Effect of Integrated Rice-Duck Farming on Rice Yield, Farm Productivity, and Rice-Provisioning Ability of Farmers

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ABSTRACT

The feasibility of the rice-duck system of rice production, practiced in some East Asian countries, is studied in Bangladesh as a sub-project of the Poverty Elimination Through Rice Research Assistance (PETRRA). The Bangladesh Rice Research Institute (BRRI) implements the sub-project in collaboration with two NGOs, FIVDB and BDS, in the northeastern (greater Sylhet) and southern (Barisal) regions of the country. Each demonstration trial, conducted in the field of the farmers, is treated as a replication. In these trials, the rice-duck system is compared with the methods of growing rice solely, as traditionally practiced by the farmers in Bangladesh. Evaluation of the activities carried out under the PETRRA sub-project shows that the rice-duck system is not only feasible, but also economically rewarding for the farmers. The yield of rice is, on average, 20% higher in the rice-duck system than the traditional rice system (sole rice), thereby ensuring about 50% higher net return and rice-provisioning ability. The ducks in the rice-duck fields control weeds and insects very effectively; as a consequence, labor and pesticide costs for controlling weeds and insects are minimized and the soil health is improved. The ducks provide another source of added income for the farmers. In view of the favorable results obtained in the study, it might be suggested that the rice-duck system be spread throughout the country as an income-generating activity for the resource-poor farmers.

INTRODUCTION

Given the continuously increasing population, coupled by the steadily shrinking farm size, Bangladesh is under tremendous pressure to increase, by all possible means, the production of rice, its staple food, in order to attain self-sufficiency in food (BBS 2001). Although increasing the area cultivated to rice remains a remote possibility, various options for a vertical increase in rice production are still available. The present system of rice production requires the use of agro-chemicals such as fertilizers and pesticides, often in heavy doses. These chemicals, particularly the latter, are harmful to the environment as they spill into the water bodies, and worse, get deposited in the bodies of animals and human beings, in toxic proportions. Moreover, resource-poor farmers (defined as the marginal farmers who have 6-8 months rice-provisioning ability and where both

husband and wife are involved in the household affairs) often cannot afford to apply optimum doses of agro-chemicals to their rice crops to get the desired results.

In 1998, two scientists of the Bangladesh Rice Research Institute (BRRI), during a training program in Japan, came to know about a system in which rice and ducks were raised simultaneously in the same land. The system was practiced in some East Asian countries, particularly Japan, Korea, Vietnam, China, and Indonesia. The farmers of these countries had adopted the rice-duck culture as one of the means of organic farming where weeds and insects could be controlled effectively by the ducks (Pham 1994; Choi Song Yoel et al. 1996). The rearing of ducks, along with rice cultivation, was reported to reduce weed growth by as much as 92-96% (Kang Yang Soon et al. 1995).

In Japan, this method is popularly known as 'Aigamo- rice cultivation'. The simultaneous raising of ducks with rice cultivation aids in the control of weeds and insects, thus helping eliminate the application of pesticides (Furono 1996; Manda 1992). The integration of rice cultivation with crossbred duck farming—also known as mixed farming—enables the poor farmers to obtain not only rice, as the main crop, but also subsidiary products (duck meat and eggs), from the same piece of land at the same time. Besides, the feces/ droppings of these ducks will provide almost all the essential nutrients to the rice crops.

Preliminary information collected about the system indicated that the agro-ecological condition in Bangladesh was suitable for this system. Hence, it was decided to explore the prospects of the system initially on an experimental basis. The present study intended to evaluate this integrated system of producing rice and raising ducks in terms of its effects on productivity, outcome, and the rice-provisioning ability of resource-poor farmers.

MATERIALS AND METHODS

The research was carried out between March, 2003 and April, 2004 by the Bangladesh Rice Research Institute (BRRI) in collaboration with two non-government organizations, namely, the Friends in Village Development in Bangladesh (FIVDB) in Sylhet and the Bangladesh Development Society (BDS) in Barisal. The work was done in 48 villages of five upazillas (parts of districts) under four districts as follows:

District	Upazillas (part of districts)	Number of villages	Collaborating NGO
Sylhet	Sadar	15	FIVDB
Sunamganj	Sadar	10	FIVDB
Moulvibazar	Sadar	14	FIVDB
Barisal	Banaripara	6	BDS
Barisal	Bakarganj	3	BDS

Sylhet region is composed of Sylhet, Sunamganj and Moulvibazar districts

The above areas were selected because they are located in the flood plains and they have relatively high rainfall. The three districts of greater Sylhet are under the Surma-Kushiara flood plain which is characterized by its medium high land, clayey and loamy noncalcareous grey soils, and an annual rainfall of 4000-5000 mm. The Barisal region belongs to the Lower Gengetic flood plain which is situated on medium low to low land, has loamy and clayey calcareous duck grey soils, and has an annual rainfall of 2500-3000 mm. The rice varieties used in the experiment were as follows:

Season	RiceVarieties Used	
	Barisal	Sylhet
T. Aman (June-December)	Bhojon*	BR 11 (Mukta)
Boro (November to May)	BR 2 (Mala)	BR 14 (Gazi)
T. Aus (March to August)	BR 2 (Mala)	BR 2 (Mala)

Local modern rice*

The trials were conducted entirely in the fields of the farmers. A total of 147 resource-poor farmers took part in this study. Each farmer made available a plot of 2800 sq m, which was divided into two equal parts: one part for the rice-duck system and the other for the farmers' traditional method of rice production (rice only).

Demarcated areas of 5m x 2m were taken as Control treatment, where no measures were taken for the control of insects pests and weeds. Weeding (twice) and application of insecticides (once) were done in the sub-plots allotted to the traditional

method. No weeding herbicide application or pesticide application were done in the rice-duck plots to bserve the effectiveness of ducks in the production system.

As to fertilization, the rice-duck plots received only cow dung at the rate of five tons per hectare (t/ha) and no inorganic fertilizers. In the sole rice plots chemical fertilizers were applied as commonly practiced by the farmers.

Locally popular and modern rice varieties were planted in both treatment areas. In the rice-duck plots, seedlings were transplanted at a distance of 25cm x 20cm. The farmers' usual method of raising rice was employed in the plots meant for comparison.

Ten days after transplanting, 20-day-old ducklings were released in the plots at the rate of 350–400 birds per ha. For the first three to five days, ducklings were kept in the plots for 2–4 hours a day. Later they were allowed to remain in the plots from morning to evening. Proper measures were taken to protect the ducklings from predators and to prevent their movement outside the designated plots. The ducklings, upon reaching four months old, were removed from the rice fields which, by then, were at the flowering stage. These ducklings were either sold or further raised in the usual way.

Each demonstration trial was treated as a replication. Data on growth, yield-contributing characteristics and yields of the crops, weed population (taken 45 days after transplanting) and insect population (taken every seven days from 30 days after transplanting until flowering) were collected and analyzed statistically. Soil samples from the trial sub-plots were collected and analyzed in the Soil Resources Development Institute (SRDI) at Barisal to determine the amounts of nitrogen, phosphorus, potassium, calcium, and sulfur.

The number and the weight (g) of the ducklings at the transplanting and flowering stages of the crops were also recorded. Marginal analysis and partial budgeting techniques were used to compare the benefits of rice-duck farming over the conventional rice production system. The statistical analysis of the data generated out of the field and laboratory analyses outlined by Gomez and Gomez (1984) and the mean differences among the treatments were compared using Duncan`s New Multiple Range Test (DMRT) following Zaman et al. (1982).

RESULTS AND DISCUSSION

It was found that the rice-duck system is superior to the traditional system of rice production (sole rice or rice only) in terms of economic benefits, as well as in its effect on the environment. The beneficial effects of the system are discussed below.

Effect on Yield of Rice

The rice-duck system enhanced the yield-contributing characteristics of the rice plants, namely, the number of tillers per hill, number of grains per panicle, and average grain weight (Table 1a). Data show that, on the average, the yields of the rice-duck sub-plots are 20% higher than those of the sole rice sub-plots (Table 1b). This echoes similar findings by Ahmed et al. (2004) and Choi Song Yoel et al. (1996). Kang Yang Soon et al. (1995) reported that grain yield (t/ha) was 3% higher in plots with ducks than in sole rice cultivation system. The superiority of the rice-duck system is consistent in all locations and all seasons as can be seen in Table 1a.

Effect on Insect Population

The insect infestation results in Barisal show that the populations of the green leafhopper, brown plant hopper, zigzag leaf hopper, rice bug, short-horned grasshopper, and long-horned grasshopper were significantly lower in rice-duck plots compared to farmers' plots without ducks (Table 2). No significant difference in the population of the white-backed plant hopper and stem borer was observed between the rice-duck plots and the farmer's plots without ducks. Ducklings were found catching insects efficiently in the rice-duck plots, thereby reducing the insect population. Similar results were reported by Choi Song Yoel et al. (1996), Hossain et al. (2002), and Foruno (2001).

Observations regarding the harmful insect populations in the Sylhet region were a little bit different compared to that of the Barisal area (Table 2). In the former, all the species did not differ significantly between the rice-duck plots and without duck plots. However, the harmful insect population was observed to be lower in the

Table 1a. Effects of integrated rice-duck system and traditional sole-rice farming on plant characteristics and grain yield of T. Aus rice

Characteristic	Location and farming system					
	Barisal			Sylhet		
	Rice-duck system	Sole-rice farming	Difference	Rice-duck system	Sole-rice farming	Difference
Plant height (cm)	103.80	99.90	3.90*	133.88	132.42	1.46*
Tiller (no. hill $^{-1}$)	17.20	12.23	4.97**	17.25	12.23	5.02**
Panicles (no. hill^{-1})	10.54	8.45	2.09**	14.36	10.45	3.91**
Grain (no. panicle^{-1})	136.57	120.71	15.86*	126.57	107.71	18.86*
1000 grain wt (g)	27.25	26.95	0.30	27.85	26.85	1.00
Grain yield (t ha^{-1})	3.89	3.33	0.57*	4.00	3.70	0.30*

* Significant at 5% level at F test. ** Significant at 1% level.

Table 1b. Comparative effects of integrated rice-duck farming and traditional sole-rice farming on the yield of rice

Cropping season	Yield (ton /ha) of different rice cultivation systems			
	Barisal		Sylhet region*	
	Rice-duck system	Sole-rice farming	Rice-duck system	Sole-rice farming
Aus 2003	3.89a	3.33b	4.00a	3.70b
Aman 2003	4.23a	3.85b	4.15a	3.89b
Boro 2004	4.10a	3.72b	4.36a	3.85b

Numbers followed by a common letter are not significantly different at the 5% level of significance using LSD.
* Covers the Sylhet, Sunamganj, and Maulvibazar districts.

Table 2. Insect population observed in the rice-duck and sole-rice plots during T. Aus season

Insects	Total number caught by sweep net (No./5 sweeps/week)					
	Barisal			Sylhet		
	Rice-duck	Sole-rice	Difference	Rice-Duck	Sole-rice	Difference
Harmful insects						
Green leafhopper	2.91	5.15	2.21*	6.21	8.21	2.00
Brown plant hopper	0.17	1.58	1.41**	0.38	0.72	0.34
White-backed plant hopper	0.13	0.33	0.20	0.15	0.15	-0.00
Zig-Zag leafhopper	0.22	0.72	0.50*	0.50	1.52	1.02
Rice bug	0.25	0.83	0.58*	0.28	0.54	0.26
Short-horned grasshopper	2.37	4.21	1.84**	8.33	11.17	2.84
Long-horned grasshopper	0.21	0.75	0.54**	0.21	0.62	0.41
Stem borer	0.12	0.12	-0.00	0.71	1.14	0.70
Beneficial insects						
Carabid beetle	1.71	2.25	0.54	2.86	2.71	-0.15
Lady bird beetle	1.37	1.29	-0.08	11.00	11.30	0.13
Damsel fly	3.29	3.29	-0.00	6.14	5.86	-0.28
Spider	0.83	0.96	0.13	7.67	7.33	-0.34
Dragon fly	0.58	0.96	0.38	1.29	2.28	0.99

*Significant at 5% level at F test. ** Significant at 1% level. ns= not significant

rice-duck plots than in the farmers' traditional plots (sole-rice) except for the white-backed plant hopper which had similar population in both the treatment plots. The populations of the green leafhopper and the short-horned grasshopper were much higher in both plots in Sylhet compared to those in the Barisal area. This might be due to the favorable environment in that season for the two harmful insects in the Sylhet area.

Beneficial insects, namely, the carabid beetle, ladybird beetle, damsel fly, spider, and dragonfly were found in the rice-duck and sole-rice plots but no significant difference was found between the test plots. The predominant beneficial insects observed in Sylhet were similar to those in the Barisal area. Although the insect population was recorded for only a single season (T.Aus 2003), the results are expected to be consistent for other seasons.

Effect on Weed Population

Weeds affect the yield of rice to a considerable extent. Weed counts showed that the number of weed plants per square meter of land was significantly lower in the rice-duck plots as compared to the farmers' sole-rice plots (Table 3).

Echinocloa crusgalli, Scirpus mucronatus, Monochoria vaginalis and *Fimbristylis miliaceae* were the predominant weed species observed in the experimental areas. The highest number of weeds, as expected, was observed in the no-weeding portion of the sole-rice plots. The same pattern in the number of weeds was observed in the three cropping seasons specified earlier, both in Sylhet as well as in Barisal.

Ducks were found to eat young weed plants and weed seeds. Moreover, their trampling activity also kept the weeds under control by as much as 90%, thereby oxygenating the water and encouraging the roots of the rice plants to grow vigorously. This conforms with the findings of Isobe et al. (1998), Kim et al. (1994), and Choi Song Yoel et al. (1996). Furthermore, Foruno (1996) and Manda (1992) found that total weed biomass was controlled better in rice-duck cultivation plots compared to the plots applied with agrochemicals in Japan. Cagauan (1997) reported, based on an on-station research in the Philippines, that total weed biomass in the rice field was reduced by ducks at rates ranging from 52-58%. According to these studies, the mechanism of weed control by ducks was through the direct consumption of plant parts and seeds, and the disturbance of weed growth as brought about by their feeding activity.

Effect on Soil Health

Soil analysis showed that the N, P, K, Ca, and S levels in the soils of the rice-duck plots were higher after cultivation than before cultivation (Table 4). This indicates that the grazing of the ducks enriched the soil's nutrients, probably through their excreta. Other mechanisms may also be involved. The movement of the ducks in the rice field enhances the aeration of the soil and prevents accumulation of harmful gases in the rhizosphere. This may be another reason for the stimulation of the growth of the rice plants.

The above results are in conformity with Furono (1996) who observed and reported that ducks' movement and feeding activity in the rice-duck plots disturbed the soil, resulting in the improvement of the soil's physical property, hence, enhancing the rice root systems. Likewise Zheng

Table 3. Weed population in different crop-growing seasons in Sylhet and Barisal sites

Cropping season	Weed population (no/m^2) and location					
	Barisal			Sylhet		
	Rice-duck farming	Sole-rice farming	Control	Rice-duck farming	Sole-rice farming	Control
T. Aus 2003	4a	16b	78c	3a	21b	76c
T. Aman 2003	6a	30b	68c	5a	9b	68c
Boro 02-03	3a	32b	67c	2a	13b	89c

Numbers followed by a common letter are not significantly different at 5% level of significance using LSD.

Table 4. Nutrient status in the soil of rice-duck plots in before and after cultivation during T. Aman and Boro seasons (Barisal and Sylhet 2003-2004)

Site/cropping season	Period of soil sample collection	Nutrient element				
		N (%)	P (ppm)	K (meq/100 g)	S (meq/100 g)	Ca (ppm)
Barisal Boro, 2004	Before cultivation	0.09b	10.57b	0.24b	24.01b	4.00b
	After cultivation (Rice-Duck system)	0.10a	15.80a	0.32a	29.65a	5.26a
Sylhet T. Aman, 2003	Before cultivation	0.11	8.22	0.21ns	33.67b	4.27b
	After cultivation (Rice-Duck system)	0.11ns	8.94ns	0.20ns	47.29a	5.51a

Numbers followed by a common letter are not significantly different from each other.

et al. (1997) had reported that the total NPK and organic matter content of rice-duck fields increased considerably.

Mortality and Growth of Ducklings

The ducklings grazing in the rice fields are vulnerable to the effects of weather changes. In spite of precautions, mortality could not be prevented. In the T. aman season of 2003, duckling mortality was 8% in Barisal and 12% in Sylhet. Ducklings attained an average weight of 1050 grams in Barisal and 990 grams in Sylhet at the time of crop flowering. On the other hand, in the Boro season of 2004, the average mortality rate was 18% and 17% and the mean weight was 940 gram and 950 gram in Barisal and Sylhet, respectively. The relatively higher mortality rate of the ducklings in the Boro season may be due to the prevalence of severe cold weather during that period. The percentage of ducklings' mortality and the average weight were consistent in both locations (Table 5).

Economic Gains

An economic analysis of the integrated rice-duck system and the farmers' traditional practice (sole-rice) shows that 50-60% higher net returns per hectare could be achieved by the former. In Sylhet, higher net returns, i.e., Taka (Tk) 11,220.00, Tk.16,103.00 and Tk. 15,920 (1US $ = 66 Bangladeshi Taka) per hectare were achieved by the rice-duck system over farmers' conventional (sole) rice production system in T. Aus, T. Aman and Boro seasons, respectively (Table 6). In Barisal, the net returns per hectare were Tk13,430.00, Tk. 8,455.00 and Tk. 13,940.00 in the rice-duck system over sole-rice production system during the same period. Similar results were reported in earlier studies by Hossain et al. (2004) and Zheng et al. (1997).

The higher income from the rice-duck system was generated in two ways namely, the higher rice yield combined with the reduced cost of production, and the additional income from the ducks. Moreover, the rice-duck system could reduce

Table 5. Number of participating farmers, and duck mortality and average weight for three consecutive cropping seasons in Barisal and Sylhet.

Cropping season	Barisal			Sylhet		
	Participating farmers	% Duck mortality	Ave. weight (g) at crop flowering	Participating farmers	% Duck mortality (g)	Ave. weight at crop flowering
T. Aus 2003	13	12	960	26	14	925
T. Aman 2003	20	08	1050	36	12	990
Boro 2004	10	18	940	42	17	950

Table 6. Comparative results of economic analysis of rice-duck and sole-rice farming systems in Sylhet and Barisal

Location season	Cropping system	Farming system	Gross return (Tk)	Total variable cost (Tk)	Gross margin (Tk)	Net margin of Rice-duck over Sole-rice
Sylhet	T. Aus	Rice-duck system	43,320	21,850	21,470	11,220
		Sole-rice system	26,700	15,450	10,250	
	T. Aman	Rice-duck system	60,120	27,748	32,372	16,103
		Sole-rice system	38,419	22,150	16,269	
	Boro	Rice-duck system	53,180	24,400	28,780	15,920
		Sole-rice system	35,660	22,800	12,860	
Barisal	T. Aus	Rice-duck system	50,280	25,700	24,580	13,430
		Sole-rice system	27,500	15,350	11,150	
	T. Aman	Rice-duck system	47,245	23,590	23,655	8,455
		Sole-rice system	33,560	18,360	15,200	
	Boro	Rice-duck system	53,500	26,260	27,240	13,940
		Sole-rice system	34,300	21,00	13,300	

1US $ = 66 Bangladeshi Taka (Tk)

Table 7. Rice-provisioning ability (RPA) of the participating resource-poor farmers

RPA at the beginning of the project		Number of farmers who increased RPA at the end of the project, by month				Percentage of farmers who increased RPA by at least one month
RPA category (months)	Number of participating farmers	Month				
		0	1	2	3 or more	
Less than 3	38	20	20	1	-	52
3-5	24	15	9	-	-	40
6-8	40	10	27	3	-	67
8 or more	45	12	22	7	4	51
Total	147	54	78	11	4	

insecticide and chemical fertilizer requirements, thereby ensuring a safe environment and organic products.

Rice Provisioning Ability

The rice provisioning ability of the farmers in all categories increased as a result of the intervention of integrated rice-duck farming technology through the additional grain yield per unit area. A total of 78 out of 147 farmers increased their rice provisioning ability (RPA) by at least one month, but the RPA of other farmers also increased (Table 7). The participating farmers having previous RPA of 6-8 months made the highest gains. Similar results were also reported by Ahmed et al. (2004).

CONCLUSION

Results showed that the integrated rice-duck system was highly beneficial for the farmers from the economic point of view. Besides increasing the yield of rice, the infestation of weeds and insect pests was controlled by ducks in the rice-duck system. As a consequence, labor and pesticide costs for controlling weeds and insects decreased or were eliminated. The long-term adverse health and environmental effects of insecticides, herbicides and chemical fertilizer use were also substantially reduced, thus making the system beneficial to the environment.

The farmers also found the system very easy to operate, aside from being economically

rewarding. Women would have a good opportunity to participate in this activity. The technology has an inherent ability to improve the nutritional status of the resource-poor farmers. Results yielded by this sub-project convincingly demonstrated that the rice-duck system is very feasible in Bangladesh.

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