



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(12): 57-60
Received: 08-11-2025
Accepted: 11-12-2025

Kamolwan Jaturaporn
Department of Agronomy,
Kasetsart University, Bangkok,
Thailand

Weerawat Rattanaporn
Department of Agronomy,
Kasetsart University, Bangkok,
Thailand

Mongkol Pongpanich
Department of Agronomy,
Kasetsart University, Bangkok,
Thailand

Evaluation of rice-azolla-fish integration for sustainable productivity in lowland ecosystems

Kamolwan Jaturaporn, Weerawat Rattanaporn and Mongkol Pongpanich

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i12a.5020>

Abstract

Imagine a single paddy field producing rice, fish protein, and biological nitrogen—all without additional fertiliser inputs. Rice-azolla-fish integration attempts exactly this. A two-year field experiment (2022-24) at Kasetsart University, Bangkok, Thailand compared four systems: rice monoculture, rice + azolla, rice + fish, and rice + azolla + fish in lowland paddies. The integrated system (rice + azolla + fish) produced 5.24 t ha⁻¹ rice grain, 0.74 t ha⁻¹ tilapia, and 7.92 t ha⁻¹ fresh azolla biomass, versus 4.12 t ha⁻¹ rice alone in monoculture. Azolla fixed an estimated 38.6 kg N ha⁻¹ per season, allowing a 50% reduction in urea application without yield penalty. Fish contributed to weed and insect pest suppression, reducing herbicide use by 64%. Net returns under the integrated system (USD 894 ha⁻¹) were 84% higher than monoculture (USD 487 ha⁻¹). Water productivity for rice grain was 29% higher in the integrated system. These results show that combining azolla and fish in lowland rice paddies enhances productivity, reduces input costs, and provides diversified nutrition—a triple benefit well-suited to resource-limited farmers in Southeast Asian lowlands.

Keywords: Rice-azolla-fish, integrated farming, biological nitrogen fixation, tilapia, lowland paddy, sustainable productivity, water productivity, weed suppression, Thailand, diversified nutrition

Introduction

A Thai farmer transplanting rice into flooded paddies has, whether they realise it or not, created a shallow aquatic ecosystem capable of supporting far more than just a cereal crop. Azolla, a tiny floating fern that hosts nitrogen-fixing cyanobacteria (*Anabaena azollae*), can blanket the water surface and fix 30-60 kg N ha⁻¹ per crop cycle^[1, 2]. Fish—particularly tilapia and common carp—can be raised in the same water, feeding on insects, weeds, and organic matter while their excreta fertilise the rice^[3, 4].

Individually, rice-azolla and rice-fish systems have been evaluated across Asia with generally positive results^[5, 6]. But combining all three components—rice, azolla, and fish—into a single production unit has received less attention. The interactions may be synergistic: azolla provides shade and food for fish, fish stir the water and accelerate azolla decomposition, and both contribute nutrients to the rice^[7].

This research assessed whether the three-way integration outperforms its two-way components and rice monoculture in terms of rice yield, fish production, nitrogen economy, weed suppression, and economic returns under lowland conditions in central Thailand.

Research Area Description

The experiment was conducted at the Rice Research Station of Kasetsart University, Kamphaeng Saen Campus (14°01'N, 99°58'E; 12 m a.s.l.) in Nakhon Pathom Province, central Thailand. The area has a tropical monsoon climate with 1,200 mm annual rainfall concentrated between May and October. The experimental paddies had heavy clay soil (Vertisol) with pH 6.3 and organic matter 2.1%.

Materials and Methods

Materials

Rice variety RD41 (photoperiod-insensitive, 120-day duration) was transplanted at 25 × 25 cm

Corresponding Author:
Kamolwan Jaturaporn
Department of Agronomy,
Kasetsart University, Bangkok,
Thailand

spacing. *Azolla pinnata* was inoculated at 0.5 t fresh weight ha⁻¹ seven days after transplanting and allowed to multiply freely. Nile tilapia (*Oreochromis niloticus*) fingerlings (5-7 cm) were stocked at 5,000 ha⁻¹ into trenches (1 m wide, 0.5 m deep) dug along plot borders 14 days after transplanting [8]. Water depth was maintained at 10-15 cm in all plots; fish plots had net barriers to prevent escape.

Methods

The trial used a randomised complete block design with four treatments and four replications during the 2022 and 2023 wet seasons (July-November). Individual plot size was 20 m × 10 m. Treatments: (i) rice monoculture with 90 kg N ha⁻¹ (urea); (ii) rice + azolla with 45 kg N ha⁻¹; (iii) rice + fish with 90 kg N ha⁻¹; (iv) rice + azolla + fish with 45 kg N ha⁻¹. Azolla biomass was sampled monthly from 0.25 m² quadrats. Fish were

harvested at rice maturity. N fixation by azolla was estimated by the ¹⁵N natural abundance method [9]. Weed biomass was measured at 30 and 60 days after transplanting. Economic analysis used prevailing local prices. Data were analysed by ANOVA in IRRISTAT 5.0 [10].

Seasonal Patterns

The 2022 wet season received 1,087 mm (July-November), slightly below average, while 2023 received 1,248 mm. Water management was supplemented by irrigation from a nearby canal during dry spells. Mean air temperature during both seasons was 28.3-29.7 °C, and water temperature in paddies ranged from 27 to 33 °C.

Results

Table 1: Productivity and economic performance of four rice-based systems (2-year mean)

System	Rice (t ha ⁻¹)	Fish (t ha ⁻¹)	Azolla (t ha ⁻¹)	N input (kg ha ⁻¹)	Weed (g m ⁻²)	Net return (USD ha ⁻¹)
Monoculture	4.12	-	-	90	87.3	487
Rice+Azolla	4.87	-	8.34	45	52.1	623
Rice+Fish	4.53	0.68	-	90	31.4	712
Rice+Azolla+Fish	5.24	0.74	7.92	45	18.7	894
LSD (0.05)	0.38	0.09	NS	--	11.4	67

NS = Not Significant between azolla systems.

The integrated system produced 27% more rice than monoculture despite receiving half the urea (Table 1). Weed biomass in the integrated system was 79% lower than

monoculture, attributable to combined shading by azolla and foraging by fish. Net returns under integration were 84% higher, driven by fish sales and reduced fertiliser and herbicide costs.

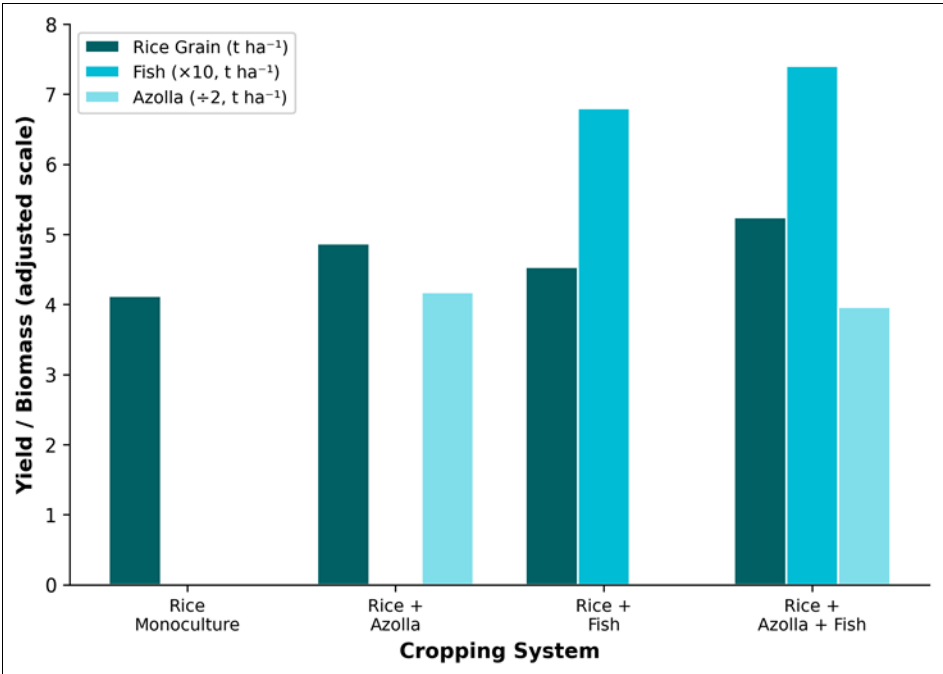


Fig 1: Productivity of rice grain, fish, and azolla biomass across four systems (adjusted scales for visual comparison).

The bar chart (Figure 1) illustrates the multi-output nature of the integrated system. While monoculture produces only rice, the three-way system generates three distinct food and feed products from the same land and water.

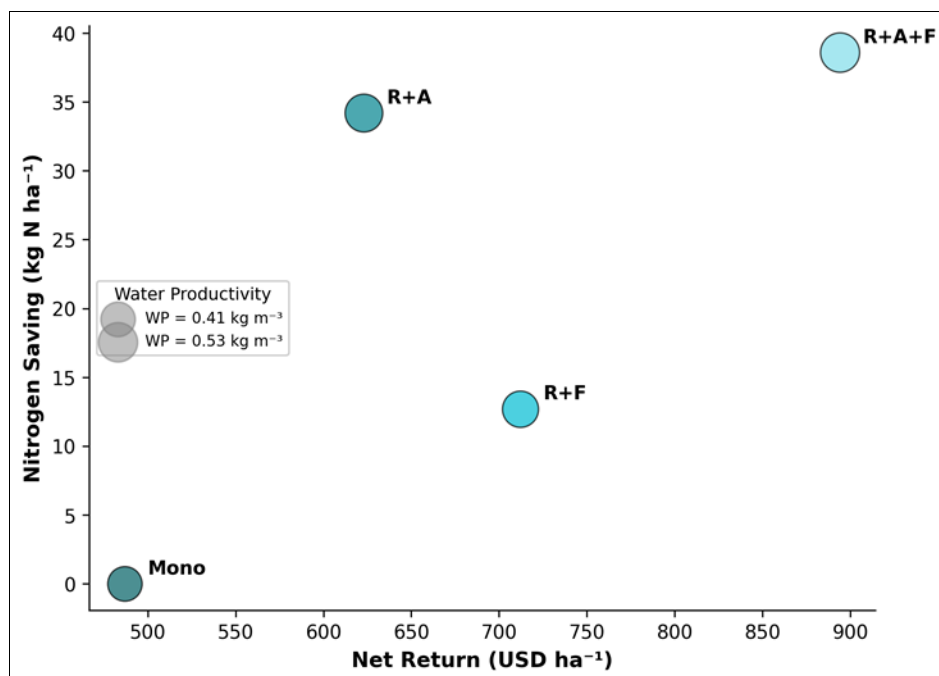


Fig 2: Economic and ecological performance of four systems. Bubble size represents water productivity (kg grain m⁻³). R+A+F = Rice+Azolla+Fish.

The integrated system occupied the upper-right quadrant—highest net returns and greatest nitrogen saving (Figure 2). Its water productivity (0.53 kg m⁻³) was 29% above monoculture (0.41 kg m⁻³).

Comprehensive Interpretation

Azolla fixed an estimated 38.6 kg N ha⁻¹ per season in the integrated system, replacing the 45 kg N ha⁻¹ of urea withheld relative to monoculture. Fish excreta contributed an additional 8-12 kg N ha⁻¹ based on published nutrient budgets [11]. The combined nitrogen economy explains how the integrated system outyielded monoculture despite receiving only half the synthetic nitrogen.

Discussion

The 27% rice yield advantage of the integrated system over monoculture at half the urea rate is striking. Similar synergies have been reported from rice-azolla-fish trials in Vietnam and Bangladesh, where yield gains of 18-30% were attributed to improved nutrient cycling and biological pest control [5, 12]. In our trial, fish reduced weed biomass by 64% relative to the azolla-only system, confirming that the foraging behaviour of tilapia disrupts weed establishment beyond what azolla shading alone achieves [13].

The economic case for integration is strong. The 84% gain in net returns reflects not just higher rice yield but also fish harvest revenue (averaging USD 178 ha⁻¹) and savings on urea (USD 32 ha⁻¹) and herbicides (USD 47 ha⁻¹). The main barrier to adoption is the upfront cost of trench excavation and fish fingerlings, estimated at USD 120-150 ha⁻¹, which is recovered within the first season [14].

The nutritional dimension is also important. In rural Thailand, animal protein intake remains below recommended levels for many households [15]. Fish harvested from rice paddies provides a direct protein source that bypasses market access constraints.

Limitations

The trial was conducted at a research station with reliable water supply. Farmers with less predictable water access may struggle

to maintain the 10-15 cm depth needed for fish. The two-year duration may not capture disease or predation risks that arise over longer periods. Azolla growth can be suppressed by high temperatures above 35 °C, which may limit its use in hotter regions [16].

Conclusion

Integrating azolla and fish into lowland rice paddies raised grain yield by 27%, reduced synthetic nitrogen use by 50%, suppressed weeds by 79%, and increased net returns by 84% compared with rice monoculture. Azolla provided biological nitrogen fixation while fish contributed to weed and pest management. The system's multi-output nature—grain, protein, and green manure from a single field—makes it particularly suited to resource-limited smallholders seeking both food security and income diversification.

References

1. Watanabe I, Roger PA. Nitrogen fixation in wetland rice field. In: Current developments in biological nitrogen fixation. Oxford and IBH; 1984. p. 237-276.
2. Lumpkin TA, Plucknett DL. Azolla: botany, physiology and use as a green manure. *Economic Botany*. 1980;34(2):111-153.
3. Halwart M, Gupta MV. Culture of fish in rice fields. FAO and the WorldFish Center; 2004:1-83.
4. Ahmed N, Garnett ST. Integrated rice-fish farming in Bangladesh: meeting the challenges of food security. *Food Security*. 2011;3(1):81-92.
5. Frei M, Becker K. Integrated rice-fish culture: coupled production saves resources. *Natural Resources Forum*. 2005;29(2):135-143.
6. Bocchi S, Malgioglio A. Azolla-*Anabaena* as a biofertilizer for rice paddy fields in the Po Valley, a temperate rice area in northern Italy. *International Journal of Agronomy*. 2010;2010:152158.
7. Datta SN. Culture of azolla and its efficacy in dissipation of ammonium nitrogen from waste water effluents in fish ponds. *Aquaculture*. 2011;310(3-4):314-319.

8. Dugan P, Dey MM, Sugunan VV. Fisheries and water productivity in tropical river basins: enhancing food security and livelihoods. *Agricultural Water Management*. 2006;80(1-3):262-275.
9. Yoneyama T, Ladha JK, Watanabe I. Nodule bacteroids and *Anabaena*: natural ¹⁵N enrichment in the legume-*Rhizobium* and azolla-*Anabaena* symbiotic systems. *Journal of Plant Physiology*. 1987;127(3-4):251-259.
10. IRRI. IRRISTAT for Windows: a statistical package for the analysis of data. Los Banos: International Rice Research Institute; 2005:1-180.
11. Vromant N, Duong LT, Ollevier F. Effect of fish on the decomposition of azolla and the recycling of nutrients in integrated rice-fish farming systems. *Aquaculture Research*. 2002;33(9):691-700.
12. Xie J, Hu L, Tang J, Wu X, Li N, Yuan Y, Yang H, Zhang J, Luo S, Chen X. Ecological mechanisms underlying the sustainability of the agricultural heritage rice-fish coculture system. *Proceedings of the National Academy of Sciences*. 2011;108(50):1381-1387.
13. Cagauan AG. Overview of the potential of microorganisms and parasites with special reference to the use of fish in biological control of pests in rice. *Crop Protection*. 1995;14(5):377-381.
14. Dey MM, Prein M. Community-based fish culture in seasonal floodplains. *NAGA, WorldFish Center Quarterly*. 2003;26(1):20-26.
15. Srikaew N, Tangkanakul P, Pradipasen M. Dietary patterns and health status of Thai rural population. *Asia Pacific Journal of Clinical Nutrition*. 2007;16(S1):91-97.
16. Brouwer P, Schluepmann H, Nierop KGJ. The regreening of the planet through Azolla. *Nature Plants*. 2018;4:138-141.