

Shrimp-tilapia polyculture or green water culture technique is a culture system to produce shrimp and tilapia in the same pond in order to benefit from water column and pond space.[10] In shrimp-tilapia polyculture system, from the disease aspect, Tilapia consume dead shrimp and small crustaceans found in the ponds,[11] reduce bacteria and pathogen. Also, tilapia do not carry or transfer viral diseases of shrimp that cause risks for that industry around the world.[12]

Shrimp-tilapia polyculture system can improve shrimp survival and growth via disturb bottom sediments to a greater degree than shrimp during feeding and nest-building activities. Disturbing the bottom improves oxidation of the substrate and interrupts the life cycles of shrimp pathogens and parasites.[13] Akiyama and Anggawati[6] reported that red tilapia assisted shrimp performance by improving and stabilizing the water quality, by foraging and cleaning the pond bottom and by having a probiotic type effect in the pond environment. Tilapia, as a filter feeder, can reduce excessive phytoplankton biomass in later stages of pond culture and recycle nutrients effectively.[14] So, shrimp-Tilapia polyculture may provide an opportunity to develop a sustainable aquaculture system.[15]

A production strategy that combines two or more complementary species can increase productivity by an adjustment in the food chain structure which is rearranged to make a better use of natural food, reducing the demand for artificial food.[16] A proper combination of ecologically different species at adequate densities will make the system more efficient because grazing pressure is distributed among different feeding niches and levels, and wastes from one species can be utilized by another.[17] It is commonly believed that polyculture gives higher production than monoculture in extensive and semi-intensive systems[18,19] and is considered to be more ecologically-sound than monoculture.[20] Other advantages of polyculture include less metabolic waste accumulation/pollution and possibly higher economic return.

Two experiments on intensive shrimp–tilapia polyculture were conducted by Yi et al.[21] in Thailand, which proved that positive interactions and mutual benefits did exist between black tiger shrimp and Nile tilapia (*O. niloticus*). Both shrimp yield and feed conversion ratio (FCR) were improved by presence of Nile tilapia in the system.

Tilapia-shrimp polyculture adoption has been expanded among producers in many countries, and some studies have been conducted to test the efficiency of these systems.[22-32]

Therefore, the present study aimed to evaluate the production of the Kuruma shrimp *Marsupenaeus japonicus* in monoculture and in polyculture systems with low and high density of red tilapia fish *Oreochromis spp*.

Materials and methods

Experimental facilities

Nine concrete ponds (4.0mx6.0mx1.25.0m, total area 24.0m^2) were used. Ponds were filled up with seawater supplied from a shallow seaside well at a salinity of 38ppt . The outlet of the ponds were screened with net to prevent shrimp and fish escape from the tested ponds. Air blower (7.5 HP) was used and operated nightly to maintain DO levels above 5.0mg/L using PVC pipes. Daily water exchange rates were 10%.The chemical and bacteriological analysis of well water used in this experiment are presented in (Table 1).

Table 1 Chemical and Bacteriological analysis of well water used in the experiment

Parameter	Value
Temperature (C°)	26
Salinity (ppt)	38
Ph	8.2
DO (mg/L)	6
Turbidity (NTU)	25
Total bacterial count (Cell/ml)	NIL
Free chlorine (Cl_2, mg/L)	NIL

NTU: nephelometric turbidity unit

Experimental shrimp and stocking density

Post larvae of Kuruma shrimp, *Marsupenaeus japonicus* (PL25) were obtained from broodstock captured in Abo-Kir port, Alexandria (Mediterranean sea) Egypt. Broodstock were transported and spawned in Mariculture research Centre MRC. Larvae were fed on micro-algae, rotifers and artemia. Juvenile shrimp (0.2g±0.02) were stocked at 10shrimp/m^2 in both monoculture (MC) and polyculture (PC) system. Red tilapia *Oreochromis* spp fingerlings (4.0g±0.5) collected from the marine hatchery of MRC were stocked at 0.25 fingerlings/m^2 (one fish/4m^3) in a system (PC1) and 0.5 fingerlings/m^2 (one fish/2m^3) in a system (PC2) in the polyculture treatment ponds with shrimp juveniles.

Feeding rates and sampling collection

Shrimp juveniles were fed for 60 days with commercial feed containing 45% crude protein purchased from Skreeting Co. Egypt, at rate of 15%/culture biomass. Feeding frequency was 4 times daily at 16.00h, 20.00h, 24.00h and 4.00h. Samples were taken every 15 days to determine the mean weight of the fish and shrimp using an electronic balance and returned to the pond after weighing.

Analytical methods

Chemical composition of feed

Proximate analysis of feed was determined according to AOAC (1990)[33] for crude protein, ether extract, ash, and crude fiber. Nitrogen free extract was calculated (Table 2).

Table 2 Chemical composition of the commercial feedused in the experiment

Proximate analysis %	Value
Dry matter) % of DM basis(	93.70
Crude protein	45.20
Crude lipids	11.00
Crude fibers	2.01
NFE[2]	29.79
Ash	12.00
GE[3] (kcal/100 g feed)	484
ME[4] (kcal/100 g feed)	399
P/E[5] ratio (mg CP/kcal ME)	113

1. Nitrogen Free Extract.
2. GE(Growth energy) was calculated by factors of 5.65, 9.45, and 4.2 for protein, ether extract, and NFE, respectively.
3. ME (Metabolism energy) was calculated by factors of 4, 9, and 4 for protein, ether extract, and NFE, respectively (Garling and Wilson, 1976)
4. Protein to energy ratio=mg crude protein CP / kcal DE. (Digestible energy)

Water quality parameters

Dissolved oxygen , temperature , pH and temperature were recorded twice a day (08:00 h and 16:00 h) using Oxygen meter (WTW Model, 315 i, Germany). Total ammonia nitrogen (TAN) was recorded using Photometer PF-11. Unionized ammonia (NH3) was estimated according to Van-Wyk et al.[34] The turbidity was also estimated using Turbidity meter Cole Parmer, model 8391-45 USA. After the experimental period (60 days), shrimp and fish were harvested and randomly samples were collected to estimate the final weight.

Statistical analysis

Statistical analysis was carried out using a completely randomized design (CRD) according to.[35] All analyses were performed using the SPSS program (SPSS 16.0, 2007). Differences were subjected to Duncan's multiple range test[36] at 0.05 significance level.

Results

Shrimp culture experiment

Water quality parameters

The water quality parameters during the experimental period are illustrated in (Table 3). Results indicated that all water quality parameters were in the acceptable ranges for the kuruma shrimp. Also, results showed that no significantly differences ($P<0.05$) were observed between water quality parameters in monoculture and polyculture system during experimental period included salinity, temperature, pH, TAN, NH3.

Significantly differences were observed between turbidity and dissolved oxygen values in monoculture and polyculture systems. Turbidity value was 21.63NTU in shrimp monoculture system and increased to 22.83 NTU in Low density of red tilapia polyculture system compared to 26.50 NTU in high density of red tilapia in PC system. Dissolved oxygen values were 5.1mg/l in the water in MC system and increased to 5.4mg/l and 5.5mg/l in PC systems, respectively.

Growth performance

The results indicated that the shrimp cultured in MC system produced higher body weight than those cultured in the PC system (low and high red tilapia density). Data in (Table 4) showed

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Significantly differences (P<0.5) in *M.japonicus* body weight cultured in MC system (5.43g) in comparison with PC1 system (3.07g) and 1.70g in PC2 System). At the same time, weekly growth rate WGR values were 0.61, 0.33 and 0.18 for the MC system, low, and high red tilapia PC systems, respectively. In contrast, No significantly differences (P<0.05) were observed in SGR between the MC system and the PC system.

Feed utilization

The results of feed utilization of the kuruma shrimp cultured in monoculture, low and high density with red tilapia in polyculture systems illustrated in (Table 5). At the end of the experiment, the best food conversion ratio FCR was for those shrimp cultured in MC. FCR ranged from 2.58 to 3.05 for experimental systems. shrimp Juveniles cultured in PC1 and PC2 system, exhibited significantly (P>0.05) higher FCR values than juveniles cultured in MC system. No significantly differences were observed in PER and PEP between shrimp cultured in the three evaluated systems. PEP values were 86.21, 77.24, and 72.98 for shrimp cultured in the MC, PC1 and PC2, respectively.

Survival rate and final density

Survival (S%) of Kuruma shrimp *Marsupenaeus japonicus* juveniles is reported in (Table 6). It was observed that the juveniles cultured in MC system had significantly (P>0.05) higher Survival values than juveniles cultured in PC1 and PC2. It was found to be 76.67%. Survival rate decreased significantly (P>0.05) at juveniles cultured in PC2 it was found to be 40.56%.

Table 3 Water quality parameters for Kuruma shrimp, *Marsupenaeus japonicus* cultured in monoculture and polyculture systems with red tilapia *Oreochromis* sp

Item	Monoculture system (MCS)	Polyculture system (PCS)		SE
		Low fish density (0.25 fish/ m²) PC1	High fish density (0.5 fish/ m²) PC2	
Salinity (ppt)	38.00ᵃ	38.00ᵃ	38.00ᵃ	0.00
Temperature (°C)	29.50ᵃ	29.80ᵃ	29.80ᵃ	0.11
pH	7.97ᵃ	8.00ᵃ	8.00ᵃ	0.05
Turbidity (NTU)	21.63ᵃ	22.83ᵃ	26.50ᵇ	0.76
TAN (mg/l)	0.18ᵃ	0.20ᵃ	0.20ᵃ	0.004
NH3 (mg/l)	0.01ᵃ	0.01ᵃ	0.01ᵃ	0.00
D.O (mg/l)	5.1ᵃ	5.4ᵇ	5.5ᵇ	0.05
Photoperiod (D/L)	12/12ᵃ	12/12ᵃ	12/12ᵃ	0.00

*Values in the same row having a common superscript letter are not significantly different (*P*<0.05).

Table 4 Growth performance of the Kuruma shrimp *Marsupenaeus japonicus* cultured in monoculture and polyculture system with red tilapia fingerlings

Item	Monoculture system MCS	Polyculture system PCS		SE
		Low fish density (0.25 fish/ m²)PC1	High fish density (0.5 fish/ m²) PC2	
Initial weight (g)	0.20ᵃ	0.20ᵃ	0.20ᵃ	0.00
Final weight (g)	5.43ᵃ	3.07ᵇ	1.70ᶜ	0.55
Gain(g)	5.23ᵃ	2.87ᵇ	1.50ᶜ	0.56
Gain %	2617ᵃ	1433ᵇ	750ᶜ	273
WGR (g/week)	0.61ᵃ	0.33ᵃ	0.18ᵃ	0.06
SGR(%/day)	2.7ᵃ	2.7ᵃ	2.7ᵃ	0.00

*Values in the same row having a common superscript letter are not significantly different (*P* <0.05).

Table 5 Feed utilization of the Kuruma shrimp, *Marsupenaeus japonicus* cultured in monoculture and polyculture systems with red tilapia fingerlings

Item	Monoculture system	Polyculture system		SE
		Low fish density (0.25 fish/m²)PC1	High fish density (0.5 fish/m²) PC2	
Feed intake (kg)	13.50ᵃ	8.25ᵇ	4.58ᶜ	1.30
Protein intake (kg)	6.08ᵃ	3.71ᵇ	2.06ᶜ	0.59
FCR	2.58ᵃ	2.88ᵇ	3.05ᵇ	0.08
FE%	38.80ᵃ	34.76ᵇ	32.84ᵇ	0.96
PER	0.86ᵃ	0.77ᵃ	0.73ᵃ	0.02
PEP	86.21ᵃ	77.24ᵃ	72.98ᵃ	2.14

*Values in the same row having a common superscript letter are not significantly different (*p* <0.05).

Table 6 Survival rate and density of the Kuruma shrimp, *Marsupenaeus japonicus* cultured in monoculture and polyculture systems with red tilapia fingerlings

Item	Monoculture system MC	Polyculture system		SE
		Low fish density (0.25 fish/m²) PC1	High fish density (0.5 fish/m²) PC2	
Initial Number (Shrimp/tank)	240 ᵃ	240 ᵃ	240 ᵃ	0.00
Final number (Shrimp/tank)	184 ᵃ	149.3 ᵇ	97.43 ᶜ	9.73
Initial density (Shrimp/m²)	10 ᵃ	10 ᵃ	10 ᵃ	0.00
Final density (Shrimp/m²)	7.70 ᵃ	6.53 ᵇ	4.07 ᶜ	0.54
Survival rate %	76.67ᵃ	62.22 ᵇ	40.56 ᶜ	5.41

*Values in the same row having a common superscript letter are not significantly different (*P*<0.05).

Total production

Data in (Table 7) showed that the total production of shrimp at the MC system (999.1g/pond) was higher than PC1 and PC2 systems (458.4 and 165.6g/pond, respectively). Results also showed that, the total production per m2 was 0.04kg for shrimp cultured in MC system compared to 0.02 and 0.01kg/m2 in PC1 and PC2 systems, respectively.

Table 7 Growth performance of red tilapia *Oreochromis* sp. cultured in two densities with the Kuruma shrimp *Marsupenaeus japonicus* in a polyculture system

Item	Low density (0.25 Fish/m^2) PC1	High density (0.5 Fish/m^2) PC2
Initial weight (g)	4.2	4.2
Final weight (g)	18.2	12.3
Gain(g)	14.0	8.13
Gain %	333	194
WGR (g/week)	1.63	0.95
SGR(%/day)	2.5	1.8

Red tilapia culture experiment

Water quality parameters

The water quality parameters during the experimental period are presented in (Table 3). Results indicated that all water quality parameters were in the acceptable ranges for red tilapia fish. Also, results showed that no significantly differences ($P<0.05$) were observed between water quality parameters in PC1 and PC2 systems during experimental period included salinity, temperature, pH, TAN, NH3. Significantly differences were observed in turbidity values of PC1 and PC2 systems. Turbidity value was 22.83 NTU in red tilapia PC1 system and increased to 26.50 NTU in PC2 system.

Growth performance

The initial, Final, gain body weight and Specific growth rate SGR, of red tilapia cultured in low and high density systems shown in (Table 8). Final BW, weight gain WG and Weekly growth rate WGR of Juveniles cultured in PC1 system were higher than Juveniles cultured in PC2 system, they were 18.2g , 14.0g, and 1.63 respectively for PC1 system, and 12.3g, 8.13g and 0.95 respectively for PC2 system.

Table 8 Survival rate and density of red tilapia *Oreochromis* sp. cultured in two densities with Kuruma shrimp *Marsupenaeus japonicus* in a polyculture system

Item	Low density (0.25 fish/ m^2) PC1	High density (0.5 fish/m^2) PC2
Initial Number (Fish/culture unit)	6	12
Final number (Fish/culture unit)	6	12
Initial density (Fish/m^2)	0.25	0.5
Final density (Fish/m^2)	0.25	0.5
Survival %	100	100

Survival rate and final density

Data of survival rate of red tilapia cultured in low and high density in the polyculture system are illustrated in (Table 8). No mortality were observed during the experimental period. So, survival rate of red tilapia cultured in PC system was 100 % in both PC1 and PC2 systems.

Total production

Data in Table showed that the total production of red tilapia at PC2 system (147.6g/pond) was high than PC1 system (109.2g/pond). Results also showed that, the total production perm^2 was 0.005kg for tilapia cultured in PC1system and 0.006kg for the tested PC2 system.

Discussion

The main objective of this study is to compare the growth and survival rate of *Penaeus japonicus* in Monoculture system and in Polyculture systems with red tilapia *Oreochromis* spp. Our results indicated that the polyculture of shrimp and red tilapia significantly affect the shrimp growth, survival rate, and total production of shrimp. Also, results showed that survival rate during this study was better in monoculture than polyculture system (low and high density). Survival rate reached 76.67% in the monoculture and decreased to 62.22% and 40.56% in the low and high density polyculture systems, respectively. The same trend was found in the total production per m^2 which reached 0.04kg for the monoculture comparable with 0.02 and 0.01kg in the low and high density polyculture systems, respectively.

The present results are in disagreement with Akiyama and Anggawati[6] who indicated that survival rate and final pond production of shrimp were increased in polyculture system with red tilapia than monoculture system. Wang et al.[8] recommended that, in shrimp-tilapia polyculture, the best stocking rates were 7.2 shrimp/m^2, 0.08 tilapia/m^2 in the polyculture of Chinese shrimp (Penaeus chinensis). Yang and Kevin[13] and Peter and Robert[37] also recommended that the optimum stocking density of Chinese shrimp and red tilapia was 6 shrimp/m^2 and 0.32 tilapia/m^2.

Gonzales-Corre[38] found that stocking of 0.6 tilapia/m2 in shrimp ponds in a polyculture system improved the growth and survival rate of shrimp in ponds, while stocking tilapia in the same shrimp ponds in high density (0.9 tilapia/m^2) decrease shrimp performance and survival rate. Carlos, et al.[39] suggested that the positive effect of polyculture of shrimp and tilapia could be due to the addition of uneaten feed and undigested food particles excreted by tilapia that served directly as shrimp feed and as fertilizer to the pond bottom, while the negative effect caused by tilapia at the high density was probably due to competition for food and space. In addition, Akiyama and Anggawati,[6] Derun Yuan et al.[40] and Stephen[41] found that the positive effect of polyculture system may be due to improving and stabilizing water quality, cleaning the pond bottom, and having a probiotic type effect in the pond environment by red tilapia fish.

The major problem in our experiment is the low survival rate and the final production per m^2. The low survival rate in polyculture may be explained by the fact that in nature *M.japonicus* is a sandy bottom species, and the sandy bed is important in rearing period to protect them from enemies and cannibalism[42,43] in addition to the behaviour of the shrimp, while our study was conducted in concrete ponds. Derun Yuan[40] suggested that food competition might have happened in all polyculture treatments both among shrimp and between shrimp and tilapia, which might be a major reason for the retarded growth of shrimp in polyculture. He also recommended that the best shrimp production *Litopenaeus vannamei*, FCR and shrimp survival rate, and net profit were achieved in the polyculture System tanks with red tilapia stocked , that is not our result, Perhaps because of the different type of shrimp.

The type and quality of shrimp feeds is an important factor affect shrimp growth and reduce the mortality rate. The used feed in our experiments was commercial sea bass and sea bream fish feed.

Türkmen[44] and Julio and Fernando[45] tested different commercial shrimp feeds made in turkey and exported from Taiwan and found that *M japonicus* reached 7.05g in 150 days when it fed in Turkey feed, while shrimp reached 16.11g final weight at the same stocking density and same rearing period when it fed in Taiwan feed. In the other hand, it is known that shrimps are slow feeders and their feeds must remain stable in water for at least 2h[46,47] which can be consumed by red tilapia.[48,49]

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Conflicts of interest

The author declares that there are no conflicts of interest.

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