WALAILAK JOURNAL

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On Farm Trial with Rice Fish Cultivation in Nakhon Si Thammarat Southern Thailand

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Received: 13 February 2012, Revised: 17 July 2012, Accepted: 5 February 2013

Abstract

The rice-fish culture investigations were conducted at rice farms in Pak Phanang, Nakhon Si Thammarat, Southern Thailand to compare the effect of the rice fish culture model on production performances of rice and fish, income, and net return. All investigations used male *Oreochromis niloticus* and a native rice variety, Leb Nok Pattani, in 6 plots (5,600 m^2 each). Two treatments, sold rice and rice-fish culture were employed with each treatment replicated three times. Juvenile *O. niloticus* with a mean weight 15 g were stocked to give 1.25 individuals per m^2 30 days after sowing the rice. Rice seeds, 15 kg rai^{-1} (rai = 1,600 m^2), were planted and commercial organic fertilizer, 100 kg rai^{-1}, was applied. Commercial feed was used as a supplementary feed, equivalent to 2 % fish body weight, once daily. The fish and rice were harvested after 122 days and 185 days, respectively. The results indicated that the rice-fish culture gave an average gross yield of 216 ± 37 and 1,122 ± 77 kg rai^{-1} for fish and rice, respectively and differed ($p < 0.05$) from the rice monoculture treatment with an average rice yield of 686 ± 96 kg rai^{-1}. In addition, the rice monoculture gave an average total income and net return of 5,490 and 1,719 baht rai^{-1} respectively while for the rice-fish culture treatment values of 17,538 and 7,338 baht rai^{-1} respectively were found indicating the treatments are significantly different ($p < 0.05$). Therefore, adoption of this system will not only increase rice production but also generate additional animal (fish) protein. Moreover, farmers who grow fish and rice together in the same area can also increase their income.

Keywords: Mono rice culture, rice-fish culture, all male tilapia, Leb Nok Pattani, Nakhon Si Thammarat, Thailand

Introduction

Fish supply in many developing countries is under 10 % of the estimated requirement of 35 g per caput per day. In Thailand, west Scandinavia, and Japan the per capita fish consumption average is 30, 45 and 69 kg $year^{-1}$ respectively [1]. The projected fish demand and supply by the year 2010 for countries in West Africa, shows only Cote D'Ivoire, Gambia, Ghana, Senegal and Togo have a per caput fish consumption above the world average of 13 kg $year^{-1}$ [2]. To meet the country's fish requirement, a low input technology that efficiently utilizes land resource by integrating fish culture with crop production is desired.

Growing fish and rice together in the same paddy fields is an old widespread method for producing two crops from the same piece of land [3]. Paddy-fish systems are low cost, effective and bring about economic returns and are recognized as an additional source of food and income in rural areas [4]. Rice-fish culture is a recent activity in this region and has been promoted by government and non-government agencies with variable success among small scale farmers. Widespread availability of fish eggs allows more farmers to try rice-fish culture but the small size of eggs at purchase is still a problem particularly where carnivorous, wild fish are prevalent. Appropriate on-farm nursery techniques may improve success and adoption of hapa nursing has been high in some parts of the region [5]. Stocking fish in rice fields has become a central theme of many development agencies in northeast Thailand over the last decade. This idea was similar to that extended in central Thailand 30 years previously [6]. This trend is mirrored by wide spread interest throughout the region but less interest has come from southern Thailand. Whereas a vast area, more than 310,000 hectares, comprises the Pak Phanang river basin and the flood plains only 80,000 hectares is suitable for rice production [7], and can play an important role in fish production. The rice fields are potential fish ponds since in its aquatic phase the rice field is a rich and productive biological system. The adoption of this technology will meet the nation's fish demands.

Trenches and sumps which serve as a fish refuge must also be provided. They can be dug on one side only, all round (peripherally) or diagonally across each plot. In recent times pond refuges have been used instead because of their flexibility to different rice-fish culture cycles [8]. The number of trenches, contour and size depends on size of the plot, fish stocked, and soil.

Leb Nok Pattani, is typically a long duration variety of rice (about 160 - 185 days) but rice breeding has brought in new varieties of short duration (105 - 125 days) [5]. The duration of the crop is important in view of the pisciculture practice, to be adopted.

A wide variety of fish species are used in rice fields including carp, tilapia, barb etc. Polycultures have also been introduced to utilize the different ecological niche available in the irrigated rice ecosystem. This has resulted in improved rice yields and reduced production costs. Moreover, the concept of integrated pest management excludes the use of pesticides and utilizes fish for biological control of pests in rice fields [5]. Fish are also known to play an important role in the control of malarial mosquitoes that abound in areas with irrigation facilities thus leading to improved health for farmers [9].

The majority of flood plains, especially the Pak Phanang river basin, are suitable for the production of rice in southern Thailand. Therefore, these rice production areas have an enormous potential to expand their aquaculture production by combining rice and fish culture, particularly duo starch-fiber based products. However, the practice of rice-fish culture in this area is limited. Therefore, a program of research into fish farming in paddy fields at Ban Khanabnak, Pak Phanang district, Nakhon Si Thammarat was established. The purpose of this study is to evaluate if integrated rice farming practices provide a competitive alternative to rice monocultures, from an economic as well as an ecological point of view. The benefits of this study may play a significant part in the development of rice farming in the Pak Phanang river basin, especially small agricultural groups, which most people in the agricultural sector of the country can use in agricultural production for sustenance and sustainability. In addition, this will not only help farmers build a better quality of life but can also contribute to the local communities with sustainable prosperity and a good environment.

Materials and methods

Planting and experimental design

The study was carried out in a field at Tambon Khanabnak, Pak Phanang, Nakhon Si Thammarat, southern Thailand (**Figure 1**). This area lies on latitude 08° 13 N and longitude 100° 14 E. The rice plots acquired their water from a canal coming from Pak Phanang River which received water from the Kuankreng wetlands.

Six plots of 5,600 m^2 were used for the experiment. Two treatments, sole rice and rice-fish cultivation were employed with each treatment randomly assigned in triplicate. Three plots designated for rice-fish culture treatment, contained a trench 1 m wide and 50 cm deep that served as fish refuge which were constructed peripherally and the soil partly used to build 60 cm high perimeter bunds. The area covered by the trench was about 5 % of the experimental rice plots. All the plots were ploughed and harrowed according to standard farming practices. Commercial organic fertilizer totaling 100 kg rai^{-1} was used, of which 50 kg rai^{-1} was used during field preparation as a basal dose. The remainder was divided into two doses for top dressing at the time of flowering and panicle initiation. Native varieties of Pak Phanang Leb Nok Pattani rice, 15 kg rai^{-1} were planted. The water level was maintained at 8 - 10 cm during the first 30 days and later gradually increased to 30 cm until the fish were harvested. Weeding was carried out 20, 30, 45 and 60 days after transplantation.

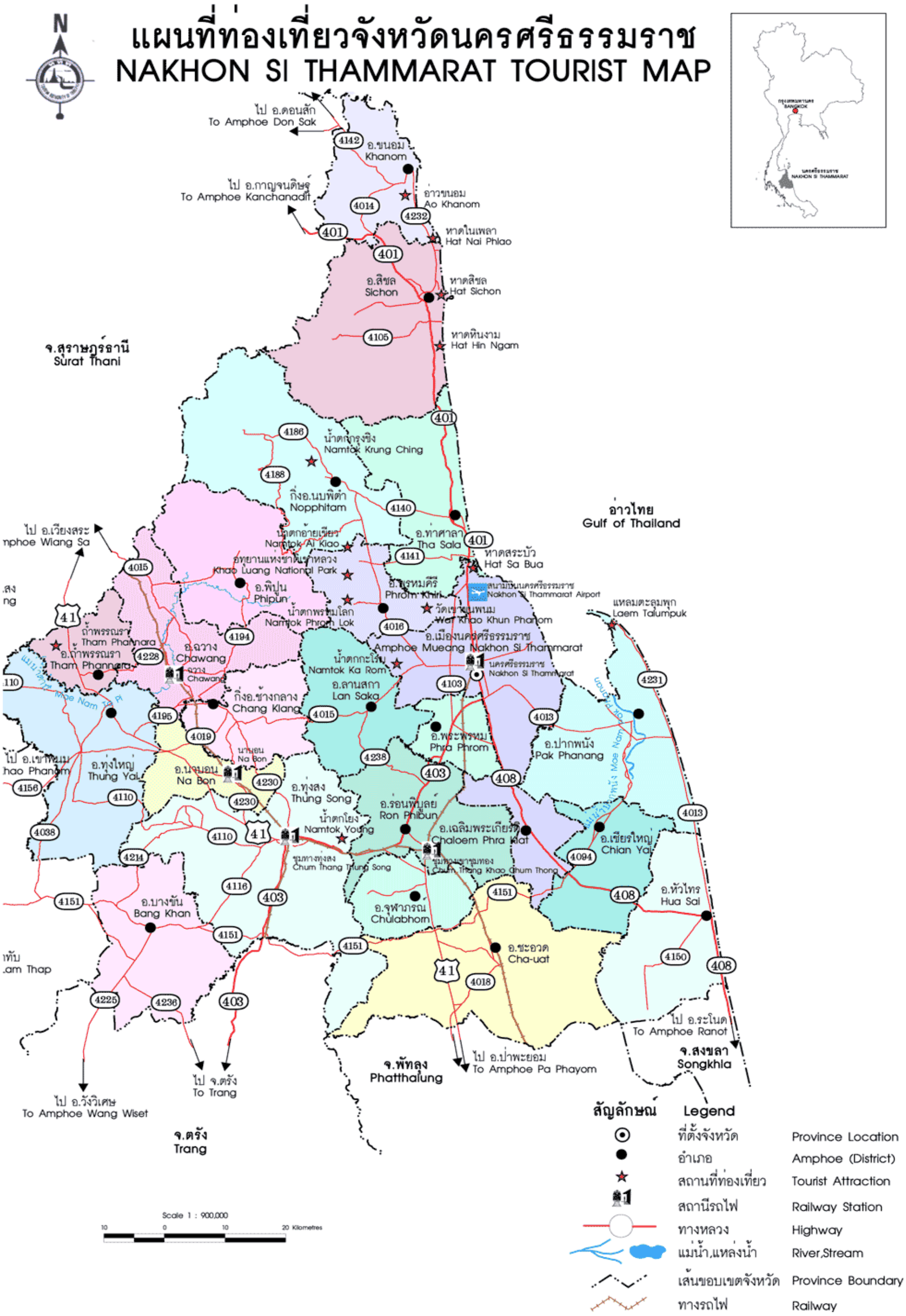

Figure 1 Study site, location of Pak Phanang, Nakhon Si Thammarat, Thailand.

Stocking and feeding

Male juvenile *O. niloticus* with a mean weight of 15 g were stocked to give 1.25 individuals per m^2 30 days after sowing the rice seedlings. Fish were fed with commercial feed, used as a supplementary feed a 25 % crude protein, 3 % fat, 8 % crude fiber and 12 % moisture floating pelleted diet (Grobest co., Ltd., Phayathai, Bangkok) once daily. Rations were recorded to monitor fish feed conversion ratios [10] equivalent to 2 % fish body weight. The fish and rice were harvested after 122 and 185 days, respectively. No pesticide was used during the culture period.

Water quality analyses

pH, water temperature, and dissolved oxygen concentration were measured *in situ* with a polarographic dissolved oxygen meter and portable pH meter at 15 day intervals between 06.00 and 08.00 a.m. and occasionally between 13.30 and 15.00 p.m. Water samples were taken with a 90 cm water column sampler [5]. All tests followed protocols presented in the Standard Methods handbook [11]. A YSI model 58 dissolved oxygen meter (YSI Co., Yellow Springs, Ohio, USA) was used for temperature and DO measurements, and a Hanna Instruments model HI 1270 pH probe (Hanna Instruments, Woonsocket, Rhode Island, USA) was used to monitor pH. Samples were transported immediately to the laboratory and analyzed for chlorophyll-a (spectrophotometric), total alkalinity (acidimetry), and total hardness (EDTA titration). Aliquots of samples also were digested in alkaline persulfate solution, and the resulting nitrate and phosphate measured by the NAS reagent method [12] and the ascorbic acid procedure [13], respectively. Turbidity was measured by bench-top turbidity meter (Hanna Instruments, model HI 98730, Woonsocket, RI., USA)

Productivity analyses

Phytoplankton and benthic fauna were measured by the method described by the American Public Health Association [14] where collection examples were done 2 times per month at about 10.00 pm till the end of study. For example, plankton and benthos taxonomic classification is made according to [15,16]. Samples of phytoplankton and benthic fauna in addition to those identified (species diversity) already were also counted to determine the amount of each type (species abundance) and then density calculated as cell ml^{-1} and the number per m^2 respectively. Rice growth and weed numbers were measured by random sampling using a 1m × 1m quadrate. Tiller from rice plants within the quadrate were counted at 15 day intervals till a nearly constant value was reached according to the method of [9].

Harvesting

Rice yield data were taken by harvesting rice in 1 m long and 1 m wide split quadrates when the 80 - 85 % of the grain turned golden yellow. These were sun dried and the grains collected after careful threshing. The rice grains were cleaned and dried to a moisture content of 14 % and yields calculated in kg rai^{-1} as described by [18].

Ponds were drained and fish were harvested by seining after 122 days. Total harvest weights and numbers of fish were obtained for each plot. A random sample of 30 fish was taken from each plot for length and weight measurements. Data of initial weight, final weight, survival rate, growth rate, and net production were calculated as described by [18]. Total income and net return from the rice monoculture and rice-fish culture were computed as described by [19].

Statistical analysis

Data were subjected to analysis of variance. Comparison of means was carried out by Student's t-test to determine any difference between the treatments. Statistical analysis was performed using the R Foundation for Statistical Computing [20].

Results and discussions

pH, Temperature, Dissolved Oxygen, Total alkalinity, Total hardness, Total nitrogen, Total phosphorus, Turbidity, and Chlorophyll a are presented in **Table 1**. From the results, water quality variables fluctuated greatly among treatments, ponds, and dates as typically observed in pond fertilization studies [21]. Thus, only treatment grand means are reported.

The pH of the surface water in an individual plot varied from 7.1 - 9.7 as a result of differences in phytoplankton photosynthesis rates. The mean pH did not differ and ranged from 8.4 - 8.7. Fertilized ponds typically have high pH in the surface water, but this phenomenon does not prevent a positive response of fish production to fertilization [1]. This could be attributed to the fact that most of the hydrogen ions were autochthonous and not affected by any allochthonous inputs.

The lowest and highest measured water temperatures in the individual plots were 28.9 °C and 29.7 °C. The mean water temperature did not differ among treatments and ranged from 29.0 - 29.8 °C. Temperature is never a limiting factor in tropical fish culture [22]. Water temperature was within an acceptable range for culture of fish and rice growth.

The dissolved oxygen level in the rice monoculture plots however was very low (mean 2.2 ± 0.9 mg L^{-1}) and significantly different ($p < 0.05$) from the value in the rice-fish culture plots. This may be attributed to the high level deposition of silt and organic matter in the rice plots [23] which utilize considerable amounts of dissolved oxygen for decomposition. This organic matter is apparently consumed by the foraging fish in rice-fish culture plots thereby significantly reducing the requirement for dissolved oxygen for decomposing organic matter. Besides, fish perturbation of the soil can result in aeration of soil and water and could be responsible for the higher dissolved oxygen level (mean value 4.9 ± 0.90 mg L^{-1}) observed in the rice-fish culture plots.

Treatment means for chlorophyll a, phytoplankton and benthos abundances in the rice monoculture plots were significantly different ($p < 0.05$) and lower than those in the rice-fish culture plots (**Table 1**). This may be the attribute of the high fertility of the environment in the rice-fish culture plots derived from fish feed and fish waste contributing to the abundance of natural food and beneficial to fish growth. [23].

Total alkalinity concentration in the individual plots varied from 66.9 - 92.3 mg L^{-1} as $CaCO_3$, but treatment means of 79.6 - 111.7 mg L^{-1} as $CaCO_3$ were significantly different ($p < 0.05$) (**Table 1**). Total hardness concentration exhibited variability similar to that of total alkalinity concentration, and treatment means were 98.1 - 156.8 mg L^{-1} as $CaCO_3$ and significantly different ($p < 0.05$) (**Table 1**). Total hardness concentration was consistently higher than total alkalinity concentration by 5 to 20 mg L^{-1} as $CaCO_3$. This is a typical result of liming acidic ponds, because bicarbonate from dissolution of liming material, the source of alkalinity, is expended in neutralizing acidity; the calcium and magnesium ions from the liming material, the source of hardness, remain in solution. Both alkalinity and hardness averaged above the minimum concentration of 20 mg L^{-1} as $CaCO_3$ considered acceptable for culture fish ponds [21].

Treatment means for total nitrogen and total phosphorus concentrations in rice monoculture plots and in rice-fish culture plots did not differ (**Table 1**). In spite of the difference in the amounts of these two nutrients applied the values are similar to those in [21] where fertilizer fish ponds were used. However, nitrogen and phosphorus are absorbed quickly by phytoplankton or assimilated by other processes within pond ecosystems. About two-thirds of phosphorus applied to ponds in feeds and fertilizers is sequestered by sediment [24]. Of course, some nitrogen accumulates in the sediment as a component of organic matter. Water samples were collected at a time of sampling when natural processes had already reduced the concentrations of the nutrients in the water.

Turbidity level in the rice monoculture plots (mean 32.2 ± 28.7 NTU) was significantly lower ($p < 0.05$) than that in the rice-fish culture plots (**Table 1**). This may be attributed to the high level sediment deposition and organic matters in the rice plots [25]. Besides, fish perturbation of the soil can result in turmoil of soil and water and could be responsible for the higher turbidity level (mean 47.6 ± 20.9 NTU) observed in the rice-fish culture plots.

Weed abundances were 17 ± 5.7 ind.m^{-2} in rice monoculture plots and significantly higher ($p < 0.05$) than that in the rice-fish culture plots, 1.5 ± 0.00 ind.m^{-2}. Integration was effective in suppressing weeds in the rice-fish plots since only a single weeding was carried out in the plots. Fish are known to control weeds by directly feeding on the weeds and by bottom feeding activity which results in the uprooting of submerged and emergent vegetation. This informed our decision to introduce fish in the rice plots 4 weeks after transplanting when the rice seedling would have fully established and withstand the foraging activities of the fish. The turbid environment created by fish feeding activities also lead to limited light penetration which results in weed control [7]. The level of water equally plays an important role in growth of weeds in rice fields. Many weeds do not germinate in flooded fields. Hora and Pillay [26] recommended that rice plots for fish culture should have 3 - 5 cm of water in the first 2 weeks after transplanting and be gradually increased to 20 cm. In this study, the water in both treatments was gradually increased to 30 cm and this may have limited the growth of weeds even in the sole rice plots which were weeded only twice as against the common practice of weeding three times in plots with low water levels.

Table 1 Grand means and standard deviations for water quality variables in rice monoculture and rice-fish culture plots at Pak Phanang, Nakhon Si Thammarat, southern Thailand. Treatments were replicated three times.

Variables	Treatment[1]	
	Rice monoculture	**Rice-fish culture**
pH	8.4 ± 1.3^a	8.7 ± 1.2^a
Temperature (°C)	29.8 ± 1.1^a	29.8 ± 0.75^a
Dissolved Oxygen (mg L^{-1})	2.2 ± 0.9^a	4.9 ± 0.90^b
Total Alkalinity (mg L^{-1} as $CaCO_3$)	79.6 ± 12.7^a	111.7 ± 11.8^b
Total Hardness (mg L^{-1} as $CaCO_3$)	98.1 ± 13.4^a	156.8 ± 13.1^b
Total Nitrogen (mg L^{-1})	0.034 ± 0.015^a	0.037 ± 0.015^a
Total Phosphorus (mg L^{-1})	0.047 ± 0.04^a	0.085 ± 0.1^a
Turbidity (NTU)	32.2 ± 28.7^a	47.6 ± 20.9^b
Chlorophyll a (mg L^{-1})	136 ± 86.3^a	152 ± 70.3^b
Plankton (cell ml^{-1})	27.32 ± 10.1^a	42.09 ± 5.15^b
Benthos (Individual m^{-2})	9.2 ± 2.3^a	20.3 ± 10.5^b
Weeds (Individual m^{-2})	17 ± 5.7^a	1.5 ± 0.00^b

[1]Entries indicated by the same superscript letter do not differ (P > 0.05) as determined by Student's T-Test horizontal comparisons only.

Rice height was 155 ± 13.23 cm in rice monoculture plots and was significantly different ($p < 0.05$) and slightly lower than those in the rice-fish culture plots (**Table 2**). This may be attributed to the high fertility of the environment in the rice-fish culture plots derived from the fish feed and fish waste contributing to the abundance of natural food and beneficial to fish growth [27].

Rice yields were 686 ± 96 kg rai^{-1} in rice monoculture plots and significantly ($p < 0.01$) lower than those in the rice-fish culture plots, 1,122 ± 77 kg rai^{-1} (**Table 2**). This is possibly due to the attributes of continuous soil moisture and a fertile environment in the rice-fish culture plots which are beneficial for rice growth. Data from this study show that the trenches which served as fish refuges did not reduce the rice yields. Nguyen *et al.* [28] reported that utilization of 10.9 % of the land for trenches in the rice-fish plots did not significantly reduce rice production.

The mean fish weight in the rice-fish culture plots increased from 15 to 180 g with an average growth rate of 1.35 g day^{-1} and 60 % survival rate. This translated to a gross yield of 216 kg rai^{-1} (**Table 2**). However, the fish yield in this study, performed better than that reported for tilapia of similar initial stocking size in north central Nigeria [29] given that the fish were cultivated for 5 months.

The average total income and net return were 5,490 and 1,719 baht rai^{-1} respectively in the rice monoculture plots and significantly ($p < 0.01$) lower than those in the rice-fish culture plots with a total income and net return of 17,538 and 7,338 baht rai^{-1}, respectively (**Table 2**). This indicates that combining rice and fish culture in the same area results in mutually beneficial interactions. These results were in agreement with those of other researchers [30-32].

Table 2 Grand means and standard deviations for production, total income and net return of rice monoculture and rice-fish culture plots at Pak Phanang, Nakhon Si Thammarat, southern Thailand. Treatments were replicated three times.

Variables	Treatments[1]	
	Rice monoculture	**Rice-fish culture**
Rice		
Plant height (cm)	155 ± 13.23[a]	182 ± 3.6[b]
Yields (kg rai^{-1})	686 ± 96[a]	1,122 ± 77[b]
Income (Baht rai^{-1})	5,490 ± 768[a]	8,978 ± 616[b]
Fish		
Initial weight (g)	-	15 ± 3.8
Initial Length (cm)	-	9.85 ± 0.18
Final weight (g)	-	180.2 ± 25.8
Growth (g)	-	165.2 ± 15.7
Final length (cm)	-	19.2 ± 2.1
Growth rate (g d^{-1})	-	1.35 ± 0.21
Survival rate (%)	-	60.6 ±15.3
FCR	-	1.1 ± 0.01
Yield (kg rai^{-1})	-	216 ± 37
Income (baht rai^{-1})	-	7,560 ± 937
Total costs (baht rai^{-1})	3,771[a]	10,199[b]
Total income (baht rai^{-1})	5,490[a]	17,538[b]
Net returns (baht rai^{-1})	1,719[a]	7,338[b]

[1]Entries indicated by the same superscript letter do not differ (P > 0.05) as determined by Student's T-Test horizontal comparisons only.

Conclusions

There is no doubt therefore from the results of this study that adopting this technology in southern Thailand holds exciting promise for farmers to maximize their resources, reduce their investment risk through crop diversification and improve nutrition and food security for the country.

Acknowledgments

This research was supported by the Research and Development Institute, Walailak University (Grant No. WU 52120).

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