Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(5): 289 – 302(2023)
www.ejabf.journals.ekb.eg

The Effect of Water Depth on Efficiency of Freshwater Prawn (*Macrobrachium rosenbergii,* de Man) Culture in the Brackish Area

My Lan Lam*[1],Tam Hoang Liem Duc Vo[1], Nhut Long Duong[1], Thi Ngoc Anh Nguyen[1], Kurihara Akira[2], Ngoc Hai Tran[1]

[1] College of Aquaculture and Fisheries, Can Tho University, Vietnam
[2] Faculty of Agriculture, Kyushu University, Japan

***Corresponding Author: lmlan@ctu.edu.vn**

ARTICLE INFO

Article History:
Received: Nov. 15, 2022
Accepted: May 27, 2023
Online: Sept. 19, 2023

Keywords:
Macrobrachium rosenbergii,
Rice field,
Growth,
Yield,
Water depth

ABSTRACT

Investigating the effect of water depth on the efficiency of the giant freshwater prawn, *Macbrobrachium rosenbergii,* cultured in the rice field was conducted in a brackish water area with salinity level of 0 – 6g L^{-1}. The experiment was designed in triplicate with two water depths on the platform; depths varied between 0.3– 0.4 and 0.5– 0.6m for low and high water depths, respectively. Postlarvae (PL) 15 were stocked in the rice field at a density of 30,000 PL ha^{-1} for 180 days. The results showed that water quality parameters in both water depths were in the suitable ranges for prawn growth. However, temperature, dissolved oxygen, N-NH_4^+ and N-NO_2^- recorded better values in the high water depth compared to the low one. Furthermore, prawns cultured in low water depth had smaller final weight and lower survival and yield (39.6 g, 25.4%, and 292 kg/ha, respectively) than those cultured in high water depth (46.9 g, 30.5%, and 358 kg/ha). Significant differences (P <0.05) were detected between the two water depth treatments. A similar result was observed for net income, profit and cost-benefit ratio. These findings suggest that prawn culture in the rice fields in brackish water areas with high water depth (0.5– 0.6m) provided an optimal environment for prawns, improving the financial efficiency of the culture system. Whereas, low water depth (0.3– 0.4m) could be an alternative in times of water shortage in the prawn production cycle.

INTRODUCTION

The giant freshwater prawn *Macrobrachium rosenbergii* (de Man, 1879) is an economically valuable species for aquaculture because of its large market size, fast growth rate, diverse range of foods and feeding habits, tolerance to a wide range of environmental conditions, ease of controlled production and breeding under hatchery conditions in addition to higher survival from stocking to harvest **(New, 2002, 2005)**. The global aquaculture production of *M. rosenbergii* increased from 130,689 tons in 2000 to 273,738 tons in 2019 **(FAO, 2021)**, and the main freshwater prawn producing countries are concentrated in Asia, such as China, India, Bangladesh, Myanmar, Taiwan, Thailand

and Vietnam; however, *Macrobrachium* spp. are also cultured in other continents **(New & Nair, 2012)**.

The Mekong Delta in Vietnam, with an area of 3.9 million ha, is an important food producing region. Since 1980, integrated rice – prawn culture systems have relied on juvenile prawns collected from natural bodies of water **(Phuong *et al.*, 2003; New, 2005)**. Freshwater prawns have been considered an important targeted species in freshwater region for cultivation since hatchery reared postlarvae became available in 2000 **(Phuong *et al.*, 2003).** Vietnamese Directorial of Fisheries reported that the aquaculture production of *M. rosenbergii* in 2022 exceeded 20,000 tons. According to the Vietnamese Action Plan for giant freshwater prawn in 2020, the area of giant freshwater prawn farming reached 50,000 ha, and the production would reach 50,000 tons by 2025. Prawn–rice rotational culture system has rapidly developed in freshwater area such as Can Tho, An Giang and Dong Thap provinces **(Lan *et al.*, 2006a; Phuong *et al.*, 2006; Lan *et al.*, 2008)**. It is worthy to mention that, freshwater prawn could be cultured in coastal area **(Nair & Salin, 2006; Loc *et al.*, 2016; Hai *et al.*, 2017)**. Farming of giant freshwater prawn has expanded rapidly and largely to the brackish water area in the Mekong Delta, Vietnam (**Hai *et al.*, 2017; Son *et al.*, 2018)**. In this context, **New (2002)** and **Huong *et al.* (2010, 2015)** recommended salinity lower than 10ppt for freshwater prawn nursery and grow-out facilities. In this respect, **Chand *et al*. (2015)** mentioned that the prawns could grow and survive at salinity level of 0– 15ppt. Previous studies have found that water depth is one of the technical parameters influencing prawn growth and production in the rotational rice–prawn system, and that the water depth on the platform of the culture system should be kept as high as possible to improve production efficiency **(Lan *et al*., 2006a, 2006b; Hai *et al*., 2017)**. For the rotational prawn–rice farming in a semi-deep water area, water depth in the rice growing area fluctuated from 0.3– 0.5m in the dry season and from 0.6– 1.0m in the flood season **(Lan *et al.*, 2008)**. According to **Nair and Salin (2006)** in the state of Kerala, India, prawn juveniles were stocked in paddy fields during the flooding season as a rotating crop with rice. In Malaysia, prawn farming was mainly in ponds, with a major technical problem of a seasonal water shortage in some areas **(Banu & Christianus, 2016)**. Presently, the effects of climate change have been substantially manifested in the Mekong River Delta of Vietnam, which has resulted in drought and saline intrusion. Consequently, agriculture and aquaculture activities frequently face water shortage during the dry season **(CGIAR, 2016)**. In this scenario, it is difficult to maintain high water depth in the fields for prawn farming in brackish water areas. Therefore, prawn culture in the rice fields at low water depth treatment was conducted in order to evaluate the technical and economic efficiency for developing sustainable system in the brackish water area under the salinity intrusion.

MATERIALS AND METHODS

Study location and time

Freshwater prawns were cultured in brackish water area in Thoi Binh village, Thoi Bind district, Ca Mau province, Vietnam, affected by saline water driven from the East Sea and the gulf of Thailand. Due to high salinity in the present years, rice could not be cultured in the rainy season as the previous years. Therefore, prawn crop was recommended in the rice fields. The experiment lasted from July 2019 to January 2020.

Experimental preparation

Six rice fields with a 1ha area/ field were selected for prawn culture. The rice field was designed with a central platform and peripheral trench of about 20% of the total area, with a depth of 0.8m. Before stocking prawn, the rice fields were drained off, and quick lime (CaO) was spread over the trench at the rate of 1,000kg/ ha. After 3 days, the trench was filled with brackish water (3– 5g L^{-1}). When water depth in the ditch reached 0.8m, the organic fertilizer (low quality and low cost fishmeal) was added to the trench at a rate of 10 kg ha^{-1} to stimulate natural food development for prawns.

Experimental design and management

The experiment was designed in triplicate with two water depths on the platform; depths varied between 0.3– 0.4 (T1) and 0.5– 0.6m (T2) for low and high water depths, respectively. Postlarvae (PL) with the mean initial weight of 0.01 g were stocked in the rice filed at density of 3 PL/m^2 (**Lan *et al*., 2006a**) equivalent to 30,000 PL ha^{-1} for 180 days.

During the first 2 months, prawns were fed commercial feed (sinking pellet for black tiger shrimp containing 42% crude protein and 5% crude lipid, UP trade mark).From the third month onwards, prawns were fed a combination of commercial feed and trash fish (Nile tilapia, which was locally available). For example, in the third month, an alternative feeding regime was used for prawns, with 1 day of commercial feed followed by 1 day of trash fish, and from the fourth month to harvest, 1 day of commercial feed and 3 consecutive days of trash fish.

Feeding was done twice daily at 08:00 and 18:00 hours and feeding rates were 3 - 10% of wet weight per day based on feed consumption of prawns that were observed in the feeding trays at a haft hour after feeding. Water was exchanged every 15-20 days, with exchange rates of 20-30% the water volume in the fields.

Water quality monitoring

The water temperature and dissolved oxygen (DO) of the experimental fields were monthly monitored at 07:00 a.m. using a DO meter (OxyGuard Handy Polaris, Denmark). Water pH was monthly measured using a pH meter (OxyGuard Handy pH, Denmark). Salinity was measured by Refractometer ATC 0-100 ppt (China). Total ammonia nitrogen ($N\text{-}NH_4^+$), nitrite nitrogen ($N\text{-}NO_2^-$) and alkalinity were monthly tested (Sera test kit, Germany). pH meter was 0.01; DO meter was 0.1 mg L^{-1}; $N\text{-}NH_4^+$, $N\text{-}NO_2^-$ and alkalinity were 0.01 mg L^{-1} precision increment.

Densities of phytoplankton, zooplankton and zoobenthos were monthly sampled at 09:00 hours. The phytoplankton quantitative samples were collected via a bucket to collect samples from various sites in the field and put them in a 20L bucket, and then a 1L- bottle was taken to store the samples. With the use of a 20L- plastic bucket, zooplanktons were collected at numerous sites in the field; they passed through a net of a 60µm- mesh size. The samples were stored in 110mL- plastic bottles. The plankton samples were fixed with 4% neutral formalin solution.

The densities of phytoplankton and zooplankton were counted by the Sedgewick - Rafter counting chamber, following the method of **Boyd and Tucker (1992)**.

Benthic samples were collected with Petersen bucket and put into a bottom sieve (0.5mm mesh). Samples were put in plastic bags and fixed with formalin at 8- 10%. Zoobenthos density (individual m^{-2}) was determined by counting the number in groups.

Growth, survival and yield of prawn

To determine the growth performance, the initial and final mean weight of prawns as well as monthly weight were sampled by catch net. The weight of prawn were measured by randomly taking at least 30 prawns from the field using an electronic balance with an accuracy of 0.01g, and then the prawns were returned back to the original cultured fields. Growth data for experimental prawn included mean weight (g) & daily weight gain (DWG). During culture cycle, female prawns were daily observed in feeding tray and around the dyke of the rice fields in the morning to determine the date (day after stocking, DAS) when female matured. In addition, ratio of berried females among caught female during monthly sampling times was determined. After 180 days of culture, the water was drained out, and all prawns were collected by net and hand. All prawns were weighed to calculate survival (%), yield (kg ha^{-1}) and eFCR for pellet and trash fish in the wet weight of feed at the end of the experiment.

The variable costs included rice field preparation, seeds, materials, feed, fuel for pumping water, labor cost for prawn culture and miscellaneous. Depreciation (ditch construction, a 2-HP water pump (All Jet, Taiwan) and net, interest and maintenance were generated to fixed costs. The cost of rice field was not included as an initial investment in this study. Total operating costs, gross revenue, net income and cost benefit ratio of two treatments were compared.

Statistical analysis

The data were statistically analyzed using independent samples T- test through SPSS for Windows (version 20.0). The significant difference was considered at $P<0.05$.

RESULTS

Water quality performance

The mean values of some water quality parameters in two treatments during prawn culture are shown in Table (1). The temperature in the rice fields of T1 was 31.8 ± 0.2^{o}C (ranging from 29.6 to 33.9^{o}C) (Fig. 1), which was statistically significantly higher (P<0.05), compared to T2 (30.7 ± 0.1^{o}C, fluctuating from 29.1 to 32.8^{o}C). During the experiment, the mean pH value of two treatments was 8.1 and 8.4. The average salinity was 2.1 - 2.4 g L^{-1} (ranging from 0- 7g L^{-1}). At the beginning of October and November, salinity dropped to 0g L^{-1}, and it increased to 6 g L^{-1} in January 2020 (Fig. 1). The salinity and alkalinity were not significantly (P>0.05) different between the two treatments since the rice fields were filled by the same water supply canal. However, salinity in T2 was higher than that of T1, resulting from the more refilled water during prawn farming in T2. DO concentration in T1 was significantly(P<0.05) lower than that recorded in T2. Total ammonia nitrogen ($N\text{-}NH_4^+$) and nitrite nitrogen ($N\text{-}NO_2^-$) in T1 were significantly higher than in T2 (P<0.05).

Table 1. Water quality parameters for prawn culture in the rotational rice – prawn farming system at different water depth treatments

Treatment	T1 (0.3 – 0.4 m)	T2 (0.5 – 0.6 m)
Temperature (^{o}C)	31.8 ± 0.2^{b}	30.7 ± 0.1^{a}
pH	8.4 ± 0.1^{a}	8.1 ± 0.3^{a}
Salinity (g L^{-1})	2.1 ± 2.1^{a}	2.4 ± 2.3^{a}
Alkalinity (mg L^{-1})	149.2 ± 10.3^{a}	148.2 ± 12.1^{a}
DO (mg L^{-1})	4.4 ± 0.1^{a}	4.8 ± 0.1^{b}
$N\text{-}NH_4^+$ (mg L^{-1})	0.33 ± 0.16^{b}	0.18 ± 0.03^{a}
$N\text{-}NO_2^-$ (mg L^{-1})	0.34 ± 0.09^{b}	0.17 ± 0.05^{a}

Mean within a row followed by different letters is significantly different at P<0.05.

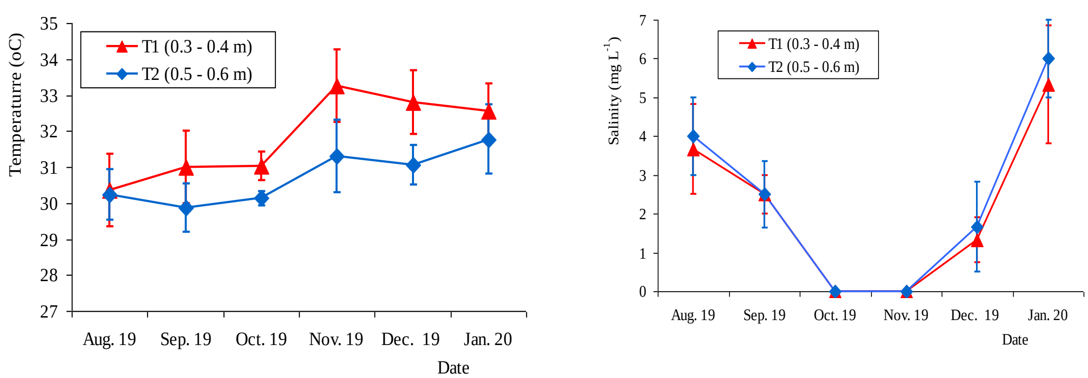

Fig. 1. Fluctuation of temperature and salinity during prawn farming in the rotational rice–prawn farming system in treatments with different water depths

Phytoplankton, zooplankton and zoobenthos density

Phytoplankton density in T1 ranged from 89,000 – 1,628,000 cells L^{-1} and T2 was 123,000 – 1,338,000 cells L^{-1}. Densities of phytoplankton in the first three months in T1 were not significantly different with T2 (P>0.05). However, during the period from November 2019 to January 2020, densities of phytoplankton in T1 were significantly higher than in T2 (P<0.05). In both treatments, densities of Bacillariophyta and Cyanophyta were higher than Chlorophyta and Euglenophyta (Fig. 2). Phytoplankton density increased in the last three months due to detritus accumulation from prawn feed and excretions.

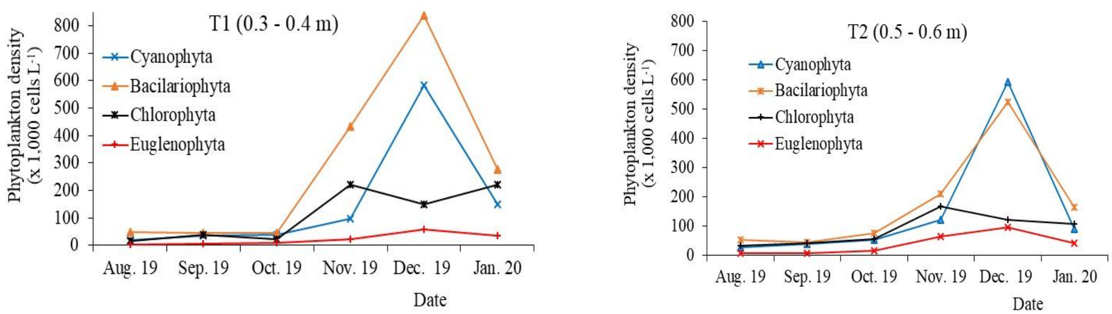

Fig. 2. Fluctuation of phytoplankton densities during prawn farming in the rotational rice–prawn farming system at different water depth treatments

The densities of zooplankton in T1 ranged from 939- 1,389 individual L^{-1}, while in T2, they fluctuated from 1,096- 2,785 individual L^{-1}. Density of Copepoda and Rotifera were higher than Protozoa and Cladocera in both treatments (Fig. 3). The density of zooplankton with high density of Rotifera increased in October to December 2019. The density of zooplankton in T1 in November and December 2019 were significantly (P<0.05) lower than in T2.

The density of Oligochaeta, Gastropoda and all groups in T1 was lower than in T2 but no significant difference (P>0.05) was detected (Table 2). The density of Gastropoda was higher than Oligochaeta in both treatments.

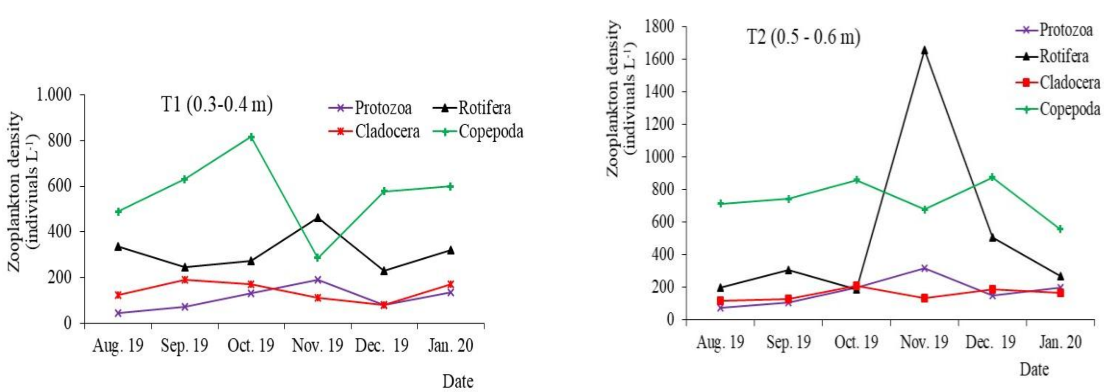

Fig. 3. Fluctuation of zooplankton densities during prawn farming in the rotational rice – prawn farming system at different water depth treatments

Table 2. Density of zoobenthos (individuals m^{-2}) for prawn culture in the rotational rice – prawn farming system at different water depth treatments

Treatment	Oligochaeta	Gastropoda	Total
T1 (0.3 - 0.4 m)	9 ± 7[a]	243 ± 43[a]	252 ± 39[a]
T2 (0.5 - 0.6 m)	27 ± 19[a]	260 ± 16[a]	287 ± 15[a]

Mean within a column followed by different letters is significantly different at $P<0.05$.

3. Growth, survival rate, eFCR and yield of prawn

The mean weight of prawns (Fig. 4) in both treatments in the first two months were not significantly different ($P>0.05$). The mean weight of prawns in T1 on day 90 to 180 was significantly smaller than in T2 ($P<0.05$). At harvest, the final mean weight of prawn in T2 was significantly higher ($P<0.05$) than T1. The daily weight gain of prawns in T2 was faster than in T1 ($P<0.05$). eFCR from trash fish was not significantly different between two treatments, but eFCR from pellet in T2 was significantly lower than in T1. Survival (25.4 ± 3.0%) and yield of prawn (262 ± 9.3 kg ha^{-1}) in T1 were significantly lower ($P<0.05$) compared to T2 due to the higher water depth in T2 (Table 3).

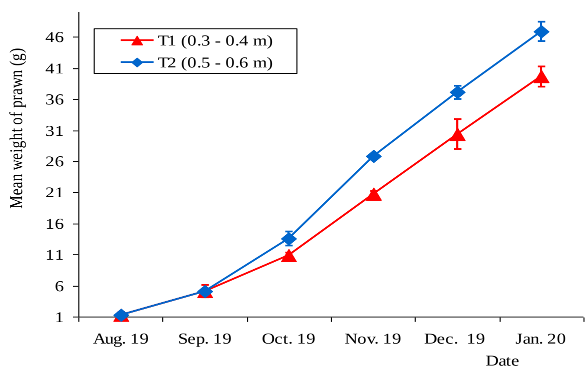

Fig. 4. Monthly mean weight of prawn during in the rotational rice–prawn farming system at different water depth treatments

Prawn female in T1 matured earlier than in T2 ($P<0.05$) (Table 4). In addition, percentage berried female on days from 90 – 180 after stocking in T1 were higher than in T2.

Table 3. Daily weight gain (DWG), eFCR, survival rate and yield of prawn culture in the rotational rice–prawn farming system at different water depth treatments

Treatment	(T1) 0.3 – 0.4m	(T2) 0.5 – 0.6m
$DWG_{1\text{-}30\ day}$ (g day^{-1})	0.042 ± 0.016^{a}	0.043 ± 0.011^{a}
$DWG_{31\text{-}60\ day}$ (g day^{-1})	0.128 ± 0.036^{a}	0.129 ± 0.007^{a}
$DWG_{61\text{-}90\ day}$ (g day^{-1})	0.194 ± 0.044^{a}	0.280 ± 0.042^{a}
$DWG_{91\text{-}120\ day}$ (g day^{-1})	0.330 ± 0.027^{a}	0.441 ± 0.046^{b}
$DWG_{121\text{-}150\ day}$ (g day^{-1})	0.317 ± 0.075^{a}	0.345 ± 0.023^{a}
$DWG_{151\text{-}180\ day}$ (g day^{-1})	0.311 ± 0.082^{a}	0.326 ± 0.072^{a}
$DWG_{1\text{-}180\ day}$ (g day^{-1})	0.220 ± 0.009^{a}	0.261 ± 0.009^{b}
$eFCR_{pellet}$	$0,28 \pm 0,03^{a}$	$0,21 \pm 0,02^{b}$
$eFCR_{trash\ fish}$	$0,88 \pm 0,04^{a}$	$0,83 \pm 0,04^{a}$
Survival rate (%)	25.4 ± 3.10^{a}	30.5 ± 3.67^{b}
Yield (kg ha^{-1})	262 ± 9.3^{a}	358 ± 10.4^{b}

Mean within a row followed by different letters is significantly different at $P<0.05$.

Tabe 4. Day for maturation and percentage berried female of prawn culture in the rotational rice–prawn farming system at different water depth treatments

Treatment	T1 (0.3 – 0.4 m)	T2 (0.5 – 0.6 m)
Day for maturation (cultured days)	66.0 ± 4.5^{a}	89.0 ± 2.5^{b}
Percentage berried female (%)		
At 90 days after stocking	9.0 ± 2.0^{b}	3.0 ± 3.0^{a}
At 120 days after stocking	28.0 ± 3.5^{b}	18.3 ± 2.5^{a}
At 150 days after stocking	32.0 ± 2.6^{b}	23.0 ± 6.1^{a}
At 180 days after stocking	39.0 ± 2.6^{b}	30.0 ± 2.5^{a}

Mean within a row followed by different letters is significantly different at $P<0.05$

Simple cost-benefit analysis

Labor costs accounted for the highest proportion (38 - 41%), followed by feed costs, seed, rice field preparation and other expenses (**Figure 5**). The total operating cost for prawn culture in T2 was significantly higher than in T1 ($P<0.05$) (Table 5). The production price for 1kg of prawn cultured in T1 was 3.67 USD/kg, which was significantly higher than that of T2 that recorded 2.87 USD/kg ($p<0.05$). Gross revenue, net income and cost benefit ratio from prawn farming in T1 were significantly lower than those recorded in T2 ($P<0.05$).

Tabe 5. Financial analysis of prawn culture in the rotational rice–prawn farming system at different water depth treatments

Treatment	T1 (0.3 – 0.4 m)	T2 (0.5 – 0.6 m)
Total operating cost (USD ha^{-1})	936 ± 26.5^a	1,027 ± 5.5^a
Gross revenue (USD ha^{-1})	1,255 ± 44.4^a	1,714 ± 49.8^b
Net income (USD ha^{-1})	291 ± 61.6^a	687 ± 44.3^b
Cost benefit ratio (time)	1.30 ± 0.07^a	1.67 ± 0.04^b

Mean within a row followed by different letters is significantly different at $P<0.05$; 1 USD = 23,000 VND.

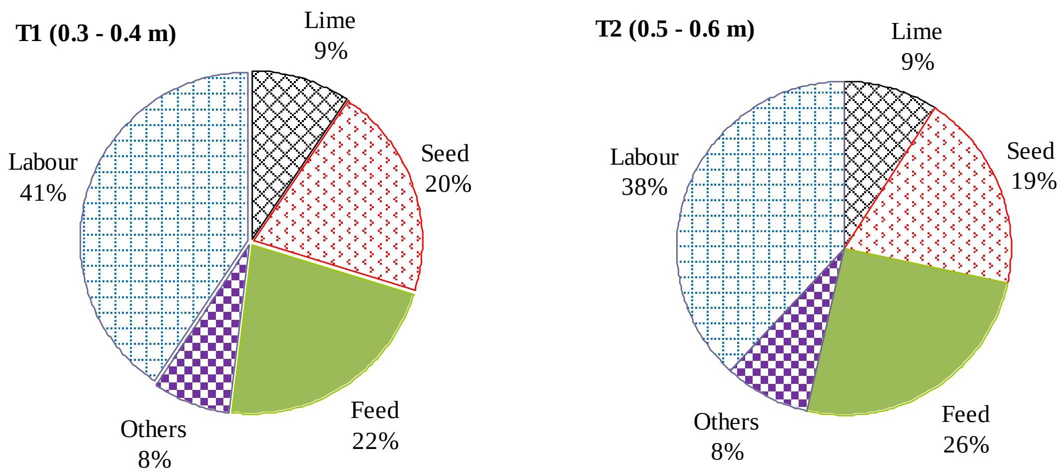

Fig. 5. Operating costs for prawn culture in the rotational rice–prawn farming system at different water depth treatments

DISCUSSION

The temperature in T2 was significantly lower than that of T1 because in T1 water depth was low and sunlight easily penetrated into water bodies. The temperature in T2 was within the suitable range (28- 31^{o}C) for prawn growth (**New, 2002**). However, temperature in T1 was higher than the recommended values due to the shallow rice fields. According to **Phuong and Hai (2003**), the giant freshwater prawn was adapted to conditions of wide temperature fluctuation (18- 34^{o}C), and cultured prawn grew well in the temperature ranging from 25- 31^{o}C. **Huong *et al.* (2014)** concluded that, the pH suitable for freshwater prawn growing well was from 7.0 to 9.0, and if the pH was out of this range, then the physiology and growth would be affected. The pH value obtained at the water depth of T1 was higher than that of T2 but it was still within the suitable range for prawn growth. Prawn can survive in water with salinity from 0 – 25 g L^{-1}; prawn grow and develop well at a salinity of 0- 16g L^{-1}; the recommended range is lower than 10ppt (**New, 2002)**. Prawns can be reared in brackish water up to 15g L^{-1}, allowing for farming in the large areas impacted by salt water intrusions in tropical deltas **(Huong *et al.*, 2010)**. According to **Chand *et al.* (2015)**, 50% lethal salinity of prawn juvenile after 96 hours was 24.6‰, and prawn grew and survived satisfactorily at 0–15 g L^{-1} salinities, but the best was at 10mg L^{-1} salinity. The salinity of the water in the experimental rice fields (0 g L^{-1} in October – November 2019 to 7 g L^{-1} in January 2020) was suitable for prawn growth. Appropriate alkalinity for prawn was from 20– 60mg $CaCO_3$ L^{-1}**(New, 2002)** or from 50 to 150mg $CaCO_3$ L^{-1}**(Phuong & Hai, 2003)**. The DO for prawn growth ranged from 3 to 7mg L^{-1} (**New, 2002)**. N-NH_4^+ and N-NO_2^- concentrations were low and within the acceptable range for prawn growth **(New, 2002)**. **Huong and Thu (2012)** concluded that, when nitrite concentration increased, it affected the growth rate and the molting of giant freshwater prawn (*M. rosenbergii*), and this species is sensitive to nitrite, the 96-h LC50 of nitrite on prawns was 28.1 mg L^{-1}. Densities of phytoplankton in high water depth fields were lower than the low one since the higher density of zooplankton and zoobenthos in T2 indicates that they are fed on phytoplankton. Both plankton and zoobenthos are important for the natural food chain in rice field ecosystem. Therefore, prawn could consume natural food. **Sheng et al. (2023)** reported that, *Macrobrachium rosenbergii* farming ponds in China should maintain deeper water depth (1.8m) and higher N/P ratio (>3) to promote phytoplankton diversity. **Boock *et al.* (2016)** mentioned that, the rice-prawn simultaneous culture at a stocking density of 2 prawns m^{-2}, without commercial diets was economically feasible because of the non- existence of feed cost from natural food. In the present study, the water quality and planktons in the fields of T2 was better than those of T1; however, most factors in both treatments were within the suitable ranges for prawn growth.

At high water depth on platform, water quality parameters were better than those registered for the low water depth, and thus the prawn growth, survival and yield in T2 were better than in T1. The final mean weight of prawns in T1 (39.6 ± 1.61 g) is similar to that recorded in the study of **Hai *et al.* (2017)**. In the brackish area where salinity fluctuated from 0- 10g L^{-1} during 180 days of culture, the prawns attained to commercial size with final mean weight of 26- 39g and daily weight gain of 0.15– 0.22g day^{-1}**(Hai *et al*., 2017)**. The final mean weight in T2 (46.9 ± 1.75 g) is greater than the finding of **Hai *et al.* (2017)** due to lower stocking density of prawn and lower salinity (0- 6g L^{-1}) in the present study.

The eFCR from pellet was lower for the high water depth fields thank to better growth of prawns. eFCR from trash fish in the both water depth treatments was similar. In the Mekong Delta of Vietnam, commercial sinking pellets and fresh feeds (mainly snail meat and trash fish) in combination were widely used to feed freshwater prawn culture **(Lan *et al.* 2006a, 2006b, 2008)**. According to **New (2002)**, freshwater prawns are omnivorous, and they can also be cannibalistic. In the large rice fields, there were many small wild mollusks, crustaceans, fish and other animals as natural food for prawns. Therefore, eFCR in the present study is smaller than that of **Lan et al. (2008)** (FCR being

2.26-2.70) since prawns benefit from natural food in the rice field. On the other hand, **Haslawati *et al.* (2022)** used alternative feeds other than commercial feeds to reduce the FCR closer to the harvest stage, and this practice of lowering FCR was better for the environment.

This experimental yield is lower compared to the outcome of **Lan *et al.* (2006a)** who conducted their study on the freshwater area, resulting in a yield of prawn of 394 ± 22kg ha^{-1} at density of 3PL m^{-2}. The smaller weight when farming in brackish water area affects the yield. **Yen and Bart (2008)** stated clearly that the mean weight of females decreased with increased salinity (31.40 ± 1.54g and 25.14 ± 1.16g at 0 and 6g L^{-1}, respectively). **Ajiboye and Aremu (2015)** concluded that, fish achieved the best growth and survival at the highest water depth. High water depth (0.5-0.6 cm) create more water volume and space for prawn as well as maintaining stable environmental conditions favor for prawn growth, while low water depth (0.3 – 0.4 m) could cause high temperature (suboptimal for prawn) at a certain time in the hot period. At low water depth treatment, prawn females matured earlier with higher percentage berried female than in high water depth treatment due to significantly higher water temperature at low water depth treatment. Therefore, more berried females are recorded at low water depth treatment. **Yen and Bart (2008)** postulated that, the number of berried females, *M. rosenbergii* observed decreased with increasing salinity. At high salinity, lower ratio of berried female was observed, and prawn took longer time for maturation and re-maturation and had lower fecundity **(Huong *et al.* 2022)**. Similarly, in the present study, the number of berried females also decreased with increasing water depth in the culture fields due to lower water temperature in the culture fields. However, climate change makes temperature increase causing drought. As a result, lower water depth in rice fields for prawn farming is an acceptable model for farmers in the coastal area.

The total investment cost in T1 was lower than in T2 due to low growth, survival and yield of prawn leading to lower feed cost. Farming giant freshwater prawn with low water depth affected gross revenue, net income as well as cost benefit ratio. However, net income (291 ± 61.3 USD ha^{-1}) and cost benefit ratio (0.30 ± 0.07) were acceptable. **Loc *et al.* (2016)** reported that, the income from prawn accounted for larger proportions of total revenues for their higher selling price compared to rice. Net income and cost benefit ratios of prawn farming in brackish water area at low water depth treatment (291 ± 61.6 USD ha^{-1} and 1.30 ± 0.07, respectively) in the present study are lower than those recorded for prawn farming in freshwater area (667 ± 91 USD ha^{-1} and 1.57 ± 0.07) at the same stocking density though feeding on commercial diet and golden apple snails (**Lan *et al.*, 2006a)** because of the lower yield and gross revenue. However, net income and cost benefit ratios of prawn farming in brackish water area at high water depth treatment (687 ± 44.3 USD ha^{-1} and 1.67 ± 0.07, respectively) in the present study are higher than the results of a previous study (**Lan *et al.*, 2006a)** thanks to lower feed cost in this present study. **Boock *et al.* (2016)** reported that, cost benefit ratio from prawn culture in Brazil was attractive and the rice–prawn integrated system was economically feasible. Prawn culture provides an opportunity for fish farmers to increase production and profit with little investment and at no cost to the environment **(Bunu & Christianua, 2016)**. Precisely, freshwater prawn is suitable candidates for culture in the brackish water with low water depth.

CONCLUSION

Freshwater prawn culture in the rotational prawn–rice farming system in brackish water, with the salinity ranging from 0– 6g L^{-1} at low water depth on platform of 0.3–0.4m produced both acceptable yield and net income for farmers. However, the higher the water depth on platform (0.5 – 0.6 m), the better the water quality, final mean weight, survival, eFCR, yield and economic return. Increasing water levels in the rice fields favors prawn culture with larger prawn sizes and lower berried females.

ACKNOWLEGMENT

This study belongs to the Vietnamese ODA F-2 project "Green Technology Innovation for Aquaculture", which is funded by the Can Tho University Improvement Project VN14-6, supported by a Japanese ODA loan. The authors express their sincere gratitude to six farmers from Thoi Binh village, Thoi Binh district, Ca Mau province for their participation in this research.

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