DYNAMIC CHANGES IN WATER QUALITY AND SOIL FERTILITY UNDER MONO- RICE CULTURE AND RICE - FRESH WATER SHRIMP SYSTEMS IN MEKONG DELTA

Tran Thi Ngoc Son¹, Bui Dinh Duong¹, Truong Thi Minh Giang¹ and R. Yamada²

ABSTRACT

Demonstration on the effect of different farming system viz., rice – rice and rice – shrimp culture since 2001 (first year) up to 2003 (third year) to study about water quality and soil fertility. The monitored data of water quality viz., pH, dissolved oxygen, NH₄-N concentration and temperature were good enough for shrimp growth under good management. In term of soil fertility under rice – shrimp system also got significantly higher value such as soil organic matter, available nitrogen, phosphorus and potassium as compared to the monoculture rice – rice system to an extent of 28.87; 37.73; 56.52; 36.28 %, respectively. At the same time, the economic efficiency of rice shrimp model also got more net return to an extent of 39.054 million VND/ha/year as compared to rice monoculture only 9.20 million VND/ha/year.

Key words: available nitrogen, dissolved oxygen, economic efficiency, marginal benefit ratio cost, NH₄-N concentration, organic matter, phosphorus and potassium.

RATIONAL

Diversification in agriculture can help farmers eradicate hunger and alleviate poverty in the Mekong Delta of Vietnam. At present, development of models with the gross return about 70,000,000 VND/ha/year is encouraged and recommended by the Ministry of Agriculture and Rural Development. Nowadays, there are many ways to obtain this target, among that model of rice - fresh water shrimp is considered as suited to the alluvial soil. The rice - fresh water shrimp model can bring about many benefit such as agricultural economic, social society and grain yield of rice increased from 3% to 22% as compared to rice monoculture (Ling et al. 1999). However, development of rice – shrimp system is still facing many risks since producers have not been trained about technology. Therefore understanding about environment such as water quality changes and soil fertility after harvest shrimp is needed. An attempt has been made to study “dynamic changes in water quality and soil fertility under rice monoculture and rice - fresh water shrimp systems in the Mekong Delta”.

MATERIALS AND METHODS

1. Pilot site:

The demonstration models is conducted at plots 4A and 5A which belonging to the seed farm of Cuu Long Delta Rice Research Institute during 2002, 2003 winter-spring, and 2002, 2003 Summer- Autumn seasons. Initial soil pH was 5.2 (1:1 H₂O). Soil initial nutrient components were 3.2 % organic carbon, 0.26 % total nitrogen, 0.04 % total P; total K: 0.07 %. Soil texture components are as sand: 12%; silt: 26%; clay: 52%; pH 5.2; CEC 32.7 meq/100 g of soil. Demonstration fields were conducted on rice – rice at plot 4A and the rice - shrimp system in 5A.

2. Methods: Cultural practices followed the recommendation methods by CLRRI, rice was cultivated in November and harvest in February.

Stocking of shrimp fingerling was done in March, with post shrimp size of 27mm and 3 fingerlings/m² rate. Harvested shrimp took place in November every year. Lime (CaCO₃)

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was applied at the rate of 500kg/ha.

Water samples were collected at two-week interval and analyzed by test kit of pH test, O\textsubscript{2} test, alkalinity test, NH\textsubscript{4} test and water analyzer. Soil samples were randomly collected from 30 different sites of each plot at the time of harvesting to analyze available N, P, K, pH, EC and organic carbon.

RESULT AND DISCUSSION

1. Water feature

Water under natural condition is a direct factor in influencing to shrimp growth and development. Dynamic change of water quality in shrimp cultivation is an important element to be monitored.

a. pH: Almost fresh water pond recorded pH value changes from 6-9 and the variation of pH every day from 1-2 units (Boyd 1998). pH of water is very important, it has direct influence to the shrimp growth and plankton (Chanratchakool et al. 2002). Optimum pH for shrimp growth varies from 7.5-8.35 and the variation should not exceed 0.5. Data recorded from demonstration model showed that pH value did not vary too much, minimum value as 6.59 and maximum as 8.10. This indicated that pH value is suited for shrimp growth (Fig.1). This research finding is lines with Kungvankij et al. (1986)

b. Dissolved oxygen (DO)

Concentration of dissolved oxygen reduced, it means possibly lead to the death of shrimp in the pond. In the pond with low in concentration of dissolved oxygen, shrimp will decrease feeding capacity and lower feeding transformation as compared to normal pond with high dissolved oxygen concentration (Boyd 1998).

Optimum concentration of dissolved oxygen for shrimp growth varied from 5 to 6 mg/l. At the lower concentration of dissolved oxygen of 4 mg.l\textsuperscript{-1} the feeding capacity of shrimp will be less efficiency, concentration of dissolved oxygen reduced up to 2-3 mg.l\textsuperscript{-1}, shrimp will stop catching a beat of pray and will be asphyxiated at the concentration of dissolved oxygen of below 2 mg.l\textsuperscript{-1} (Chanratchakool et al. 2002). This showed that the max DO fallen at fifth month after stocking. Concentration of dissolved oxygen varied from 4.25 to 5.55 mg.l\textsuperscript{-1} (Fig. 2). According to the international standard, concentration of dissolved oxygen of 4 mg/l confirms enough oxygen for supplying to shrimp growth (Nguyen Thanh Phuong et al. 2001).

Fig. 1. Dynamic changes in pH value with time in rice-shrimp model

Notes:

<table>
<thead>
<tr>
<th>Oxygen concentration</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mg/l (ppm)</td>
<td>Dangerous, oxygen is not sufficient for shrimp growth</td>
</tr>
<tr>
<td>4 mg/l (ppm)</td>
<td>Oxygen is sufficient for shrimp growth.</td>
</tr>
<tr>
<td>6 mg/l (ppm)</td>
<td>Good, oxygen is more than enough for shrimp growth</td>
</tr>
</tbody>
</table>

Fig. 2. Dynamic changes in DO value with time in rice-shrimp model
c. NH₄-N concentration

The aquatic plants can absorb a huge amount of NH₄⁺ and they influenced in the control of NH₃-N concentration in water pond. The aquatic plants that can be consumed by creature or they can be died and decomposed to supply again inorganic N (Boyd 1998).

Variation of NH₄-N concentration at different ponds depend upon soil characteristics, fertilizer application, timing of fertilization, decomposition of creature and consumption of floated living things (Hein and Riemann 1995, Lai and Lam 1997, Lewis 1974, Noriega-Curtis 1979). Critical standard of optimum N-NH₄ concentration for shrimp growth is 0.003 - 0.01 mg/l. Based on the results, NH₄-N concentration in the field got a big variation. The lowest value was 0.003 mg/l and the highest as 0.05 mg/l. Almost at different stages of shrimp growth, the value of NH₄-N concentration was recorded at lower dangerous level, except at 2 stages as 1/9 and 15/10, this maybe due to decomposition of microorganisms and direct consumption of floating creature. However, NH₄-N concentration has been recovered as normal after changing of water from canal and this phenomenon did not cause any harmful effect to shrimp growth (Fig.3)

d. Temperature

The dynamic changes of temperature showed in fig.4 indicated that temperature in the field did not vary much, the lowest value as 27.9 °C and the highest value as 31.34°C. These value were lower as compared to the critical standard, therefore there is unfavorable condition for shrimp growth (Fig.4)

![Fig. 3. Dynamic changes in NH₄-N concentration with time in rice -shrimp model](image1)

![Fig. 4. Dynamic changes in temperature with time in rice -shrimp model](image2)

2. Soil characteristics

a. Soil organic carbon:

The organic matter in the pond mainly initiated from the excreta of shrimp, extra feeding mill and wastes of plankton. Accumulation of organic carbon will occur quickly and increase soil organic matter in pond (Chanratchatkool et al. 2002).

Statistical analyses of organic carbon at 30 different sites in the rice - shrimp (3.85%) as compared to rice monoculture (2.98 %). It addressed a significant difference, with t value as = 4.684 **. Organic carbon increased 28.87 % under rice - shrimp field as compared to rice monoculture

b. Soil available nitrogen:

Soil available nitrogen got significantly higher value in rice - shrimp field as compared to rice monoculture. Soil available N under rice - shrimp field was 0.763 meq/100g of soil as compared to rice monoculture as 0.554 meq/100g with t value as 0.884 **. Soil available N contributed to the rice –shrimp
Effect of long-term application of organic and bio-fertilizer on soil fertility …

system was 37.73 % as compared to rice monoculture

c. Soil available phosphorus:

The planitophyte can absorb quickly phosphate from water, dissolved phosphate from fertilizers or from organic in pond bottom to respond their own living need. When the planitophyte die, they become feeding source of plankton or settled down and decomposed later. The former result showed that there was 70% phosphate added to the pond in the form of fertilizer of feeding that accumulated in the mud of pond bottom (Masuda and Boyd 1994).

Soil available phosphorus also got significantly higher value in rice - shrimp field as compared to rice monoculture. Soil available P under rice - shrimp field was 1.969 ppm as compared to rice monoculture as 1.258 ppm with t value as 3.204 **. Soil available N contributed to the system as 56.52 % as compared to rice monoculture

d. Soil available K:

Soil available potassium also got significantly higher value in rice - shrimp field as compared to rice monoculture. Soil available K under rice - shrimp field was 76.43 ppm as compared to rice monoculture as 56.8 ppm with t value as 6.556 **. Soil available N contributed to the system as 36.28 % as compared to rice monoculture.

Table 1. Differences in soil characteristics under rice - shrimp and rice monoculture

<table>
<thead>
<tr>
<th>Parameter</th>
<th>System</th>
<th>Rice - Shrimp</th>
<th>Rice - Rice</th>
<th>Difference</th>
<th>Difference percentage (%)</th>
<th>T value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic C (%)</td>
<td>3.848</td>
<td>2.986</td>
<td>0.862</td>
<td>28.87</td>
<td>4.684**</td>
<td></td>
</tr>
<tr>
<td>N (meq/100g)</td>
<td>0.763</td>
<td>0.554</td>
<td>0.209</td>
<td>37.73</td>
<td>6.884*</td>
<td></td>
</tr>
<tr>
<td>P (ppm)</td>
<td>1.969</td>
<td>1.258</td>
<td>0.711</td>
<td>56.52</td>
<td>3.204**</td>
<td></td>
</tr>
<tr>
<td>K (meq/100g)</td>
<td>76.426</td>
<td>56.081</td>
<td>20.345</td>
<td>36.28</td>
<td>6.556**</td>
<td></td>
</tr>
</tbody>
</table>

ECONOMIC EFFICIENCY OF RICE – SHRIMP MODEL

Economic efficiency of rice and shrimp model got benefited. Practical economic efficiency showed in table 2, 3 and 4

Table 2. The economic efficiency of rice and fruit tree around the bund under rice shrimp system (CLRRI, 2003)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Rice (Winter – Spring)</th>
<th>Fruit trees</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Banana</td>
<td>Papaya</td>
<td></td>
</tr>
<tr>
<td>Gross return (1000 VND/ha)</td>
<td>14,700</td>
<td>250</td>
<td>2.250</td>
</tr>
<tr>
<td>Gross input (1000 VND/ha):</td>
<td>10,297</td>
<td>40</td>
<td>995</td>
</tr>
<tr>
<td>Net return (1000 $/ha)</td>
<td>4,403</td>
<td>210</td>
<td>1,255</td>
</tr>
</tbody>
</table>

*Notes: Price of rice in Winter – Spring season 2002-2003 is of 3000 VND/kg.

The total product of shrimp was 3,705 kg and equally to 260,809 million VND. Average shrimp yield was 823.3 kg/ha and total gross return from fresh water shrimp as 57.96 million VND/ha.

Total gross input as 111.47 million VND, with net profit of rice shrimp model as 149.34 million VND. Average net profit was 33.186 million VND/ha. (table 3)
Table 3. The economic efficiency of shrimp under rice shrimp cultivation system (CLRRI, 2003)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Total production</th>
<th>Average /ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity (kg)</td>
<td>3,705</td>
<td>823.3</td>
</tr>
<tr>
<td>Gross return (1000 VND)</td>
<td>260,809</td>
<td>57,958</td>
</tr>
<tr>
<td>Total input (1000 VND)</td>
<td>111,472</td>
<td>24,772</td>
</tr>
<tr>
<td>Net return (1000 VND)</td>
<td>149,337</td>
<td>33,186</td>
</tr>
</tbody>
</table>

Table 4. The economic efficiency of rice-shrimp cultivation system (CLRRI, 2003)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Gross return (1000 VND/ha)</th>
<th>Total input (1000 VND/ha)</th>
<th>Net return (1000 VND/ha)</th>
<th>Marginal benefit cost ratio (1000 VND/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice, fruit trees</td>
<td>17,200</td>
<td>11,332</td>
<td>5,868</td>
<td>1.6</td>
</tr>
<tr>
<td>Shrimp</td>
<td>57,958</td>
<td>24,772</td>
<td>33,186</td>
<td>2.3</td>
</tr>
<tr>
<td>Total</td>
<td>75,158</td>
<td>36,104</td>
<td>39,054</td>
<td>2.1</td>
</tr>
</tbody>
</table>

CONCLUSION

Rice – shrimp model showed a great potential in sustainable agriculture in terms of soil fertility and economic efficiency. The gross return of rice shrimp model was 75.16 million VND and the net return as 39.05 million VND/ha and marginal benefit cost ratio as 2.1 (>2) that can be accepted. Besides that soil fertility under rice – shrimp system also recorded significantly higher in term of soil organic matter, available nitrogen, phosphorus and potassium as compared to the rice monoculture. Therefore, the demonstration should be extended to advanced farmers in Mekong Delta.

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