Ecological Engineering 94 (2016) 315–319

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Short communication

# Nutrient removal ability and economical benefit of a rice-fish co-culture system in aquaculture pond

Jinfei Feng, Fengbo Li, Xiyue Zhou, Chunchun Xu, Fuping Fang*

*China National Rice Research Institution, Hangzhou 310006, China*

ARTICLE INFO

*Article history:*
Received 7 April 2015
Received in revised form 31 May 2016
Accepted 2 June 2016
Available online 18 June 2016

*Keywords:*
Eutrophication
Remediation
Economical analysis
Rice-fish co-culture
Fish pond

ABSTRACT

Integrated culture of fish with crops has gained increasing attention to remediate the nutrients pollution of aquaculture. However, rice-fish co-culture system has rarely been investigated. In this study, we constructed a rice-fish co-culture system in the pond by using a new high-stalk rice variety, and conducted an on-farm experiment to examine the nutrients removal efficiency and economical benefit of this system. The results showed that this system significantly reduced the nutrients levels in the water and bottom soil in pond comparing with fish monoculture. The contents of total nitrogen (TN), ammonia-N, nitrate-N, nitrite-N, total phosphorus (TP) and orthophosphate (OP) were 70.63%, 60.27%, 54.86%, 71.54%, 85.05% and 78.54% lower in the water of rice-fish co-culture than fish monoculture pond, respectively. And the contents of ammonia-N, TP and OP in the bottom soil were also respectively reduced by 91.14%, 36.99% and 58.57% under rice-fish co-culture system. The total cost was only increased by 2.88%, but the net income was enhanced by 114.48% for rice-fish co-culture than fish monoculture, which was primarily attributed to extensive rice cultivation. These results suggested that rice-fish co-culture in pond was an efficient method to mitigate the eutrophication in an intensive culture pond, and also a potential new way to increase rice production for food security and extra income for fish farmers.



## 1. Introduction

Pond aquaculture is one of the main contributors to the eutrophication of ambient aquatic environment (Bosma and Verdegem, 2011). Reducing the nutrient loss to aquatic environment is urgent for the sustainable development of pond aquaculture. Phytoremediation has showed great potential in the purification of nutrient-rich aquaculture water for its environmental and economic advantages (Ghaly et al., 2005). A key factor determining the feasibility is the plant used in remediation. A wide varieties of plants, such as reed, algae and crop plants, has been investigated to remediate the effluents of aquaculture by constructed wetland, sequencing batch reactor or hydroponics system in previous studies (Graber and Junge, 2009; Lin et al., 2002; Van Den Hende et al., 2014). Crops are expected to be more suitable for the remediation of large-area pond aquaculture, because the cultivation of crops is beneficial to reuse the redundant nutrients, provide extra food income and reduce remediation cost (Enduta et al., 2011).

Rice is the only cereal crop grown well in flooded soil. So, it has the inherent advantage in the remediation of eutrophic waters (Zhou and Hosomi, 2008). However, previous studies were mostly focused on vegetable or triticeae crops (Graber and Junge, 2009; Snow et al., 2008), but paid little attention to rice. Rice-fish co-culture has been practiced in paddy field over 2000 years in Asian countries (Anita et al., 2014; Islama et al., 2015; Lu and Li, 2006). The results from paddy field have demonstrated that rice-fish co-culture could enhance nutrients use efficiency and reduce nutrients loss to environment because the complementary use between fish and rice (Li et al., 2008a; Oehme et al., 2007; Saikia et al., 2015; Xie et al., 2011). However, this system was rarely conducted in an aquaculture pond, because the rice varieties for paddy field could not grow well in the pond with deep water. Though, some studies have tried to planting rice with floating bed in lakes (Foo, 2000; Song et al., 1996); it was not accepted by fish farmers in a pond aquaculture, because the floating bed inhibited the $O_2$ exchange from atmosphere into water. Therefore, in order to construct a rice-fish co-culture system in a pond, we developed a new high-stalk rice variety; the height of which is up to 1.85 m (Fig. 1(b)), and can be directly cultivated in the bottom soil and grow well in fish pond.

In this study, an on-farm experiment was conducted to investigate the nutrient removal ability and economical benefit of this rice-fish co-culture system in a yellow catfish culture pond.

* Corresponding author at: No. 359, Tiyuchang Rd., Hangzhou, Zhejiang, 310006, China.
*E-mail address:* Fangfuping@caas.cn (F. Fang).

http://dx.doi.org/10.1016/j.ecoleng.2016.06.002
0925-8574/

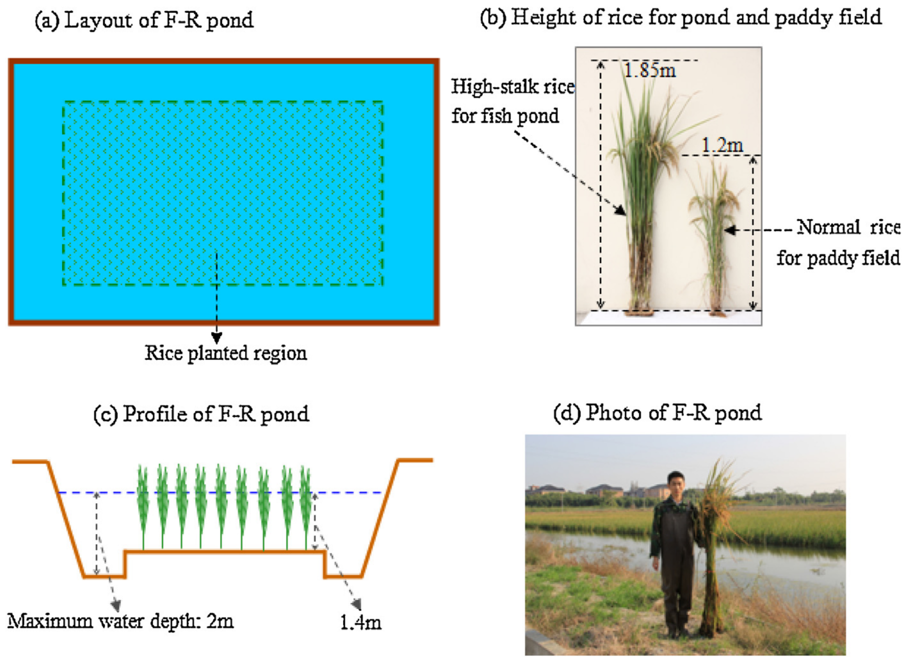


**Fig. 1.** Layout, profile and photo of F-R.

## 2. Materials and methods

### 2.1. Experiment design

This experiment was carried out in a commercial aquaculture farm (120.08° E and 30.49° N) located in Zhejiang province, which is one of the major pond aquaculture regions in South China. Two yellow catfish ponds were selected from the farm. One pond was used for yellow catfish and rice co-culture (F-R), and the other one was for yellow catfish monoculture (F). The area of F-R and F was both 1.5 ha. The shape and profile of pond are shown in Fig. 1. Rice was planted in the center region of pond, occupying nearly 60% of the total area. The region around rice was left for feeding and harvesting yellow catfish. The rice-fish co-culture system tested in this study was characterized by intensive fish culture with extensive rice cultivation in an aquaculture pond, which was contrary to the rice-fish co-culture system conducted in paddy field.

The rice planted in fish pond (namely Yudao No.1) is a new high-stalk rice variety (*Oryza sativa* L.) developed by the hybridization of local rice variety and its high-stalk mutant. The height of this rice can reach up to 1.85 m, which is suitable for being directly planted in fish pond with the water depth below 1.5 m. The water in fish pond was drained off, and pond was empty before planting rice. Rice seeds were manually broadcasted onto the surface of bottom soil at a seed rate of 22.5 kg $ha^{-1}$ on June 11, 2014. Bottom soil was kept moisture but no water flooded after seeding. When the height of rice seedlings reached to 30 cm, the water was added to 20 cm at rice planting region on July 1, 2014. The rice was harvested on November 9, 2014. No chemical fertilizer, pesticide and herbicide were used for rice cultivation.

The fingerlings of yellow catfish were stocked into two ponds on July 10, 2014 at a density of 150 000 fingerlings $ha^{-1}$. The yellow catfish in two ponds were hand fed commercial formulated feed (35–40% protein and 0.8–1.2% phosphorus) two times per day. The water was added with the height of rice plant increased. The maximum water depth was 1.4 m at rice planting region (Fig. 1). The management methods for fish were similar in two ponds.

### 2.2. Sampling and analyses

Two ponds were both divided into four sub-plots for water, soil and plant sampling. In each sub-plots, more than five water, soil or plant samples were taken and mixed together to form a composite sample. Water samples were taken at an interval of two weeks from July 2 to November 7. Composite bottom soil samples were taken at a depth of 0–15 cm at the same day after water sampling. Rice plant samples were taken at the mature stage. Rice yield and biomass were recorded at the harvest time.

The concentrations of TN, ammonia-N, nitrate-N, nitrite-N, TP and OP in water samples and ammonia-N, nitrate-N and OP in bottom soil samples were analyzed by using AA3 Auto Analyzer (Bran-lube, GmbH Co., Germany) according to classical colorimetric methods. The content of nitrite-N in bottom soil was not analyzed, because it did not present in detectable amounts. The contents of TN and TP in rice and bottom soil samples were determined by the Kjeldahl and $H_2SO_4$-$H_2O_2$ methods, respectively (Lu, 2000).

## 3. Results

### 3.1. Nutrients contents in the water

The concentrations of nitrogen and phosphorus were significantly lower in the water of F-R than F, especially from August 15 to December 7 (Fig. 2), which was the primary rice growing stage (jointing, heading and grouting) of high nutrients demand. The mean levels of different forms of nitrogen and phosphorus were 70.63% (TN), 60.27% (ammonia-N), 54.86% (nitrate-N), 71.54% (nitrite-N), 85.05% (TP) and 78.54% (OP) lower in the water of F-R than F during rice growing season, respectively. At most sampling dates, the levels of TN and TP in the water of F were higher than the worst level of environmental quality standards for surface water in China (Grade V, 2.0 and 0.4 mg $L^{-1}$ for TN and TP, respectively). While for F-R, TN and TP contents were lower than the recommended level of surface water (Grade III, 1.0 and 0.2 mg $L^{-1}$ for mg $L^{-1}$ for TN and TP, respectively).