Recycling of fishpond waste for rice cultivation in the Cuu Long delta, Vietnam

Cao van Phung[1], Nguyen be Phuc[1,2], Tran kim Hoang[2] and Bell R.W.[3]

1. Cuu Long Rice Research Institute, O'Mon, Cantho Province, Vietnam. Email: caovanphung@hcm.vnn.vn
2. An Giang University, Long Xuyen, An Giang Province, Vietnam
3. Murdoch University, Murdoch 6150, Australia

Cat fish (*Pangasianodon hypophthalmus*) production has expanded to over one million tonnes in 2007 and 2008 from ponds that cover about 5,000 ha in the Cuu Long delta, Vietnam. From these ponds, large quantities of liquid and solid waste are discharged to waterways without treatment. Consequently, the pollution of canals or rivers by loading of fishpond waste, rich in nutrients (especially nitrogen and phosphorus) has emerged as a major concern. A survey in the dry season 2007 of 8 paired fields showed that rice yield in 8 paddies receiving waste from fishpond was 1 t/ha higher than in another 8 paddies that did not use wastes. Field experiments were conducted starting from the wet season 2007 up to dry season 2008-2009 using three doses of compost (1, 2 and 3 tonne/ha) in combination with 1/3 or 2/3 of the recommended inorganic fertiliser rates per hectare of 80N and 60N for dry and wet season respectively meanwhile 17P-24K were equally applied for both two rice crops. Rice yields were more or less the same in all treatments, suggesting that compost prepared from fishpond waste could replace 1/3 to 2/3 of the fertiliser normally applied. Another experiment was carried out using liquid waste from fishponds for irrigating rice together with inorganic fertilisers at 1/3 of the recommended farmer dosage. Rice yields were also the same in all treatments. These results confirmed that solid and liquid wastes from fishponds can be recycled for rice culture to mitigate pollution of waterway and reduce fertiliser costs.

I. Introduction

Catfish culture in the Cuu Long Delta has been practiced for a long time but this industry became important for export only after the year 2000 with an annual growth rate of about 15-20 %. Total catfish production in the Cuu Long delta has increased from 265 thousand tonnes in 2004 to 1.5 million tonnes in 2007. In the production of these large quantities of fish, it is estimated that about 450 million cubic metres of solid and liquid waste from fishponds is discharged annually directly to water sources (Phuong, 1998). As a result, pollution due to fishpond waste contains high organic carbon and nutrients (Pillay, 1992). The quantity of waste produced depends upon the quantity and quality of feed (Cowey and Cho, 1991). However, integration of aquaculture into existing agricultural systems has been reported to improve productivity and ecological sustainability through better management and improved soil fertility arising from waste recycling (Bartone &

[1] Cuu Long Rice Research Institute, O'Mon, Vietnam
[2] An Giang University, Long Xuyen, Vietnam
[3] Murdoch University, Murdoch 6150, Australia

Arlosoroff; 1987). Moreover, properly managed composts can reduce the need for fertilisers (Falahi-Ardakani et al. 1987).
The present study aims at recycling of solid and liquid wastes from fishponds for rice cultivation to make use of nutrients and organic content in wastes in order to reduce inorganic fertiliser application by farmers and to reduce pollution of surface water bodies from discharge of fishpond wastes.

II. Materials and methods

Solid waste from fishponds in the form of sludge (FS) was mixed with rice straw (RS) at the ratio of 1:1 on dry weight basis then incubated at 60% humidity in closed tank for decomposition. It was then turned over every 4 days during first month to make the bulk homogenous. After 2-3 months compost was ready for use. The composition of compost is shown in Table 1. Inorganic fertilisers used for field experiments were urea, superphosphate and muriate of potassium.

Table 1: Nutrient content of compost (fishpond sludge 50% + rice straw 50%)

Sample	N%	P%	K%	Ca (mg/kg)	Mg%	Avail. N (mg/L)	Avail. P (mg/L)	Org. C %	pH	Ec (mS/cm)
FS	0.491	0.472	0.34	42.0	0.371	285	199	8.60	6.80	0.54
RS	1.420	0.334	1.54	150	0.110	n/a	n/a	38.80	7.80	0.54
Compost	0.94	0.44	1.16	84	0.254	677	463	8.62	7.40	2.37

Field experiments on recycling of solid waste were carried out during the wet season 2007 and dry season 2008-2009 at the Cuu Long Rice Research Institute farm at Omon, Can Tho city (soil type Umbri-EndoOrthiThionic-Gleysols). Soil characterisation is given in Table 2. Treatments comprised inorganic fertiliser (T1-control) at the recommended dosage of 60N-40P_2O_5-60K_2O/ha for wet season and 80N-40P_2O_5-60K_2O/ha for dry season crops, respectively. Fishpond sludge compost was applied at 1, 2 or 3 tonnes/ha in combination with inorganic fertiliser dosages of 1/3 or 2/3 quantity of treatment T1 for T2, T4, T6 and T3, T5 and T7 respectively

A survey on the beneficial use of fishpond waste for rice cultivation was carried out in the dry season 2007 at Chau Phu and Phu Tan districts of An Giang province. Soil characterisation is shown in Table 2. In every district, 16 fields were selected comprising 8 which used waste water from fishponds and the other 8 did not. Rice samples were harvested in 5 m^2 with 3 replications for yield evaluation.

Table 2: Soil characterization of experiments at CLRRI and on farmers' fields in An Giang province

Location	Soil name (FAO/UNESCO)	pH (1:5 H_20)	Org. C %	Total (%)		
				N	P	K
CLRRI	Eutric Gleysol	4.8-5.2	2.29	0.268	0.021	0.915
Chau Phu	Umbric Fluvisol	5.6-6.2	0.8-1.1	0.161	0.047	1.556
Phu Tan	Thionic Fluvisol	4.9-5.5	0.9-1.3	0.198	0.035	1.368

Experiments on recycling of waste water for rice production were carried out during the wet season 2007 and dry season 2008 at Chau Phu district. Another 2 experiments were conducted during the dry season 2008 at Phu Tan district (two sites) of An Giang province. Nutrient composition of wastewater is shown in Table 3.

There were 6 treatments for experiments at Phu Tan using chemical fertilisers (N-P_2O_5-K_2O rates in kg/ha given in parentheses(as follows: T1(90-60-60); T 2(60-30-30); T3(30-0-30); T4(30-60-30); T5(30-30-60) and T6(0-30-60). Experiments in Chau Phu did not include T5. These experiments were laid out in a randomized complete block design with 3 replications. Irrigation with wastewater was done at 7-10 day intervals for the wet season and about 4-5 day intervals for dry season rice crop. Quantity of wastewater used for irrigation was 2000 m^3/ha/time.

Table 3: Nutrient composition in wastewater at An Giang province

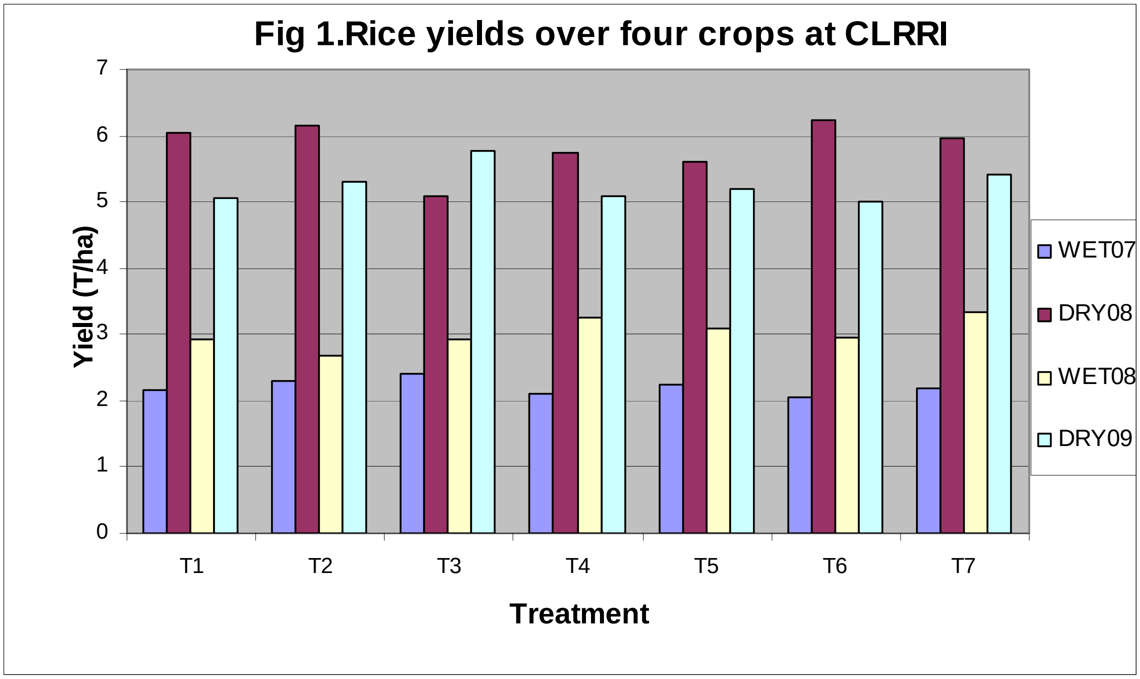
Location	pH	EC (µS/cm)	NH4-N(mg/L)	NO3-N (mg/L)	TN (mg/L)	TP (mg/L)
Chau Phu	7.13	234	3.4	0.418	5.40	8.46
Phu Tan	7.32	243	4.84	0.793	7.66	6.44

Organic carbon is determined by wet digestion; analysis of nutrients (N, P, K, Ca, Mg, Fe, Cu, Zn, Mn) followed standard methods for soil (Page et al. 1982), plant and water analysis (Chapman and Pratt, 1961). Statistical analysis was done by using IRRISTAT software with balance ANNOVA.

III. Results and discussion

III.1. Experiment on recycling of fishpond sludge

In the first crop, rice yields of all treatments were not significantly different between different (yields variation ranging from 2.04 to 2.40 t/ha). In dry season 2007-2008, rice yields of treatments (T1, T2, T4, T5, T6, T7) were more or less same except treatment T3 which was significant different with others. The same experiment was repeated in wet season 2008 and dry season 2008-2009. Results were shown in figure 1 that rice yields in all treatments were not significant different over two following crops. This proved that recycling of fishpond sludge to form compost by mixing with rice straw can save inorganic fertilisers for rice cultivation because nutrients contents in compost is quite rich (Table 1)



Analysis of soil, straw and grain for macro, secondary and micronutrients showed some variations among treatments over four crops but they were not statistically significant. This indicated that the use of fishpond sludge for rice cultivation did not cause any deleterious effect on rice growth.

III.2. Survey on the use of liquid waste in An Giang province

Results from the survey showed that rice yields in fields using wastewater from fishponds for irrigation had higher yield than paddies without recycling of wastewater. Yield difference between the two methods was about 1 t/ha (Table 4). This indicates that wastewater can help to further increase in rice yield.

Table 4: Survey on rice yields in farmers' fields at Chau Phu and Phu Tan districts. Values are means from 8 fields.

Treatments	Chau Phu	Phu Tan
Irrigation with wastewater	7,920 a	7,436 b
Irrigation with river water	6,898 b	6,613 c
CV%	6.1	6.1

Analysis of soil samples at harvest time showed that total nitrogen, phosphorus and potassium in paddies with wastewater application were significantly higher than plots without wastewater application but organic carbon was lower (Table 5). Wastewater is rich in nitrogen, phosphorus, potassium (e.g. see Table 3) and bacteria which is likely why soils receiving it have higher nutrient contents. By contrast, the high bacterial loading in waste water may accelerate decomposition of organic matter leaving lower organic C levels but higher mineralized nitrogen.

Table 5: N, P, K and organic carbon in soils after harvesting rice in fields with and without application of wastewater to crops.

Soil properties	Chau Phu		Phu Tan		CV%
	+ waste water	- waste water	+ waste water	- waste water	
Org C	1.59b	2.60a	2.24ab	3.05a	37
N%	0.380b	0.155c	0.469a	0.156c	8.9
P%	0.369a	0.224b	0.354a	0.211b	9.2
K%	2.375b	0.948c	2.620a	0.874c	10.3

Note: Values in same row with the same letter were not statistically different P < 0.05.

The survey also recognized that farmers usually added zeolite, lime and dolomite while cleaning fishponds after harvesting. This resulted in high contents of calcium and magnesium in paddies receiving wastewater. Besides that, iron and manganese were also statistically different between these two treatments (Table 6).

Table 6: Ca, Mg, Fe and Mn in soils after harvesting rice in fields with and without application of wastewater to crops.

Soil properties	Chau Phu		Phu Tan		CV%
	+ waste water	- waste water	+ waste water	- waste water	
Ca (mg/kg)	55.0a	31.0b	49.8a	30.6b	22.8
Mg (%)	0.11 a	0.06b	0.12a	0.06b	9.5
Fe (%)	3.32a	2.82b	3.29a	2.72b	5.1
Mn (mg/kg)	332a	187c	262b	157c	21.8

Note: Values in same row with the same letter were not statistically different, P < 0.05.

IIII.3. Experiments on recycling of wastewater for rice cultivation at Chau Phu

Results of field experiments at Chau Phu indicated that rice yields of all treatments in the wet season 2007 were not statistically different. However, rice yields of T1 and T2 were highest and were statistically different to the other treatments (T3, T4 and T5) in the dry season 2008 (Table 7). The higher yields in T1 and T2 are attributed to the acidity of soils in which phosphorus is a key factor for crop growth (Cong et al. 1995). This explains why yields in T3 were low. Besides that, nitrogen in T3, T4 and T5 was low and not sufficient to achieve potential yields for the dry season. Rice yield in the wet season is usually lower than in dry season in the Cuu Long Delta (Hung et al., 1995)

Table 7: Rice yields in Chau Phu district for the wet season (WS) 2007 and dry season (DS) 2008. Values are means of three replicates. All plots were watered with fishpond waste water at 7-10 day intervals (see Table 3 for composition of waste water applied).

Treatments ($N-P_2O_5-K_2O$ kg/ha)	WS2007	DS2008
T1(90-60-60)	3.99	5.59
T2(60-30-30)	4.38	5.58
T3(30-00-30)	3.91	4.21
T4(30-60-30	3.96	4.32
T5(00-30-60)	3.91	4.62
LSD5%	NS	0.885
CV%	14.0	11.8

Analysis of soil, straw and grain samples at harvesting time showed no significant difference among treatments in N, P and K (data not shown).

III.4. Experiments on recycling of wastewater for rice cultivation at Phu Tan

Results in Table 8 indicated that rice yields in T1 and T2 achieved the highest yield and they were significantly different from others. This suggests that irrigation by wastewater from fishponds can save 30kg of N, P2O5 and K2O. By comparison, treatment T2 and T4 showed that further decrease in nitrogen fertiliser resulted in reducing yield. T3 was the lowest yield because this treatment did not use phosphorus because P application help to increase N efficiency (Cong et al., 1995)

Table 8: Rice yields of Phu Tan at two sites in the dry season 2008. Values are means of three replicates. All plots were watered with fishpond waste water at 4-5 day intervals (see Table 3 for composition of waste water applied).

Treatments ($N-P_2O_5-K_2O$ kg/ha)	Phu Thanh (1)	Phu Thanh (2)
T1(90-60-60)	6.89	5.74
T2(60-30-30)	7.34	5.47
T3(30-00-30)	5.05	4.08
T4(30-60-30)	6.19	5.02
T5(30-30-30)	4.91	5.06
T6(00-30-60)	4.52	4.39
LSD5%	0.162	0.683
CV%	15.3	7.6

Macro and secondary nutrient uptake of Phu Thanh sites in Tables 9 and10 showed that plots with high yield were also high in nutrient uptake (kg/ha) in straw and grain except P in straw of Phu Thanh 1.

Table 9: Macro and secondary nutrients uptake in grain of Phu Thanh1 (see Table 8 for treatment yields). Values are means of three replicates.

SN	Treatments	N	P	K	Ca	Mg
1	T1	86.7	22.4	17.8	4.21	1.95
2	T2	90.5	23.5	16.5	4.14	1.98
3	T3	61.7	15.3	11.2	2.86	1.28
4	T4	71.2	19.2	14.4	3.44	1.73
5	T5	56.7	16.1	12.3	2.90	1.50
6	T6	51.0	15.5	11.9	2.75	1.39
	LSD5%	*19.73*	*6.94*	*4.68*	*1.00*	*0.57*
	CV%	*15.6*	*20.4*	*18.3*	*16.2*	*19.2*

Table 10: Macro and secondary nutrients uptake in straw of Phu Thanh1 (see Table 8 for treatment yields). Values are means of three replicates.

SN	Treatments	N	P	K	Ca	Mg
1	T1	45.0	13.6	83.1	15.5	4.35
2	T2	48.0	13.3	85.8	14.8	4.37
3	T3	28.0	13.5	63.2	6.95	2.87
4	T4	37.5	11.1	77.6	11.7	3.52
5	T5	28.5	10.8	61.7	9.24	3.05
6	T6	26.1	8.58	54.3	10.4	2.65
	LSD5%	*8.98*	*7.99*	*22.65*	*5.89*	*0.79*
	CV%	*13.9*	*37.2*	*17.6*	*28.3*	*17.9*

In the experiment at Phu Thanh 2, nutrient uptake in grain followed the same trend as in the experiment Phu Thanh 1 but K and Ca uptake in straw was not statistically different among treatments (Table 11 and 12).

Table 11: Macro and secondary nutrient uptake in grain at Phu Thanh 2. (see Table 8 for treatment yields). Values are means of three replicates.

SN	Treatments	N	P	K	Ca	Mg
1	T1	81.1	10.2	18.0	0.22	3.59
2	T2	79.2	9.93	16.9	0.23	3.43
3	T3	52.3	7.12	12.6	0.16	2.49
4	T4	75.5	9.56	16.1	0.19	3.14
5	T5	67.1	9.20	16.0	0.18	3.17
6	T6	50.7	7.54	14.1	0.16	2.65
	LSD5%	*9.45*	*1.28*	*2.43*	*0.31*	*0.40*
	CV%	*7.7*	*7.9*	*8.6*	*8.9*	*7.1*

Table 12: Macro and secondary nutrient uptake in straw at Phu Thanh 2. (see Table 8 for treatment yields). Values are means of three replicates.

SN	Treatments	N	P	K	Ca	Mg
1	T1	50.0	12.6	63.4	13.5	4.35
2	T2	54.6	11.1	56.0	9.81	3.61
3	T3	33.8	6.48	49.0	7.87	2.69
4	T4	51.5	9.22	56.6	9.29	3.71
5	T5	53.4	9.96	54.7	12.1	4.17
6	T6	37.2	6.22	50.0	11.0	2.60
	LSD5%	*12.64*	*4.05*	*11.77*	*5.78*	*0.98*
	CV%	*14.9*	*24.1*	*11.8*	*30.0*	*15.4*

IV. Conclusions

- Wastewater from fishponds can help to increase rice yield because it contains high quantities of nutrients, especially nitrogen, phosphorus, calcium and magnesium, for rice growth;
- The use of waste, either in solid or liquid forms, can save a significant amount of nitrogen, phosphorus and potassium about 30 kg/ha each of currently applied inorganic fertiliser dosage ;
- Recycling of waste from fishponds for rice cultivation can alleviate water pollution by reducing the quantity discharged directly to water sources;
- No phytotoxicity to rice plants was observed on application of waste from fishponds to paddies.
- Continued monitoring of fields under treatment with fishpond waste is necessary to determine longer term effects on nutrient budgets, soil quality, rice yields and environmental water quality.

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