

Effects of Dry Chicken Manure and Fermented Liquid Swine Manure on Growth, Yield, Seed Quality, and Soil Properties in Organic Riceberry Rice Production Systems

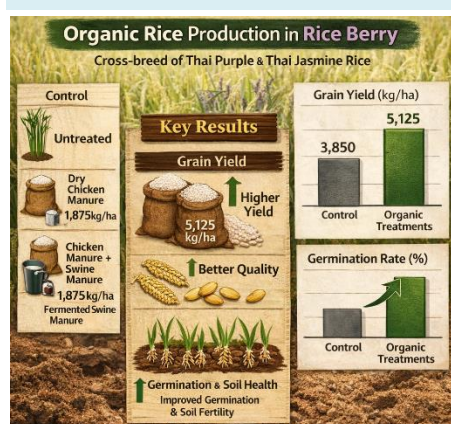
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ABSTRACT



Riceberry is a cross between Thai purple rice and Thai Jasmine rice, combining high nutritional value with desirable eating quality. This study aimed to evaluate the effects of dry chicken manure and fermented liquid swine manure, applied individually and in combination, on rice performance under an organic production system. The experiment was conducted in 2022 at two locations using a randomized complete block design with four replications. Four treatments were applied: (1) untreated control, (2) dry chicken manure at 1,875 kg.ha⁻¹, (3) fermented liquid swine manure at a ratio of 1 kg per 10 L of water, and (4) a combination of dry chicken manure (1,875 kg.ha⁻¹) and fermented liquid swine manure (1 kg per 10 L of water). Soil parameters were evaluated before planting and after

harvest. Results showed that grain yield was significantly higher ($P < 0.05$) in all organic fertilizer treatments compared with the untreated control (3,850 kg.ha⁻¹) with the combined application producing the highest yield (5,125 kg.ha⁻¹). All fertilizer treatments also improved 100 - grains weight and grain length compared with the control. However, the untreated control showed significantly higher percentages of head rice and broken kernels than the dry chicken manure treatment. Seed quality parameters, including germination after harvested and growth rate, were significantly improved by the combined application of dry chicken manure and fermented liquid swine manure. Moreover, the application of organic fertilizers enhanced rice productivity and contributed to improved soil fertility under organic production systems.

Keywords: Germinated seed, Grain yield, Nutrition, Organic fertilizers, Pigmented rice

1. Introduction

Worldwide, rice (*Oryza sativa* L.) is a staple food, a major source of nutrition, and an important economic crop (Kammapana, 2023). Among specialty rice types, organic rice has gained increasing attention due to its premium quality, high market value, and growing consumer demand. In Thailand, Riceberry rice is a recently developed variety derived from a cross between Hom Nin rice and Hom Mali rice (Thai Jasmine rice; Khao Dawk Mali 105) (Suttiarporn et al., 2016). This variety combines the high eating quality of Hom Mali rice with the strong antioxidant properties of Hom Nin rice. Riceberry rice is rich in bioactive compounds, particularly anthocyanins such as cyanidin-3-O-glucoside and peonidin-3-O-glucoside, which contribute to its nutritional and health-promoting properties

(Pitija et al., 2012). Previous studies have also suggested its potential role in reducing neurodegeneration and memory loss (Pannangrong et al., 2011). Due to these characteristics, Riceberry rice has become a high-value crop with increasing demand in both domestic and international markets.

Organic farming is an agricultural system that avoids or strictly limits the use of synthetic fertilizers, pesticides, and growth regulators, relying instead on natural inputs and ecological processes (Leifert, 2022). Soil fertility management in organic systems depends largely on organic amendments such as crop residues, animal manures, green manures, and biological nutrient cycling (USDA, 1980; Diacono & Montemurro, 2010). Among these practices, the incorporation of green manure and organic residues plays a crucial role in maintaining soil fertility, improving soil structure, and enhancing crop productivity (Zhang et al., 2025; Way et al., 2024). Leguminous green manure crops such as sunn hemp (*Crotalaria juncea* L.) are widely used due to their ability to fix atmospheric nitrogen and improve soil fertility (Tripathi et al., 2013).

In addition to green manure, animal manures such as chicken manure and swine manure are commonly used in organic farming systems as cost-effective nutrient sources (Surekha et al., 2013). Chicken manure is rich in essential nutrients, particularly nitrogen, phosphorus, and potassium, while fermented liquid swine manure provides readily available nutrients and beneficial microorganisms that can enhance nutrient uptake and soil biological activity. Previous studies have demonstrated the positive effects of individual organic fertilizers on soil fertility and rice productivity (Zhao et al., 2024a). However, most studies have focused on the separate application of these organic inputs, and limited information is available on their combined use, particularly for high-value colored rice such as Riceberry.

Therefore, a clear research gap exists regarding the synergistic effects of combining dry chicken manure and fermented liquid swine manure on the growth, yield, and quality of Riceberry rice under organic production systems. Understanding the combined effects of these organic inputs is essential for optimizing nutrient management strategies and improving both soil fertility and crop performance in sustainable rice production.

The objectives of this study were to:

- (1) evaluate the effects of dry chicken manure and fermented liquid swine manure, applied individually and in combination, on the growth, yield, milling quality, and seed quality of Riceberry rice; and
- (2) assess the residual effects of these organic fertilizers on soil properties under an organic production system.

This study provides important insights for improving nutrient management practices and enhancing the productivity of organic Riceberry rice cultivation.

2. Research method

2.1 Crop management and experimental design

Fieldwork was conducted at the research station of Buriram Rajabhat University and a farmer's farm just 6 kilometers from the research farm during rainy season 2022. The soil of the research farm included an organic carbon content and a texture of red sandy loam of 0.57%, medium available nitrogen (245 kg.ha⁻¹), phosphorus (30 kg.ha⁻¹), accessible potassium (170 kg.ha⁻¹), and was acidic in reaction with pH 6.74. There were similar characteristics between the two farms, such as red sandy loam, medium with

accessible nitrogen (245 kg.ha^{-1}), phosphorus (30 kg.ha^{-1}), available potassium (170 kg.ha^{-1}) and organic carbon content (0.57%). At two locations, sunn hemp (*Crotalaria juncea*) was sown as green manure and the experimental fields were ploughed at 60 days after sowing or at flowering of sunn hemp. The soil samples at two locations were collected for analysis.

A seedling bed was prepared and the seed of Riceberry was sown to prepare the seedling for the experiment. At 30 days after sowing, the seedlings were used for transplanting. Transplanting was carried out on July 13, 2022 for both locations.

At both locations, the soil was ploughed, leveled and puddled. Rice bunds were also constructed for each plot with plot size of $2 \times 4 \text{ m}$. Each hill was transplanted with three seedlings maintaining a $25 \times 30 \text{ cm}$ gap between rows and plants within row. The experiment was arranged in a randomized complete block design with four replications at both locations. The experiment consisted of four treatments: (1) untreated control, (2) dry chicken manure at $1,875 \text{ kg.ha}^{-1}$, (3) fermented liquid swine manure at a ratio of 1 kg per 10 L of water, and (4) a combination of dry chicken manure ($1,875 \text{ kg.ha}^{-1}$) and fermented liquid swine manure. The fermented liquid swine manure was diluted at a ratio of 1:20 (v/v) (equivalent to 50 mL L^{-1} of water) and applied as a foliar spray at a rate of 187.5 L.ha^{-1} per application using a knapsack sprayer. Applications were conducted twice, at the tillering stage and flowering stage (approximately 60 and 90 days after transplanting, respectively).

2.2 Data Collection

Soil analysis was done using soil samples before sowing sunn hemp, before transplanting and after harvest. Data on the soil were recorded, including pH (Black, 1965), electrical conductivity, organic matter (Walkley and Black method) (Black, 1965), percentages of sand, silt, and clay, available phosphorous (Bray II extraction (Drilon, 1980), total nitrogen (Kjeldahl) (Black, 1965), and extractable potassium (1 N Ammonium acetate (NH_4OAc) method) (Cottenie, 1980).

Tiller number and plant height for four plants rejected from harvest area were counted at tillering and at maximum tillering, the information was examined to significance. Data were recorded at harvest for leaf dry weight, stem dry weight, stubble dry weight, grain yield, panicles/hill, filled grains/panicle, unfilled grain/panicle, 100 grain weight, grain width and grain length on plants in the area of $2 \times 4 \text{ m}$.

The grain was milled and milling quality characters were recorded for % head rice, % broken and % whole kernel. The germination test was conducted under laboratory conditions following the standard procedures of the International Seed Testing Association (ISTA, 2022). Germination percentage and accelerated aging germination percentage were calculated based on the number of normal seedlings relative to the total number of seeds tested.

In addition, the germination rate index (GRI) or growth rate was calculated using the equation $\text{GRI} = \Sigma (\text{Gt} / \text{Dt})$, where Gt is the number of seeds germinated on day t and Dt is the number of days from the beginning of the germination test.

2.3 Data analysis

The data from each location were analyzed separately using analysis of variance (ANOVA) based on a randomized complete block design (RCBD). Prior to combined analysis across locations, homogeneity of error variances was tested. A combined analysis of variance was then performed for parameters with homogeneous variances to determine the effects of treatments, locations, and their interactions. Mean comparisons among treatments were conducted using Duncan's Multiple Range Test (DMRT) at $P < 0.05$.

3. Results and discussion

3.1 Results

3.1.1 Location

Plant height at 30, 60, and 90 days after transplanting (DAT) and the number of tillers per hill at 30 and 60 DAT did not differ substantially between locations (Table 1). However, significant different ($P \leq 0.05$) between locations was observed for tiller number per hill at 90 DAT, and experimental station (10.39 tillers) was significantly higher than farmer's farm (9.10 tillers).

Table 1: Means for rice plant height and the quantity of tillers were assessed at two locations at 30, 60- and 90-days following transplanting (DAT)

Location	Plant height (cm)			Tillers/hill		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Farmer's farm	69.5	76.7	107.7	7.55	16.40	9.10 ^b
Research station	68.8	73.1	109.0	7.17	16.65	10.39 ^a
F-test	ns	ns	ns	ns	ns	*
CV (%)	5.63	8.91	6.85	1.63	2.06	2.64

At the 0.05 probability level, means in the same column with the same letter do not differ substantially according to DMRT.

*Significant at the 0.05 probability level; not significant (ns).

At 120 days post-planting, the weights of leaves and stems exhibited substantial variation ($P \leq 0.05$) across different locations, however the stubble weight showed no significant differences (Table 2). Farmer's farm had significantly higher leaf weight and stem weight than did experimental station. Locations were also not significantly different for grain yield, number of panicles per hill and number of filled grains per panicle although experimental farm was higher than farmer's farm for these traits. However, experiment station (6.94) was significantly ($P \leq 0.05$) higher than farmer's farm (4.35) for number of unfilled grains per panicle.

Table 2: 120 days after transplanting, leaf dry weight, stem dry weight, stubbles, grain yield, number of panicles and number of rice grains that are full and number of rice grains that are not filled were evaluated at two locations.

Location	Leaves (g)	Stems (g)	Stubbles (g)	Yield (kg.ha ⁻¹)	Panicles/hill	Filled grains/panicle	Unfilled grains/panicle
Farmer's farm	86.12 ^a	77.48 ^a	30.64 ^a	4384.6	9.06	93.16	4.35 ^b
Research station	51.03 ^b	30.76 ^b	27.86 ^b	4530.1	12.36	107.86	6.94 ^a
F-test	*	*	*	ns	ns	ns	*
CV (%)	6.41	7.84	2.91	7.56	2.92	2.94	5.15

According to DMRT, there is no significant difference between means in the same column with the same letter at the 0.05 probability level.

*Significant at the 0.05 probability level; not significant (ns).

There was no significant difference between locations for 100-grain weight, grain width, grain length percentage of head rice, percentage of broken kernels and percentage of whole kernels (Table 3). The results indicated that grain characters and milling quality of rice at both locations were very similar.

Table 3: Means for 100-grain weight, grain width, grain length, % head rice, % broken and % whole kernels of rice evaluated at two locations at 120 days after transplanting.

Location	Grain characters			Milling quality		
	100-grain weight (g)	Grain width (mm)	Grain length (mm)	% head rice	% broken kernels	% whole kernels
Farmer's farm	2.73	2.47	10.19	36.99	10.86	88.70
Research station	2.83	2.44	10.16	38.18	10.79	89.02
F-test	ns	ns	ns	ns	ns	ns
CV (%)	5.75	1.50	0.49	5.40	3.97	0.58

At the 0.05 probability level, means in the same column followed by the same letter are not significantly different according to DMRT, and (ns) indicates non-significant differences.

The seeds from two locations were germinated under laboratory condition and subjected to accelerated aging. Locations were not significantly different for germination percentage (71.33-72.78%) and growth rate (0.004 - 0.005) though, there was a significant difference ($P \leq 0.05$) for germination percentage of accelerated aging seeds, in which farmer's farm (34.77%) was significantly higher than experimental station (22.24%) (Table 4).

Table 4: Means for germination percentage, accelerated aging percentage and growth rate of rice evaluated at two locations at 120 days after transplanting.

Location	Seed quality characters		
	% germination	Accelerated aging (%)	Growth rate
Farmer's farm	71.33	34.77 ^a	0.004
Research station	72.78	22.24 ^b	0.005
F-test	ns	*	ns
CV (%)	4.63	3.02	7.50

At the 0.05 probability level, means in the same column with the same letter do not differ substantially according to DMRT.

*Significant at the 0.05 probability level; not significant (ns).

3.1.2 Fertilizer treatment

At 30, 60, and 90 DAT, there were significant differences ($P \leq 0.05$) between the fertilizer treatments for plant height and the number of tillers per hill (Table 5). Fermented swine manure plus dry chicken manure had the highest plant height at 30 and 60 DAT followed by chicken manure, fermented swine manure an untreated control, respectively. At 90 DAT, dry chicken manure and fermented swine manure had the highest plant heights, which were significantly higher than dry chicken manure+fermented swine manure and untreated control.

Table 5: Average for plant height and the quantity of tillers in rice treated with chicken manure and fermented swine manure at 30, 60, and 90 days following transplanting.

Treatment	Plant height (cm)			Tillers/hill		
	30	60	90	30	60	90
	DAT	DAT	DAT	DAT	DAT	DAT
Un-treated control	61.3 ^d	67.7 ^d	106.5 ^b	5.67 ^c	13.13 ^c	7.18 ^c
Dry chicken manure ¹	70.0 ^b	76.6 ^b	108.7 ^a	8.26 ^b	18.70 ^b	11.63 ^{ab}
Fermented swine manure ²	68.4 ^c	70.7 ^c	110.4 ^a	6.20 ^c	13.67 ^c	10.20 ^b
1+2	76.94 ^a	85.6 ^a	107.1 ^b	9.17 ^a	20.60 ^a	13.19 ^a
F-test	*	*	*	*	*	*
CV (%)	5.63	8.91	6.85	1.63	2.06	2.64

At the 0.05 probability level, means in the same column with the same letter do not differ substantially according to DMRT.

*Significant at the 0.05 probability level.

For tiller numbers per panicle over 30, 60, and 90 DAT, fertilizer treatments were consistently and statistically different ($P \leq 0.05$). Dry chicken manure+fermented swine manure was highest at 30, 60 and 90 DAT followed by fermented swine manure, dry chicken manure and untreated control, respectively. For all treatments tiller numbers were highest at 60 DAT and then declined at 90 DAT.

There was significant difference ($P \leq 0.05$) (Table 6) between fertilizer treatment for leaf dry weight, stubble dry weight, stem dry weight, grain yield, number of panicles and full grains and unfilled grains but not for stem dry weight. The highest leaf dry weight and stubble dry weight were found in the chicken manure+fermented swine manure.

Table 6: Means of leaf dry weight, stem dry weight, stubble dry weight, grain yield, number of panicles, number of rice grains that are full and number of rice grains that are not filled with chicken manure and fermented swine manure were evaluated at 120 days after transplanting.

Treatment	Weight of Leaf dry (g)	Weight of Stem dry (g)	Weight of Stubble dry (g)	Yield (kg.ha ⁻¹)	Panicle s/hill	Filled grains/panicle	Unfilled grains/panicle
Un-treated control	52.28 ^c	55.36	31.16 ^b	3,850.0 ^d	8.5 ^b	78.6 ^b	6.15 ^{ab}
Dry chicken manure ¹	54.14 ^b	55.42	24.23 ^b	3,950.6 ^c	11.1 ^b	113.1 ^a	6.65 ^a
Fermented swine manure ²	50.19 ^d	49.54	24.14 ^b	4,903.1 ^b	9.1 ^b	72.6 ^b	6.65 ^a
1+2	57.68 ^a	40.78	37.46 ^a	5,125.0 ^a	14.1 ^a	137.7 ^a	3.13 ^b
F-test	*	ns	*	*	*	*	*
CV (%)	6.41	7.84	2.91	7.56	2.92	2.94	5.15

At the 0.05 probability level, means in the same column with the same letter do not differ substantially according to DMRT.

*Significant at the 0.05 probability level; not significant (ns).

Grain yield was the highest (5,125 kg.ha⁻¹) in chicken manure+fermented swine manure followed by fermented swine manure (4,903.1 kg.ha⁻¹), dry chicken manure (3,950.6 kg.ha⁻¹) and untreated control (3,850.0 kg.ha⁻¹). Grain yield from all fertilizer treatments exceeded that of control. Both Chicken manure+fermented swine manure and Fermented swine manure had the highest number of

panicles, number of filled grains, but the lowest of unfilled grains.

Regarding grain characteristics, there were significant ($P \leq 0.05$) variations across fertilizer treatments for grain length and 100-grain weight, but not for grain width (Table 7). Fermented swine manure had the highest grain weight (2.88 g) followed by dry chicken manure (2.86 g), dry chicken manure+fermented swine manure (2.70 g) and untreated control (2.68 g), respectively. Grain length ranged between 10.12 mm and 10.25 mm. Dry chicken manure had the highest grain length (10.25 mm) followed by fermented swine manure (10.17 mm), dry chicken manure+fermented swine manure (10.17 mm) and untreated control (10.12 mm), respectively.

Table 7: Means for 100-grain weight, grain width, grain length, % head rice, % broken and % whole kernels of rice treated with chicken manure and fermented swine manure evaluated at 120 days after transplanting.

Treatment	Grain characters			Milling quality		
	100-grain weight (g)	Grain width (mm)	Grain length (mm)	% head rice	% broken	% whole kernels
Un-treated control	2.68 ^c	2.45	10.12 ^c	35.96 ^c	10.78 ^{ab}	88.37 ^b
Dry chicken manure ¹	2.86 ^{ab}	2.46	10.25 ^a	39.88 ^a	11.23 ^a	88.42 ^b
Fermented swine manure ²	2.88 ^a	2.43	10.17 ^b	35.50 ^c	10.71 ^b	89.27 ^a
1+2	2.70 ^b	2.40	10.17 ^b	39.01 ^b	10.58 ^b	89.39 ^a
F-test	*	ns	*	*	*	*
CV (%)	5.75	1.50	0.49	5.40	3.97	0.58

At the 0.05 probability level, means in the same column with the same letter do not differ substantially according to DMRT.

*Significant at the 0.05 probability level; not significant (ns).

Significant differences ($P \leq 0.05$) among fertilizer treatments were observed for milling quality traits (% head rice, % broken kernels and % whole kernels). Dry chicken manure had the highest % head rice (39.88%) followed by dry chicken manure+fermented swine manure (39.01%), un-treated control (35.96%) and fermented swine manure (35.50%), respectively. Dry chicken manure also had the highest proportion of broken kernels (11.23%) followed by un-treated control (10.78%), fermented swine manure (10.71%) and dry chicken manure+fermented swine manure (10.58%), respectively. Dry chick manure+fermented swine manure had the highest parentage of whole kernels (89.36%), which was not significantly different from 89.32% of fermented swine manure, whereas dry chicken manure and un-treated control had similar percentages of whole kernels of 88.42 and 88.37%, respectively.

3.1.3 Seed quality

Seed quality characters including germination percentage after harvest, germination percentage after accelerated aging and growth rate of seedlings were evaluated for the fertilizer treatments. Table 8 indicates that growth rate, and germination % at harvest were significantly different ($P \leq 0.05$) between the fertilizer treatments, but no discernible variations ($P \leq 0.05$) for germination % after accelerated aging. All fertilizer treatments have significantly higher germination percentage after harvest than un-treated control. Dry chicken manure+fermented swine manure had the highest germination percentage (76.20%) which was significantly higher than dry chicken manure alone (73.07%), whereas dry chicken manure alone was significantly higher than fermented swine manure (71.63%). Dry chicken manure+fermented swine manure and fermented swine manure had the maximum growth rate (0.009) which was significantly greater than untreated control and dry chicken manure (0.002).

Table 8: Means for germination percentage after harvest, germination percentage after accelerated aging and growth rate of rice treated with chicken manure and fermented swine manure evaluated at 120 days after transplanting.

Treatment	Seed quality characters		
	Germination after harvest (%)	Germination after accelerated aging (%)	Growth rate
Un-treated control	67.33 ^d	33.33	0.002 ^b
Dry chicken manure ¹	73.07 ^b	23.66	0.002 ^b
Fermented swine manure ²	71.63 ^c	30.77	0.009 ^a
1+2	76.20 ^a	26.27	0.009 ^a
F-test	*	ns	*
CV (%)	4.63	3.02	7.50

At the 0.05 probability level, means in the same column with the same letter do not differ substantially according to DMRT.

*Significant at the 0.05 probability level; not significant (ns).

3.1.4 Soil properties

Table 9 shows the soil characteristics both before and following the use of green manure. Soil pH range from 4.83 at the research stations after green manure application. Electrical conductivity (EC) values were in the range between 0.033 dS m⁻¹ in the experimental farm after application of green manure and 0.078 dS m⁻¹ in the farmer's farm after application of green manure.

Total nitrogen values for the farmer's farm with application of green manure ranged from 270.28 mg kg⁻¹ to 363.99 mg kg⁻¹ before application of green manure. Available phosphorus values ranged from 3.72 mg kg⁻¹ to 9.64 mg kg⁻¹. The range of extractable potassium values measured in the experiment station before application of green manure to the farmer's farm before application of green manure were in the range of 43.70 mg kg⁻¹ to 78.29 mg kg⁻¹. Application of green manure resulted in the lowest organic matter (0.54%) in the farmer's farm and the highest organic matter (0.75%) in the farmer's farm before application of green manure.

The soil texture transitioned from loam to sandy loam following the application of green manure in both experiments.

It is noteworthy that the soil properties, after application of green manure, the changes in chemical properties were not consistent across locations. Application of green manure increased pH, EC, and available phosphorus and reduced total nitrogen, extractable potassium and organic matter in the farmer's farm. Application of green manure did not change pH in the experimental farm. However, it increased total nitrogen, extractable potassium and organic matter and available phosphorous (Table 9).

Table 9. Soil properties at two locations before planting of sunn hemp and after mowing (incorporating) of sunn hemp.

Soil property	Farmer's farm		Research station	
	Before	After	Before	After
pH (1:5)	4.85	5.32	4.84	4.83
EC (dS m ⁻¹)	0.063	0.078	0.051	0.033
Total N in mg kg ⁻¹	363.99	270.28	287.19	359.39

Available P in mg kg ⁻¹	6.65	9.64	5.22	3.72
Extractable K in mg kg ⁻¹	78.29	49.29	43.70	73.23
Organic Matter (%)	0.75	0.54	0.56	0.73
Soil texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam

There were no significant differences between pH, EC, organic matter, total nitrogen available phosphorus and extractable potassium after rice harvest between Farmer's farm and experimental farm (Table 10). For these parameters of soil properties, there was a significant difference ($P \leq 0.05$) between the fertilizer treatments (Table 11). A value of pH ranged between 4.61 for fermented swine manure and 5.21 for dry chicken manure-fermented swine manure. Dry chicken manure-fermented swine manure was not significantly different from untreated control (5.16), whereas dry chicken manure (5.06) and fermented swine manure (4.61) were significantly lower than untreated control.

Table 10: Means for pH, organic matter (OM), electrical conductivity (EC), extractable potassium (K), accessible phosphorus (P), and total nitrogen (N) in soil at two locations evaluated after rice harvest.

Location	pH	EC (dS m ⁻¹)	OM (%)	Total N (mg kg ⁻¹)	Available P (mg kg ⁻¹)	Extractable K (mg kg ⁻¹)
Farmer's field	4.59	0.014	0.728	27.42	21.64	25.35
Research station	5.04	0.013	0.699	27.42	21.63	25.33
F-test	ns	ns	ns	ns	ns	ns
C.V. (%)	4.79	17.98	14.08	7.29	2.06	6.70

ns; not significant

Table 11: Means for pH, organic matter (OM), electrical conductivity (EC), extractable potassium (K), accessible phosphorus (P), and total nitrogen (N) in soil treated with chicken manure and fermented swine manure evaluated after rice harvest.

Treatment	pH	EC (dS m ⁻¹)	OM (%)	Total N (mg kg ⁻¹)	Available P (mg kg ⁻¹)	Extractable K (mg kg ⁻¹)
Un-treated control	5.16 ^a	0.014 ^b	0.612 ^c	27.67 ^b	17.88 ^d	22.84 ^c
Dry chicken manure ¹	5.06 ^b	0.013 ^b	0.640 ^c	30.17 ^a	28.73 ^a	26.90 ^a
Fermented swine manure ²	4.61 ^c	0.010 ^c	0.738 ^b	26.67 ^b	18.96 ^c	24.83 ^b
1+2	5.21 ^a	0.016 ^a	0.863 ^a	25.17 ^c	20.60 ^b	26.77 ^a
CV (%)	4.79	17.98	14.08	7.29	2.06	6.70

At the 0.05 probability level, means in the same column with the same letter do not differ substantially according to DMRT.

*Significant at the 0.05 probability level; not significant (ns).

EC values were in the range between 0.010 dS m⁻¹ for fermented swine manure and 0.016 dS m⁻¹ for dry chicken manure-fermented swine manure, which were significantly lower and higher than un-treated control (0.014 dS m⁻¹), respectively, whereas dry chicken manure (0.013 dS m⁻¹) was not significantly different from un-treated control. The values of organic matter were lowest (0.612 %) for un-treated control and highest (0.863 %) for dry chicken manure+fermented swine manure. Dry chicken manure (0.640 %) was not significantly different from un-treated control, whereas fermented swine manure (0.738%) and dry chicken manure+fermented swine manure (0.863 %) were significantly higher than un-treated control (0.612%).

The values of total nitrogen were lowest for dry chicken manure+fermented swine manure (25.17 mg kg^{-1}) and highest for dry chicken manure (30.17 mg kg^{-1}). Fermented swine manure (26.67 mg kg^{-1}) did not differ substantially from untreated control, these treatments were both considerably higher and lower than untreated control (27.67 mg kg^{-1}).

Available phosphorus was lowest (17.88 mg kg^{-1}) for untreated control and highest (28.73 mg kg^{-1}) for dry chicken manure. Fermented swine manure (18.96 mg kg^{-1}) and dry chicken manure+fermented swine manure (20.60 mg kg^{-1}) were significantly lower than dry chicken manure, but still significantly higher than untreated control.

Un-treated control was lowest for extractable potassium (22.84 mg kg^{-1}) and it was significantly lower than dry chicken manure (26.90 mg kg^{-1}), fermented swine manure (24.83 mg kg^{-1}) and dry chicken manure+fermented swine manure (26.77 mg kg^{-1}). Dry chicken manure and dry chicken manure+fermented swine manure was highest and significantly higher than fermented swine manure.

3.2 Discussion

Dry chicken manure and fermented swine manure were evaluated as single use and combination use for application in this study. After sunn hemp as a green manure crop, organic fertilizers were applied. Sunn hemp is a versatile legume belonging to the family Fabaceae, commonly used as a green manure or cover crop adding benefits to the cropping system (Hariniharishma et al., 2025). Nowadays, the hypothesis for the research project is that green manure will not be enough for normal growth of the crop throughout the crop season as green manure is quickly decomposed and nitrogen was released and depleted soon after release (Jeon, 2010). The latter growth stages of the crop still required sufficient fertilizers for acceptable yield under organic production systems. Therefore, additional organic nutrient sources are often required to maintain continuous nutrient availability throughout the crop cycle.

The results of this study confirmed that application of fermented swine manure and dry chicken manure significantly improved plant growth, yield components, grain quality and seed quality compared with the untreated control. These improvements are likely associated with enhanced nutrient availability, increased soil organic matter inputs, and stimulation of soil microbial activity, which collectively contribute to improved crop performance under organic production systems.

Thus our study next evaluated the effects of fermented swine manure and chicken manure on the yield components and growth parameters of Riceberry rice. Green manure is an important source of organic fertilizer. Exploring green fertilizer and nitrogen fertilizer reduction is important for agricultural production. However, few studies have been conducted, especially on the effects of different green fertilizers along with reduced nitrogen fertilizer application on soil ammonia volatilization emissions, rice yield, and nitrogen fertilizer uptake and utilization (Hu et al., 2024). The rice grains from the experiment were further milled and milling quality of milled rice was investigated. The rice seeds were also tested for seed quality under laboratory condition soon after harvest. In order to assess the lingering effects of the organic fertilizers on the chemical characteristics of the soil, soil samples were taken both before and after harvest.

3.2.1 Growth and yield

Locations did not have significant effects on development and yield of Riceberry for most characters investigated. Fermented poultry products and processed swine residues (e.g., digestate, biochar, fermented manures) exhibit improved stability and prolonged nutrient availability compared with raw green manure, and can therefore complement green manure to sustain N supply through late growth stages (Pagliarini, 2024). Although they were significantly different for some characters, the differences were low. The small differences between locations indicated the high similarity of the locations as the locations had the same soil series and fertility. Industries play a significant role in the

improvement of lifestyle and in the development of a country. However, the byproducts from these industries are a source of environmental pollution. The proper use of the byproducts of these industries can help to cope with environmental pollution. Some byproducts have high nutritional content and are good for crop plants (Rasool et al., 2023). Not only for growth and yield, locations were also similar for other parameters including milling quality, soil properties and seed quality. Location effects were generally not significant for most growth and yield parameters of Riceberry rice, indicating that the two experimental sites had comparable soil fertility conditions and similar responses to organic fertilizer application. This consistency suggests that the results obtained in this study may be applicable to areas with similar soil characteristics.

In contrast, fertilizer treatments significantly affected most growth parameters and yield components. The combined application of dry chicken manure and fermented swine manure produced the highest plant height, tiller number, panicle number and filled grains per panicle, resulting in the highest grain yield. These results indicate that sunn hemp alone could not supply sufficient nutrients throughout the crop growth period and that supplemental organic fertilizers were required to maintain adequate nutrient availability. The superior performance of the combined manure treatment may be explained by complementary nutrient release patterns. Dry chicken manure generally contains relatively high concentrations of nitrogen and phosphorus, which support early vegetative growth, whereas fermented swine manure provides readily available nutrients and soluble organic compounds that enhance microbial activity and improve nutrient mineralization during later growth stages. The combined use of both organic fertilizers therefore likely ensured a more balanced and sustained nutrient supply throughout the rice growth cycle.

However, the relationship between soil fertility and crop yield remains unclear in saline-alkaline soil. Zhao et al. (2024b) studied the effect of organic manure on crop yield, soil properties, and economic benefit in wheat-maize-sunflower rotation system at Hetao Irrigation District. The results showed that in the third cropping rotation cycle, combined application of manure and mineral fertilizers (NPKO) caused a 6.2, 38.9, 65.3, and 132.2% increase in wheat, sunflower, wheat equivalent yield, and the economic income of sunflower, respectively. The effect of organic fertilizer quantity on the yield and seed qualities of Pathumthani 1 rice revealed that the highest grain yield, 3,893 kg/ha, was attained with the application of 2.24 kg N/ha of organic fertilizer, whereas rice without fertilizer exhibited the lowest yield. However, the application of 1.6 kg N/ha of organic fertilizer resulted in the highest seed germination rate, germination index, and pure seed percentage, with values of 98.00, 32.43 and 99.71%, respectively (Kaewtaphan et al., 2024).

Although sunn hemp can fix large amount of nitrogen, nitrogen is not available to the crop for all crop season and it depletes from the soil at early growth stages of rice (Murugan & Swarnam, 2013). Adding the organic matters with high CN-ratio such as rice straw and stubble might delay decomposition of sunn hemp and increase the efficiency of green manure (Aulakh et al., 2011). Legume is an essential alternative approach in the organic agricultural system to produce ecologically safe nitrogen (N), while restoring soil health in an appropriate mode to supply nutrients for subsequent crops. The experimental study was conducted in the summer (March) 2024 at Tamil Nadu rice research institute, Aduthurai, Tamil Nadu to study the residual effect of Sun hemp varieties either alone or incorporation along with rice stubbles and their impact on nutrient availability of soil, soil organic carbon and yield attributes of succeeding rice in sunn hemp-rice cropping system (Hariniharishma et al., 2025).

At 30 and 60 days after transplanting, the application of organic fertilizers, particularly for 1875 kg.ha⁻¹ of chicken manure with fermented swine manure, produced the maximum plant heights (DAT). Application of fermented swine manure alone was highest for plant height at 90 DAT. The results indicated the benefits of these organic fertilizers on growth promotion of the crop and confirmed that application of green manure alone was not sufficient for normal growth of the crop. Sun hemp is a

tropical to subtropical crop known for its versatile nature with profitable value for farmers because of its numerous characteristics, such as high biomass, fibre crop, weed suppressive, insect and pathogen resistance and mainly cultivated as a green manure crop (Maheshwari et al., 2020).

Similar to plant height, application of organic fertilizers was better than untreated control for most growth and yield characters. Applications of organic fertilizers increased tiller number, grain yield, leaf dry weight, and stubble dry weight. The combination of dry chicken manure+fermented swine manure also increased panicle number and filled grain number, and it had the highest grain yield (5125.0 kg.ha⁻¹). Applications of organic fertilizers also increased grain weight and grain length but they did not increase grain width.

3.2.2 Grain quality

Milling quality traits including percentage of head rice, broken kernels and whole kernels were significantly influenced by fertilizer treatments. Application of dry chicken manure either alone or in combination with fermented swine manure increased head rice percentage, while fermented swine manure treatments tended to increase the proportion of whole kernels. These improvements in milling quality may be attributed to enhanced nitrogen availability during grain filling stages. Adequate nitrogen supply during reproductive growth improves protein synthesis and grain structure, resulting in stronger kernels that are less susceptible to breakage during milling (Leesawatwong et al., 2005). Previous studies have similarly reported that application of organic amendments including poultry manure increases head rice recovery compared with unfertilized treatments (Bergman et al., 2022).

Nitrogen application reduced the percentage of broken kernels and increased head rice yield (Dilday, 1988). Late nitrogen application at flowering stage increased protein of milled rice, head rice and translucence of IR rice varieties (Perez et al., 1996).

Although the percentage of broken kernels varied among treatments, differences were relatively small, suggesting that organic fertilizer application primarily influenced kernel integrity rather than grain dimensions such as width.

3.2.3 Seed quality

Application of organic fertilizers significantly improved germination percentage and seedling growth rate compared with the untreated control. These improvements may be associated with enhanced nutrient accumulation in developing seeds under improved soil fertility conditions.

Organic manures provide essential macro- and micronutrients that contribute to improved seed development and vigor. Enhanced nitrogen availability during seed filling stages promotes protein accumulation in seeds, which plays an important role in germination performance and early seedling growth. Similar responses have been reported in several crops where improved nutrient availability increased seed germination and vigor through enhanced metabolic activity during early growth stages (Mohammadi et al., 2013).

However, fertilizer treatments did not significantly affect germination percentage after accelerated aging, suggesting that while organic fertilizers improved initial seed vigor, they may not strongly influence physiological mechanisms related to seed longevity such as antioxidant activity, membrane stability or reserve mobilization efficiency. Future studies should therefore investigate biochemical indicators of seed storability to better understand long-term effects of organic fertilizer application on seed quality.

All organic fertilizer treatments increased germination, whereas fermented swine manure and dry chicken manure+fermented swine manure increased growth rate. However, all organic fertilizer treatments did not increase germination percentage after accelerated aging. Organic manures (including swine and chicken) are rich sources of macro- and micronutrients, as well as organic matter. Accelerated

aging test (AA) has been applied as a technique to evaluate seed vigor and to predict seed storability (Chor-unchun & Wongvarodom, 2023).

Nitrogen (N) application increased seed germination from 150 to 450 mg L⁻¹ N in okra (Mohammadi et al., 2013). Maize germination percentage and growth rate were increased by biofertilizer containing *Azotobacter chroococcum* and *Bacillus megaterium* var. phosphaticum (Bákonfi et al., 2013), and the authors provided the reason that biofertilizer increased mobilization of seed nutrients and excreted phytohormones. In this study, nutrients accumulated in seeds might play a role in seed germination. However, further study on seed nutrients is still required. One possible explanation is that organic fertilizers improve the immediate nutrient environment for germination and early growth, but do not fundamentally alter the internal seed quality parameters that determine ageing tolerance (such as antioxidant systems, membrane integrity, or reserve mobilization). Future studies should therefore investigate the interaction between organic fertilizer treatments and seed maturation/storage processes, focusing on physiological markers of seed longevity such as ROS accumulation, membrane damage and enzyme activity. Furthermore, the use of accelerated-aging protocols as a screening tool for seed quality should be complemented by long-term storage trials to fully assess the impact of organic fertilizers on rice seed storability.

3.2.4 Soil properties

Soil in two locations were classified into different soil series. Soil at the experimental station was classified as Satuek soil series and soil at the farmer's farm was classified as Chum Phuang soil series. Differences in soil series may influence nutrient retention capacity, microbial activity and mineralization rates, which can subsequently affect nutrient availability to rice plants and contribute to variation in growth performance and yield components between locations. Although the soils were similar in general, the responses to fertilizer applications may be different between different soil series. In this study, soil pH was low and it might affect available nutrients in the soil. Lime application is necessary to raise soil pH (Nduwumuremyi, 2013). Low soil pH can reduce the availability of essential nutrients such as phosphorus and potassium and may limit root development, thereby influencing crop productivity under organic production systems.

The soils in both locations are sandy and organic matter was very low. Application of green manure and organic fertilizers especially for chicken manure was expected to increase organic matter. Soil organic matter is a key resource base for agriculture. However, its content in cultivated soils is low and often decreases (Lipiec et al., 2021). An increase in soil organic matter can enhance soil aggregation, improve water-holding capacity and stimulate microbial activity, which together support nutrient mineralization and improve nutrient uptake efficiency by rice plants. In previous investigation, soil organic matter increased in the following order of sunn hemp amendment, sesbania, mungbean and rice straw (Buarach et al., 2014). However, change in organic matter was unclear in this study, and applying organic fertilizers and green manure consistently over an extended period of time may enhance soil fertility and organic matter. Therefore, the relatively small short-term changes observed in this study may reflect the time required for organic amendments to accumulate measurable effects on soil organic matter under field conditions. Soybean meal greatly reduced soil pH in a four-year study on Oxisol soil, and dairy cattle dung compost had the highest soil organic carbon and total nitrogen, while soybean meal and chicken dung compost resulted in the lowest soil electrical conductivity (Chang et al., 2008). These findings support the role of different organic amendments in modifying soil chemical environments and suggest that manure type may influence nutrient release patterns and crop responses differently.

After application of green manure, changes in soil chemical properties were different between Satuek soil series (research station) and Chum Phuang soil series (farmer's farm). However, after rice

harvest, locations were not significantly different for all soil chemical properties. This result suggests that the additional application of dry chicken manure and fermented swine manure may have contributed to balancing nutrient availability between locations through improved nutrient cycling and mineralization processes. The results might indicate that these two soil types had similar response to organic fertilizer application. Such similarity in soil response is consistent with the comparable growth performance, yield components and seed quality observed between locations, indicating that organic fertilizer application effectively supported crop development across both soil series.

4. Conclusion

Application of green manure alone is not sufficient for sustaining yield of Riceberry rice under organic production systems and adding organic fertilizers is necessary. This finding highlights the importance of integrating additional organic nutrient sources with green manure to maintain adequate nutrient availability during critical growth stages of Riceberry rice cultivated in sandy soils under organic management conditions. It could potentially be possible to boost the grain yield of Riceberry rice and enhance the quality of the seed and milling process by applying dry chicken manure at the proper rate of 1875 kg.ha⁻¹, either alone or in conjunction with the foliar application of liquid swine manure at the rate of 1/20 L of water. The combined use of these organic fertilizer sources provides a practical nutrient management option for improving productivity and grain quality of Riceberry rice under farmer field conditions. However, for soil improvement, the results were rather confounding and long-term studies are required. Therefore, although short-term improvements in soil chemical properties were observed in some parameters, continued application of organic amendments over multiple seasons may be necessary to confirm their cumulative effects on soil fertility and sustainability of organic rice production systems.

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References

- Aulakh, M. S., Khera, T. S., Doran, J. W., & Bronson, K. F. (2001). Managing crop residue with green manure, urea, and tillage in a rice–wheat rotation. **Soil Science Society of America Journal**, 65(3), 820–827.
- Bákonny, N., Bott, S., Gajdos, É., Szabó, A., Jakab, A., Tóth, B., Makleit, P., & Veres, S. (2013). Using biofertilizer to improve seed germination and early development of maize. **Polish Journal of Environmental Studies**, 22(6), 1595–1599.
- Black, C. A. (1965). **Methods of soil analysis: Part A**. American Society of Agronomy.
- Buarach, K., Thongjoo, C., Udomprasert, N., & Amkha, S. (2014). Effects of tillage system and soil organic matter amendment on growth, yield of Pathumthani 80 rice and carbon sequestration in paddy soil. **Modern Applied Science**, 8(4), 1–7.
- Chang, E. H., Chung, R. S., & Wang, F. N. (2008). Effect of different types of organic fertilizers on the chemical properties and enzymatic activities of an Oxisol under intensive cultivation of vegetables for 4 years. **Soil Science and Plant Nutrition**, 54(4), 587–599.
- Chor-unchun, P., & Wongvarodom, V. (2023). Rice (*Oryza sativa* L.) seed quality after storage in the humid tropics and after accelerated aging. **Recent Science and Technology**, 17(1), 259351.
- Cottenie, A. (1980). **Soil and plant testing as a basis of fertilizer recommendations** (FAO Soil Bulletin No. 38/2). FAO.

- Diacono, M., & Montemurro, F. (2010). Long-term effects of organic amendments on soil fertility: A review. **Agronomy for Sustainable Development**, 30(2), 401–422.
- Dilday, R. H. (1988). Effect of nitrogen fertilizer on milling quality of rice (*Oryza sativa*). **Journal of the Arkansas Academy of Science**, 42, 26–27.
- Drilon, J. D., Jr. (1980). **Standard methods of analysis for soil, plant, water and fertilizer**. University of the Philippines Los Baños.
- Hariniharishma, V. P., Subrahmaniyan, K., Elamathi, S., Devi, T. S., & Abarajitha, P. (2025). Residual management of sun hemp (*Crotalaria juncea*) varieties in releasing soil nutrients and their impact on succeeding rice crop. **Legume Research**, 48(11), 1912–1917.
- Hu, Z., Yang, D., Feng, Y., Zhang, S., Wang, A., Wang, Q., Yang, Y., Chen, C., Zhang, Y., & Wang, X. (2024). Green manure combined with reduced nitrogen reduces NH₃ emissions, improves yield and nitrogen use efficiencies of rice. **PeerJ**, 1–23.
- International Seed Testing Association (ISTA). (2022). **International Rules for Seed Testing**. International Seed Testing Association, Bassersdorf, Switzerland.
- Jeon, W. T., Seong, K. Y., Lee, J. K., Oh, I. S., Lee, Y. H., & Ok, Y. S. (2010). Effects of green manure and carbonized rice husk on soil properties and rice growth. **Korean Journal of Soil Science and Fertilizer**, 43(4), 484–489.
- Kaewtaphan, P., Maniin, P., Nilkong, P., Aninbon, C., & Teamkao, P. (2024). Effect of organic fertilizer rates on grain yield and seed qualities of rice. **International Journal of Agricultural Technology**, 20(3), 1067–1074.
- Kammapana, L. (2023). Physical characteristics, phytochemical contents and antioxidant activity of ten organic-pigmented rice varieties from Surin Province. **Trends in Sciences**, 20(4), 1–14.
- Leesawatwong, M., Jamjod, S., Kuo, J., Dell, B., & Rerkasem, B. (2005). Nitrogen fertilizer increases seed protein and milling quality of rice. **Cereal Chemistry**, 82(5), 588–593.
- Leifert, C. (2022). Organic farming provides a blueprint to improve food quality, safety and security. **Agronomy**, 12(3), 1–4.
- Lipiec, J., Usowicz, B., Kłopotek, J., Turski, M., & Frąc, M. (2021). Effects of application of recycled chicken manure and spent mushroom substrate on organic matter, acidity, and hydraulic properties of sandy soils. **Materials**, 14(14), 4036.
- Mohammadi, G., Khah, E. M., Petropoulos, S. A., Yarsi, G., & Vlasakoudis, A. (2013). Effect of fertilizer and drying methods on seed germination of okra (*Abelmoschus esculentus* L.) cultivars at different harvesting times. **Journal of Agricultural Science**, 5(4), 1–14.
- Murugan, A. V., & Swarnam, T. P. (2013). Nitrogen release pattern from organic manures applied to an acid soil. **Journal of Agricultural Science**, 5(6), 174–184.
- Nduwumuremyi, A. (2013). Soil acidification and lime quality: Sources of soil acidity, effects on plant nutrients, efficiency of lime and liming requirements. **Journal of Agriculture and Allied Sciences**, 2(4), 26–34.
- Pagliarini, E., Gaggia, F., Rossin, M., Franceschi, C., & Gioia, D. D. (2024). High-agronomic value of selected poultry manure valorized through aerobic fermentation: The AFRODITE® process. **Journal of Environmental Management**, 371, 123184.
- Pannangrong, W., Wattanathorn, J., Muchimapura, S., Tiamkao, S., & Tong-un, T. (2011). Purple Riceberry is neuroprotective and enhances cognition in a rat model of Alzheimer’s disease. **Journal of Medicinal Food**, 14(7–8), 688–694.
- Perez, C. M., Juliano, B. O., Liboon, S. P., Alcantara, J. M., & Cassman, K. G. (1996). Effects of late nitrogen fertilizer application on head rice yield, protein content, and grain quality of rice. **Cereal Chemistry**, 73(5), 556–560.
- Pitija, K., Nakornriab, M., Sriseadka, T., Vanavichit, A., & Wongpornchai, S. (2012). Anthocyanin

- content and antioxidant capacity in bran extracts of some Thai black rice varieties. **International Journal of Food Science & Technology**, 48, 300–308.
- Rasool, A., Ghani, A., Nawaz, R., Ahmad, S., Shahzad, K., Rebi, A., Ali, B., Zhou, J., Ahmad, M. I., Tahir, M. F., Alwahibi, M. S., Elshikh, M. S., & Ercisli, S. (2023). Effects of poultry manure on the growth, physiology, yield, and yield-related traits of maize varieties. **ACS Omega**, 1–14.
- Surekha, K., Rao, K. V., Rani, N. S., Latha, P. C., & Kumar, R. M. (2013). Evaluation of organic and conventional rice production systems for their productivity, profitability, grain quality and soil health. **Agrotechnology**, 11, 1–6.
- Suttiarporn, P., Sookwong, P., & Mahatheeranont, S. (2016). Fractionation and identification of antioxidant compounds from bran of Thai black rice cv. Riceberry. **International Journal of Chemical Engineering and Applications**, 7(2), 109–114.
- Tripathi, M. K., Majumdar, B., Bhandari, H. R., Chaudhary, B., Saha, A. R., & Mahapatra, B. S. (2013). Integrated nutrient management in sunn hemp (*Crotalaria juncea*)–rice cropping sequence in Eastern Uttar Pradesh, India. **Indian Journal of Agricultural Research**, 47(3), 253–257.
- United States Department of Agriculture (USDA). (1980). **Report and recommendations on organic farming**. USDA.
- Way, M. P., Ngwe, K., Soe, Y. M., & Moe, K. (2024). Potential impacts of green manure incorporation on soil fertility enhancement and rice yield. **Asian Soil Research Journal**, 8(4), 42–53.
- Zhang, H., Chen, L., Wang, Y., Xu, M., Qiu, W., Liu, W., Wang, T., Li, S., Fei, Y., Liu, M., Nie, H., Li, Q., Ni, X., & Yi, J. (2025). Straw and green manure return can improve soil fertility and rice yield in long-term cultivation paddy fields with high initial organic matter content. **Plants**, 14(13), 2–19.
- Zhao, N., Ma, J., Wu, L., Li, X., Xu, H., Zhang, J., Wang, X., Wang, Y., Bai, L., & Wang, Z. (2024a). Effect of organic manure on crop yield, soil properties, and economic benefit in wheat–maize–sunflower rotation system, Hetao Irrigation District. **Plants**, 13(16), 2250.
- Zhao, T., He, A., Khan, N. M., Yin, Q., Song, S., & Nie, L. (2024b). Coupling of reduced inorganic fertilizer with plant-based organic fertilizer as a promising fertilizer management strategy for colored rice in tropical regions. **Journal of Integrative Agriculture**, 23(1), 93–107.