Integrating Fish and Azolla into Rice-Duck Farming in Asia

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Abstract

Several countries in Asia practice integrated rice-duck farming. On-farm resources such as duck manure and feed waste are not adequately used and recycled in the system. This indicates the potential for research to increase the productivity of the rice-duck system. The integration of fish and the nitrogen-fixing aquatic fern azolla show promise for increasing the production potential of the system. Fish, azolla and ducks integrated with rice farming can result in nutrient enhancement, pest control, feed supplementation and biological control. Some of the results of a case study on integrated rice-fish-azolla-duck farming systems conducted in the Philippines are presented in this paper.

Introduction

In Asia, duck production is often closely associated with wetland rice farming. Rice-duck farming is a traditional practice in China, Indonesia, the Philippines, Taiwan, Thailand and Vietnam, with ducks being raised in the waterways around the ricefields and feeding in the ricefields after harvest. The ducks are useful in controlling weeds and pests in ricefields. In Japan and South Korea rice-duck farming is being promoted in organic rice cultivation to reduce/ eliminate the use of chemical fertilizers and pesticides.

Fig. 1. Duck house near the ricefield in Hoonsong County, Choongnam Province, South Korea.

The practice of raising duck with rice cultivation, common to many Asian countries, usually involves housing the birds in sheds near the ricefields (Fig. 1). In this system, there is an accumulation of duck manure and uneaten feed resulting in the fouling of the sheds. This develops an unpleasant odor, attracts flies, eventually becomes unhygienic for raising ducks and is a hazard to human health. The disposal of accumulated organic matter from the duck sheds is an additional labor cost. Duck manure and spilled feed in the duck sheds are generally not recycled and are, therefore, classed as wasted on-farm resources.

Integration of Fish and Azolla with Rice-Duck Farming

The productivity of the current practices of rice-duck farming in Asia has a great potential for improvement. Rice-duck farming can be integrated with fish and the nitrogen-fixing aquatic fern azolla. Fish is a cheap source of protein

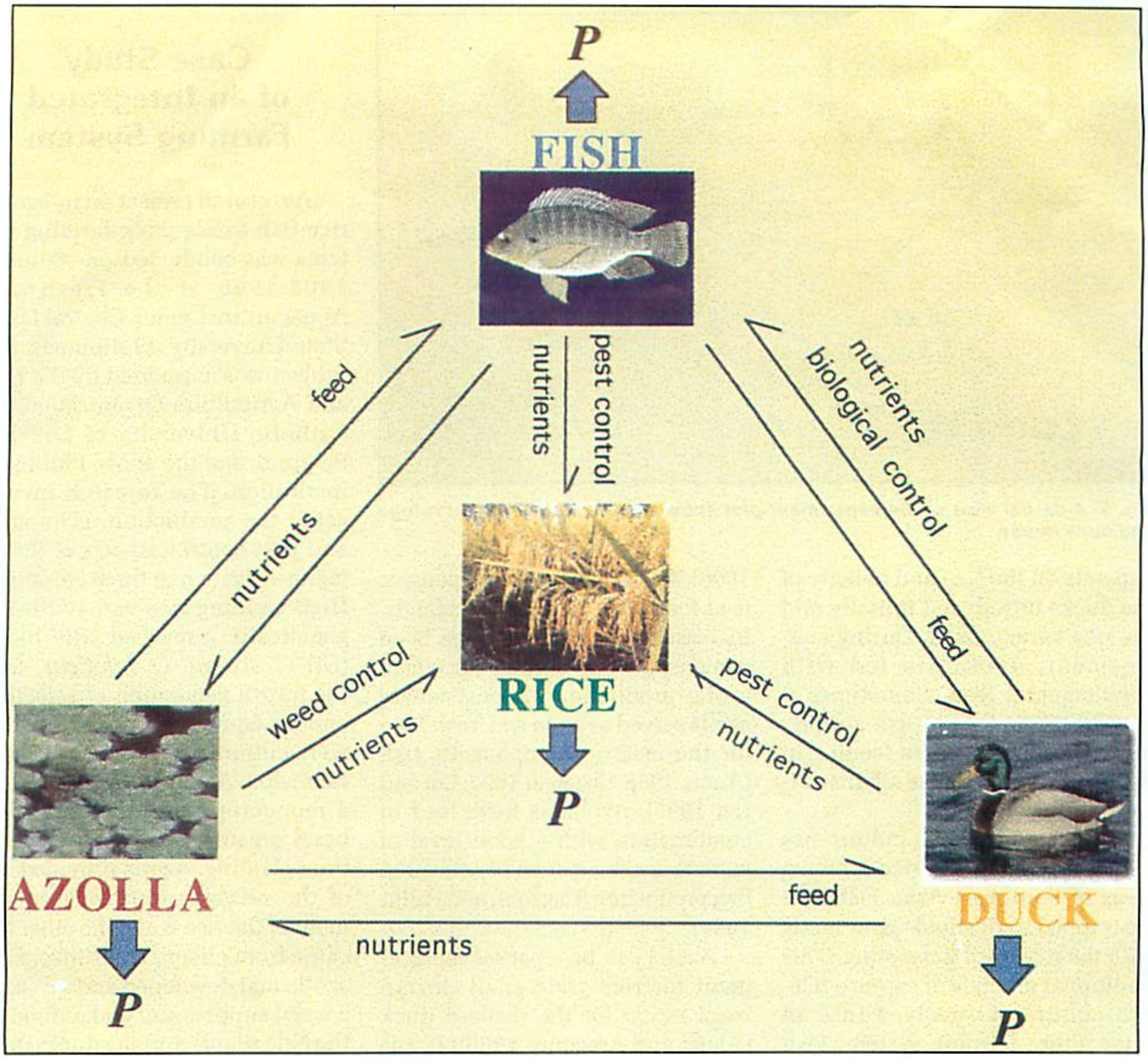

Fig. 2. Schematic presentation of the interrelationships among rice, fish, azolla and duck in an integrated farming system (P refers to production) (Source: modified from Cagauan et al. 1996).

that can be grown in ricefields while the aquatic fern azolla naturally grows in them. Fish, azolla and ducks integrated with a rice farming system can result in nutrient enhancement, pest (weed, insect, golden apple snail) control, feed supplementation and biological control (Fig. 2). Nutrient recycling in an integrated rice-fish-azolla-duck farming system is better and more efficient compared to a rice-duck or rice-fish farming system (Cagauan et al. 1996) resulting in higher productivity.

In rice-fish-azolla-duck integration, duck sheds are constructed over the fish pond refuge that is contiguous to the ricefield. The floor of the duck house has some spaces to allow the manure and spilled feed to fall directly into the fish pond. The duck manure serves as an organic fertilizer for plankton production while the spilled feed can be directly consumed by the fish. Duck manure contains a total N concentration of 2% and available phosphorous of 446 ppm (Table 1). Nutrients from the fish pond refuge are dispersed to the ricefields by irrigation water or by the movement of fish and ducks.

The ducks are herded into the paddy fields after the rice harvest. They are confined in their sheds during land preparation and until the fish are at least 2-3 weeks old. By this time any toxicity of pesticides applied at rice transplanting has dissipated and the size of fish is large enough to prevent predation by ducks. Ducks are either confined or allowed to move around the ricefields until rice harvest. The animals are confined at the onset of rice flowering to prevent damage to the rice. The damage to rice

Table 1. Nutrient composition of mallard duck manure (dry weight) in an integrated rice-fish-azolla-duck system.

Organic matter (%)	4
Total nitrogen (%)	2
Available phosphorous (ppm Olsen P)	446

Fig. 3. A partial view of the experiment plot showing the ricefield, pond refuge and duck house.

depends on the size and density of the ducks introduced initially and the rice variety used. During confinement, ducks are fed with supplemental feed. Sometimes it may be necessary to use supplemental feed even when feeding in the ricefields because of insufficient nutrients.

Integrated rice-fish culture has a long history in the rice growing areas of Southeast Asia. Fish that are trapped in ricefields grow along with the rice until harvesting. This traditional practice of capture rice-fish culture has evolved into an aquaculture farming system. Fish production in such a system can be augmented by using naturally growing azolla and spilled duck feed that fall directly into the pond as fish feed. The duck manure serves as an organic fertilizer for plankton production for the fish. For prolific spawners such as the Nile tilapia *(Oreochromis niloticus)*, overpopulation results in small size fish at harvest. Ducks may serve as a biological control for tilapia reproduction if they are allowed to forage in the ricefield throughout the culture period.

Azolla can be utilized not only as organic fertilizer for crops but also as feed for livestock and fish (Van Hove 1989; Van Hove and Lejeune 1996). Azolla can be an inexpensive feed for tilapia grown in ricefields. Increased fish production has been demonstrated in integrated rice-fish-azolla production systems where azolla served as an *in situ* fresh food for the macro-phytophagous fish (Anon. 1988; Cagauan 1995; Liu and Liu 1995). Azolla as fresh feed in combination with a good level of natural feeding can be beneficial to fish production (Cagauan and Pullin 1994).

Azolla can be a partial replacement for rice grain-snail-shrimp basal ration for the mallard duck (Alejar and Aragones 1989). It was noted that egg production of mallard ducks fed with 20% azolla in the ration was similar to those fed with commercial feed and the rice grain-snail-shrimp feed. The effect of azolla on the thickness of the shell of mallard duck eggs is not certain. The thickness of the egg shell is a very important factor in the handling and processing of embryonated and salted eggs. Eggyolk coloration in mallard duck eggs (Alejar and Aragones 1989; Joome 1996) and chicken eggs (Anon. 1985) is intensified with azolla in the diet. The carotene content of azolla was estimated by Becerra (1994) at 366 mg/kg on a dry matter basis.

Case Study of an Integrated Farming System

A research project on integrated rice-fish-azolla-duck farming systems was conducted on-station in 1995-1996 at the Freshwater Aquaculture Center, Central Luzon State University, Philippines. The project was supported by the Food and Agriculture Organization, the Catholic University of Louvain, Belgium, and the above Philippine institution. The research investigated the production, economics and pest control aspects of the integrated system in three croppings. High yielding rice variety (IR 64), genetically improved Nile tilapia (GIFT* strain), *O. niloticus*, from the fourth generation of selection, and an aquatic fern azolla hybrid were cultured in lowland irrigated ricefields. Azolla was cultivated as a monocrop and incorporated as basal organic fertilizer before rice transplanting. Azolla provided half of the nitrogen fertilizer requirement of the rice while the other half came from chemical fertilizers. An azolla mat developed and served as a weed suppressant and as food for the Nile tilapia and the ducks. Mallard ducks of a domesticated Philippine strain (*Anas platyrhynchos*) were integrated in the farming system at a density of 400 birds/ha (367 ducks and 33 drakes). The birds were herded into the ricefields during the fallow period (at least one month) and after rice transplanting (14 to 19 days). The ducks were confined at the start of rice flowering to prevent damage to the rice plants due to their foraging. A duck house made of low-cost local materials was built over the fish pond refuge where ducks were confined when they were not foraging (Fig. 3). Nile tilapia with an initial size of 10-20 g were stocked at a density of 10 000 fingerlings/ha.

*GIFT-Genetically improved farmed tilapia. See Eknath (1992).

Production

The mean yields of rice, Nile tilapia and mallard duck eggs from the different rice-based production systems are summarized in Table 2.

Based on the mean of two croppings (dry season 1996 and wet season 1996), the rice grain yield (3 t/ha) in the conventional rice-fish culture system was not significantly different from the yield (2.7 t/ha) ($P>0.05$) in the conventional rice monoculture system. However, significant yield increases over conventional rice monoculture were observed when rice-fish culture was combined with either azolla or duck or both. These increases were 33% in rice-fish-azolla (RFA), 25% in rice-fish-duck (RFD) and 58% in rice-fish-azolla-duck (RFAD) systems. Among the ten production systems, the RFAD and RAD gave the highest rice grain yield of 4 t/ha. The increases in rice production were 1.3 t/ha over conventional rice-fish culture and 1.6 t/ha over conventional rice monoculture.

The rice-fish system integrated with azolla and duck gave a higher Nile tilapia yield compared to the conventional rice-fish system. Based on the mean of three croppings, Nile tilapia yield in the conventional rice-fish system was 195 kg/ha, increasing by 33% with azolla, 90% with ducks, and 120% with the combination of azolla and ducks. After 83 culture days, the largest Nile tilapia (80 g) was harvested in RFAD, followed by RFD (70 g) and RFA (40 g) (Fig. 4). Lowest harvest weights were obtained in the conventional rice-fish system (32 g) and rice-fish system with no herbicide and molluscicide (31 g). Fish less than 50 g in weight command a lower price in the market.

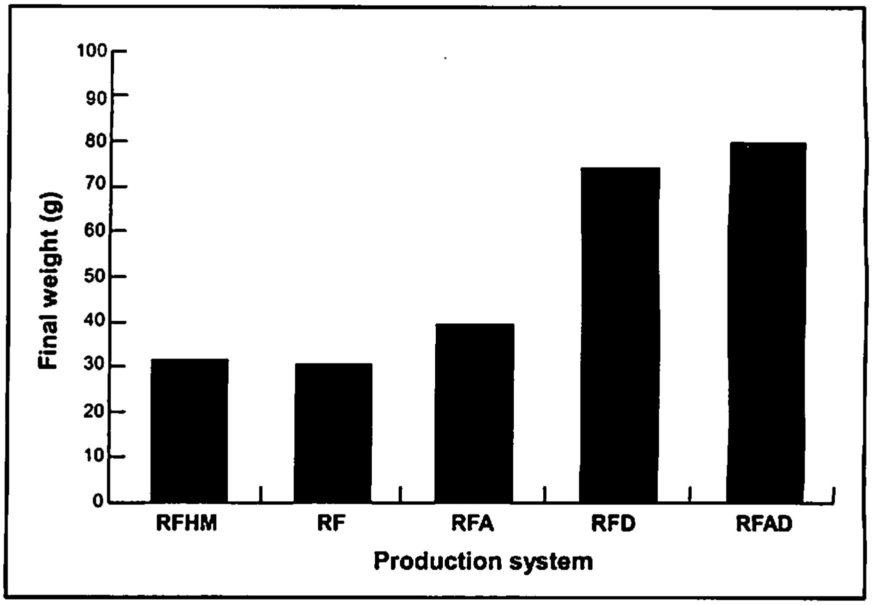

Fig. 4. Mean final weight of GIFT strain Nile tilapia after 83 culture days in three croppings in lowland irrigated rice-fish culture systems. (RFHM = conventional rice-fish culture with pesticide; RF = rice-fish culture without herbicide and molluscicide; RFA = rice-fish-azolla; RFD = rice-fish-duck; and RFAD = rice-fish-azolla-duck).

Table 2. Yields of rice, GIFT strain Nile tilapia (Oreochromis niloticus) ***and mallard duck egg* in different rice-based systems.***

Production system[1]	Rice yield (kg/ha)				Nile tilapia yield (kg/ha)				Egg production (number of eggs/ha)			
	WS95[2]	DS96[3]	WS96[4]	Mean[5]	WS95	DS96	WS96	Mean[6]	WS95	DS96	WS96	Mean[6]
Conventional rice (RHM)	1 819	2 700	2 786	2 743								
Conventional rice-fish (RFHM)	1 733	3 072	2 973	3 023	191	160	232	195				
Rice (R)	1 889	2 935	2 388	2 661								
Rice-fish (RF)	1 528	2 114	2 207	2 161	152	108	184	148				
Rice-azolla (RA)	1 991	3 189	3 172	3 180								
Rice-duck (RD)	1 832	2 899	2 917	2 908					22 941	46 216	38 558	35 905
Rice-fish-azolla (RFA)	1 563	3 934	3 448	3 691	231	234	311	259				
Rice-fish-duck (RFD)	1 739	3 536	3 313	3 424	415	587	674	559	23 488	48 434	40 731	37 551
Rice-azolla-duck (RAD)	1 920	4 242	4 575	4 409					24 544	49 431	38 469	37 481
Rice-fish-azolla-duck (RFAD)	1 608	4 379	4 307	4 343	460	769	624	618	26 257	43 667	37 941	35 955
$LSD_{0.05}$	-	625	343	760	182	50	140	147				
$LSD_{0.01}$	-	856	469	1 040	221	72	202	214				

[1] Conventional rice and rice-fish systems applied with pesticide. Other systems not applied with herbicide and molluscicide.
[2] Wet season 1995 (Trial I). Rice production affected by tungro virus disease.
[3] Dry season 1996 (Trial II).
[4] Wet season 1996 (Trial III).
[5] Mean of two trials (II and III).
[6] Mean of three trials.
* Total egg-laying period = 482 days.

The systems with more food available for the fish, such as azolla and spilled duck feed, gave higher fish yields. Moreover, plankton production stimulated by duck manure may have contributed to the better growth and yield performance of the Nile tilapia in the duck systems.

Egg production did not differ significantly in the various cropping systems with ducks. Most of the eggs produced were of medium and large size. Generally, the overall egg laying percentage was over 60%, which is well above the country's national average of 35% for ducks under traditional management (Alejar and Aragones 1989). The egg laying percentage of mallard ducks was highly variable, attributable to the sensitivity of the birds to changes in weather and feeding conditions from herding to confinement. Feed given to the ducks during herding was greatly reduced (30% to zero of the normal feeding rate) to economize on feed costs. Natural food such as aquatic plants, snails, fallen rice grains, shrimps and other on-farm resources served as duck feed during herding in ricefields.

Pest Control

The various production systems offered different management practices for controlling the golden apple snail and weeds.

The herding of ducks in ricefields not only economized on feed costs but was also very effective in controlling the herbivorous golden apple snails. Duck herding of 400 ducks/ha for a period of at least 30 days before rice transplanting effectively reduced the density of golden apple snails. The density was 1 snail/m^2 and 1.5 snails/m^2 of snails with shell size greater than 2 cm in the first and second croppings, respectively. According to Litsinger and Estano (1993), snail size greater than 1.5 cm at a density of <2 snails/m^2 is considered low density, denoting low risk to the newly transplanted rice. A density of >2 snails/m^2 denotes high risk. In the third cropping, the snail density was 6 snails/m^2 as duck herding was not considered favorable for the newly transplanted rice plants. This high density was probably the result of re-inoculation done before duck herding in this cropping period. The reason for re-inoculation in the third cropping was experimental as it was observed that the densities of snails decreased considerably after two succeeding fallow periods in the first and second croppings. Ducks were size-selective as a significant effect was observed on the density of snails with shell height less than 4 cm.

The Nile tilapia did not have any impact on the density of the golden apple snail. There were some indications that densities of small snails with shell height 2-2.9 cm decreased in the presence of Nile tilapia. It is suggested that future investigations on the evaluation of Nile tilapia for golden apple snail control consider the effect of fish size in relation to the size of the golden apple snail. The short culture period that goes along with high yielding rice varieties and the recommended initial size (10-20 g) of Nile tilapia for growout in ricefields may limit the efficacy of fish in controlling the golden apple snail population. Perhaps, a high density of small fish could increase pressure on food availability enforcing a condition that enhances the opportunistic feeding of Nile tilapia. However, this measure is not suitable in growout systems because the economic value of the fish will be affected. The use of breeder size Nile tilapia for the production of fingerlings in ricefield may yield interesting results on golden apple snail control. Tilapia fingerling production in ricefield is prevalent in the Philippines and Indonesia (Dela Cruz et al. 1992). Research on bigger fish has been suggested by Halwart (1994).

Azolla served as a biological attractant for the snail. The study indicated that azolla combined with snail predators (Nile tilapia and mallard duck) tended to reduce snail density at rice harvest. Chemical molluscicides did not reduce the snail density in either the ricefield or the pond refuge after 90 days.

It was observed that snail density in the fish pond refuge with a water depth of 1 m was not significantly reduced to levels desirable to the vulnerable stage of the rice plants by any of the snail control measures employed before and after rice transplanting. This poses a question on the compatibility of this physical structure in rice-fish culture in relation to control of the golden apple snail.

Nile tilapia significantly reduced grasses (*Poaceae*) but not total weed abundance. Azolla and duck in lowland irrigated ricefields were more effective in weed control than the Nile tilapia. The integration of azolla consumers (Nile tilapia and duck) appeared to decrease the effect of azolla on weed control. The specific weeds decreased in plots with azolla and ducks were *Echinochloa glabrescens*, *Echinochloa* spp., *Cyperus difformis*, *Cyperus* spp., *Fimbristylis miliaceae* and *Sphenoclea zeylanica*. The weed *E. crusgalli* was significantly reduced in plots with azolla while *E. colona* decreased in the plots with duck. The specific *Poaceae* weeds controlled by Nile tilapia were *E. glabrescens* and *E. colona*.

Costs and Returns

Table 3 presents a summary of the costs and returns in the various systems in three croppings. The integration of Nile tilapia, azolla and duck with rice farming required different levels of production inputs and management levels resulting in varying levels of production costs. The integration of Nile tilapia and/or mallard duck increased production costs but net returns were higher compared to the systems that produced only rice. The increase in production costs due to integrating fish with conventional rice monoculture averaged 28%, while the integration of azolla with conventional rice-fish culture increased costs by 22-42%. Differences in azolla costs are attributed to varying N fertilizer rates in the wet and dry seasons, i.e., 60 kg N and 90 kg N, respectively. The integration of ducks with conventional rice-fish culture increased production costs 4-5 times. The combination of azolla and duck with conventional rice-fish culture increased costs 4-6 times. Higher costs were incurred in the duck systems in the first cropping due to the initial investments in the house and the flock.

Conventional rice-fish culture was more profitable than conventional rice monoculture. The economic profitability of the integration of azolla in rice farming appeared better in the RFA, RAD and RFAD systems. The systems with ducks appeared to have the highest profitability among the different production systems. However, the duck systems were not profitable in the first cropping due to the high initial investment cost. Egg production during this period was not as high as in the other croppings since the flocks used were not ready to lay eggs. In the first cropping, there was a positive net return in the rice-duck system with fish but a negative net return in the system without fish. Among the systems without ducks in the first cropping when the rice production was affected by disease, the systems with fish appeared to give higher net returns than systems with rice as the only source of return. Results indicate the advantages of integrating fish with rice. Incomes derived from duck systems were evenly distributed throughout the experimental period because of the daily egg production.

Based on a cash-flow analysis over three croppings, all the systems had positive net present values (NPV) indicating their economic feasibility at the prevailing interest rate, despite the fact that there was a low return on rice production because of rice disease incidence in the first cropping. The highest NPVs were observed in the duck systems while the system with fish tended to increase net worth. The conventional rice-fish system and the RFA gave NPVs that were 89% and 56% higher, respectively, than in the conventional rice monoculture system. This system had the lowest net worth over three croppings.

Conclusion

The research demonstrated the general effects of the integration of Nile tilapia, the aquatic fern azolla and the mallard duck on production, profitability and pest control in lowland irrigated rice farming. Results showed that it is possible to enhance the productivity of rice farming by the integration of Nile tilapia, azolla and duck with a reduction in the use of pesticides. The integrated system provides biological, non-chemical strategies for pest control in rice farming. These strategies can be used as part of integrated pest management (IPM) and are considered friendly to the environment and the health of the farmers. Fish and duck raised together with rice have their own economic value resulting in increased overall productivity of the farm. Rice-duck farming integrated with fish and azolla increases the production potential of this traditional farming practice. Natural resources management in tropical wetland ricefields through integrated production systems is a promising approach to introducing sustainability in rice farming and addressing ecological issues pertaining to the conservation of ricefield ecology and aquatic biodiversity.

Table 3. Gross returns, total costs, net income and NPV (in PhP) of the various cropping systems.

Production system	First cropping (WS95)			Second cropping (DS96)			Third cropping (DS96)			Net present value[2]
	Gross returns	Total costs	Net income	Gross returns	Total costs	Net income	Gross returns	Total costs	Net income	
RHM	24 550	15 736	8 814	28 350	17 023	11 327	29 257	16 663	12 595	23 270
RFHM	32 287	20 081	12 206	40 303	21 827	18 476	41 831	21 133	20 698	42 144
R	25 500	15 716	9 784	30 813	17 267	13 546	25 070	15 767	9 304	23 683
RF	27 695	19 441	8 254	27 667	19 925	7 742	31 694	19 576	12 118	19 878
RA	26 883	20 825	6 058	33 483	25 526	7 957	33 302	22 056	11 246	17 693
RD	108 718	123 382	-14 664	198 573	105 830	92 743	204 570	95 029	109 540	137 997
RFA	31 671	24 399	7 271	52 347	31 002	21 345	50 970	26 687	24 283	36 218
RFD	130 498	125 815	4 682	243 290	111 277	132 013	251 539	100 377	151 162	207 874
RAD	115 774	133 179	-17 405	224 325	117 956	106 369	221 234	105 300	115 934	149 351
RFAD	140 852	137 606	3 246	243 476	122 006	121 470	249 407	110 292	139 115	191 752

[1]US$1 = PhP40.
[2] Over three croppings.
Note: Refer to Table 2 for legend of the different production systems.

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