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Effects of Kakawate (*Gliricidia sepium*) and Fish Entrails Extracts as Organic Fertilizers on the Growth and Yield of Rice

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ABSTRACT

Background: Fish entrails, which have minimal commercial value, can be processed into organic fertilizer to enhance soil fertility, improve crop yield and reduce CO_2 emissions associated with chemical fertilizers. Similarly, kakawate (*Gliricidia sepium*), a nutrient-rich shrub commonly used as fencing material in the Philippines, can serve as an additional organic fertilizer source. The study evaluated the impact of *Gliricidia sepium* extract (GSE) and fish entrails suspension (FES), applied at different frequencies, on rice growth and yield and ROI.

Methods: The field experiment was conducted from February to July 2024 using a randomized complete block design (RCBD) with three replications. Treatments were: T_0 - no fertilizer (control); T_1 - 120-90-90 N, P_2O_5, K_2O inorganic fertilizer (643 kg complete fertilizer + 66 kg urea ha^{-1}); T_2 - 4 L ha^{-1} GSE + FES applied weekly; T_3 - 4 L ha^{-1} GSE + FES applied every three days and T_4 - 4 L ha^{-1} GSE + FES applied daily. Data were analyzed using Analysis of Variance (ANOVA) and means were compared using Duncan's multiple range test (DMRT).

Result: Soil pH, OM, Available P and exchangeable K, improved under daily applications of GSE and FES compared with inorganic fertilizer and the control. The highest leaf area index (LAI) was recorded under inorganic fertilizer, although daily and three-day organic applications produced comparable values. The number of productive tillers per hill and percent of filled spikelets per panicle, weight of field spikelets per panicle and grain yield under daily organic fertilizer application were statistically similar to those under inorganic fertilizer. Grain yield was lowest in the control (4.42 t ha^{-1}) and highest with inorganic fertilizer (7.25 t ha^{-1}). Weekly and three-day organic applications yielded 5.00 t ha^{-1}, while daily application produced 6.25 t ha^{-1}, statistically comparable to inorganic fertilizer. These findings indicate that daily GSE and FES application is a viable organic alternative for sustainable rice production, although weekly application was more economically favorable due to lower labor and input costs.

Key words: Fermented fish entrails, Kakawate (*Gliricidia sepium*), Liquid organic fertilizer, Rice production, Soil fertility, Sustainable agriculture.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food in the Philippines and many regions worldwide. However, domestic rice production often fails to meet increasing demand due to population growth, natural calamities and limited arable land. PSA, (2024) reported that rice imports reached 4.77 million metric tons, primarily from Vietnam, Thailand and Myanmar. Enhancing fertilizer management remains a critical strategy to improve productivity and reduce reliance on imports.

Inorganic fertilizers are widely used but their continuous application can degrade soil fertility and contribute to environmental pollution. Consequently, sustainable agricultural practices are increasingly promoting organic inputs and biofarming technologies that improve soil health and crop productivity (Abraheem *et al*., 2024). Organic fertilizers provide essential nutrients, are environmentally safe and support long-term soil sustainability (Hussein, 2023).

Fish entrails represent a low-value by-product with limited commercial use and significant disposal challenges due to rapid decomposition and associated environmental pollution. Converting fish waste into organic fertilizer offers a sustainable solution that enhances soil fertility, increases crop yield and reduces greenhouse gas emissions linked to chemical fertilizers. Another potential organic input is *Gliricidia sepium* (kakawate), a common shrub in the Philippines whose leaves are rich in macro- and micronutrients essential for plant growth (Aye and Adegun, 2013; Kumar *et al*., 2013; Alamu *et al*., 2023; Murtiningsih *et al*., 2023).

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Because solid organic materials decompose slowly, liquid organic fertilizers are increasingly recommended to accelerate nutrient availability. However, most studies have been conducted under controlled conditions, with limited field validation and few standardized recommendations on application rate and frequency. Therefore, this study evaluated the combined use of fish entrails suspension and *G. sepium* extract as liquid organic fertilizers in rice production, focusing on their effects on soil properties, agronomic performance, yield and optimal application interval.

MATERIALS AND METHODS

The experiment was conducted at the Northwest Samar State University Agri-Nursery from February to July 2024. The site is characterized by loam soil, located at approximately 18 m above sea level (12.073679° N, 124.602365° E), with mean monthly temperatures of 24.1-28°C and rainfall ranging from 250-300 mm.

Prior to transplanting, composite soil samples were collected at 0-20 cm depth, air-dried, ground and sieved (2 mm) for analysis. Soil pH (1:1 soil-water), organic matter (Walkley-Black), total nitrogen (Kjeldahl), extractable phosphorus (Bray No. 2) and exchangeable potassium (ammonium acetate, pH 7.0) were determined. Post-harvest soil samples were similarly collected and analyzed.

The study was laid out in a randomized complete block design (RCBD) with three replications. Plot size was 5 m × 4 m, separated by 1.0 m alleyways and 2.0 m between replications. Treatments included: T_0 (no fertilizer); T_1 (120-90-90 kg ha^{-1} N-P_2O_5-K_2O inorganic fertilizer); T_2 (4 L ha^{-1} Gliricidia *sepium* extract [GSE] + fish entrails suspension [FES] applied weekly); T_3 (same rate applied every 3 days); and T_4 (same rate applied daily).

Fields were puddled using a hand tractor and dikes were constructed to prevent water and fertilizer movement between plots. PSB Rc18 rice was used. Seedlings were raised in a prepared seedbed and transplanted at 18 days after sowing at one seedling per hill, with missing hills replanted after seven days. GSE and FES were prepared through seven-day fermentation of chopped *G. sepium* leaves or fish entrails with brown sugar and water, then diluted at two tablespoons per liter prior to application. GSE was applied during the vegetative stage, while FES was applied during the reproductive stage. Inorganic fertilizers were applied following standard split application practices.

Weeding was done manually at 10, 20 and 35 days after transplanting. Pest control was carried out using a selective insecticide against green leaf hopper. Agronomic traits, yield and yield components were recorded from five randomly selected plants per plot. Data were analyzed using ANOVA for RCBD and treatment means were compared using Duncan's Multiple Range Test (DMRT). Net return was calculated as gross income minus total cost and return on investment (ROI) was expressed as net income divided by total cost × 100.

RESULTS AND DISCUSSION

The most prevalent weed species that infested the area were *Leptochloa chinensis*, *Eleusine indica, Echinochloa colona, Monochoria vaginalis* and *Cyperus spp.* (sedges).

During the vegetative stage, infestation of tungro carried by a green leaf hopper was observed. To prevent further spread of the disease, a chemical pesticide was applied. The product used was Fenthion with the active ingredient Fenthion 100 EC. It was applied as a foliar spray at a rate of 40 mL per hectare, mixed in 800 mL of water and sprayed twice at 15 and 30 days after transplanting (DAT). At booting stage until maturity, some plants were attacked by rats *(Rattus argentiventer*) which was controlled by cleaning the area.

Soil parameters

Table 1 shows that the type and frequency of fertilizer application exerted significant effects on soil chemical properties, including soil pH, organic matter (OM) and the availability of key nutrients such as available P and K. T_4 recorded the highest soil pH and OM and exchangeable K which was significantly greater than that observed in all other treatments. Moderate application frequencies (T_2 and T_3) indicating that regular additions of organic-rich inputs can enhance soil chemical buffering and nutrient dynamics. In contrast, the chemical fertilizer treatment (T_1) tended to show the lowest pH, reflecting the acidifying effects commonly associated with intensive inorganic nutrient inputs. Kumar *et al.* (2023) supported that long-term application of organic manures alters soil physico-chemical properties more positively than inorganic fertilizers, resulting in increased soil organic carbon, improved nutrient status (including N, P and K) and differences in soil pH across growth stages of rice cultivation. Organic amendments consistently improved soil fertility parameters and macro-nutrient availability (including K) compared with inorganic fertilization and control treatments, highlighting the role of organic inputs in enhancing soil health parameters under field conditions. The increase in soil pH under organic amendments can be attributed to the incorporation of organic compounds that enhance buffering capacity and release basic cations during decomposition, which neutralize soil acidity and promote the availability of essential nutrients like K. In contrast, Abiyot *et al.* (2024) synthetic inorganic fertilizers can contribute to soil acidification over time through processes such as nitrification and proton release, which can lower soil pH and potentially affect nutrient balance.

Available phosphorus (P) was significantly enhanced by organic fertilizer applications. T_4, T_3 and T_2 were statistically similar and higher than T_1 and T_0. The gradual release of phosphorus from decomposing organic matter and the mobilization of soil-bound P by microbial activity likely explain the superior P availability under organic treatments (Kucey *et al.*, 1989; Magdoff and van Es, 2009). Available potassium (K) increased markedly with the

frequency of organic fertilizer application. T_4 resulted in the highest available K, while the control (T_0) had no detectable K. The increase in K under organic amendments is attributed to the decomposition of K-rich plant residues and fish entrails, which release soluble K into the soil solution (Brady and Weil, 2016; Marschner, 2012). Similarly, Ji *et al.* (2017) concluded that Fish Amino Acid (FAA) is an effective strategy for maintaining soil fertility and promoting plant growth, while Johari *et al.* (2020) also confirmed the positive effect of FAA in improving soil fertility and enhancing the yield of okra.

Agronomic characteristics of lowland rice

No significant differences were observed among treatments in the number of days from transplanting to heading and to maturity. Tallest plants were obtained from plots applied with inorganic fertilizer at 120-90-90 kg ha^{-1} N, P_2O_5, K_2O, followed by those applied with organic fertilizers at different intervals, while the control produced the shortest plants. Leaf Area Index (LAI) was highest in plants treated with inorganic fertilizer, which was statistically comparable to those applied daily and every three days with GSE and FES (Table 2). Inorganic fertilizers do not

Table 1: Chemical properties of soil before and after harvest of lowland rice as affected by application of GSE and FES as organic fertilizer.

Treatments	Soil pH	Organic matter (%)	Total N (%)	Available P mg kg	Exchangeable K mg kg
Initial soil analysis	5.25	3.20	0.20	7.06	16.824
Final soil analysis					
Rate of fertilizer application					
T_0 - No fertilizer	5.18bc	2.50e	0.19	0.66b	0.00e
T_1 - 120-90-90 kg ha^{-1} N, P_2O_5, K_2O Inorganic fertilizer	5.09c	2.73d	0.19	0.70b	5.88d
T_2 - 4 L ha^{-1} (FES) and (GSE) at weekly interval of application	5.25b	2.78c	0.19	0.85a	8.36c
T_3 - 4 L ha^{-1} (FES) and (GSE) at 3 days interval of application	5.28b	2.99b	0.20	0.85a	11.04b
T_4 - 4 L ha^{-1} (FES) and (GSE) at daily interval	5.49a	3.15a	.21a	0.92a	16.88a
Mean	5.26	2.83	0.20	0.80	8.43
C.V. %	1.58	0.74	5.57	5.64	1.43
SE	0.06	0.017	0.089	0.036	0.098
Pr (≥F)	0.00	0.00	0.37	0.00	0.00

Means having the same letter on each column are not significant different at 5% level, DMRT.

Table 2: Agronomic characteristics of lowland rice as affected by GES and FES as organic fertilizer.

Treatments	Days from transplanting to heading	Days from transplanting to maturity	Plant height (cm)	Leaf area index at heading stage
Interval of application				
T_0 - No fertilizer	50.00	93.00	94.03c	1.73c
T_1 - 120-90-90 kg ha^{-1} N, P_2O_5, K_2O Inorganic fertilizer	54.00	94.00	110a	3.63a
T_2 - 4 L ha^{-1} (FES) and (GSE) at weekly interval of application	51.00	93.00	96.03b	2.57b
T_3 - 4 L ha^{-1} (FES) and (GSE) at 3 days interval of application	52.00	93.00	97.9b	3.23a
T_4 - 4 L ha^{-1} (FES) and (GSE) at daily interval	54.00	94.00	99.95b	3.14a
CV%	5.51	0.63	1.26	7.87
SE	2.34	0.48	1.02	0.18
Pr (≥F)	0.396	0.119	0.000	0.000

Means within column having the same letter are not significantly different at 5% level, DMRT.

require decomposition, as they contain concentrated nutrients that are rapidly released, thereby enhancing plant growth and overall productivity (Sharma and Chetani, 2017). Nevertheless, the gradual nutrient release from GSE and FES may enhance soil fertility and microbial activity over time, offering a more sustainable option for maintaining soil health compared to sole reliance on inorganic fertilizers. A higher LAI and plant height are associated with increased light interception, photosynthetic activity and biomass accumulation, which ultimately contribute to improved yield potential (Nur Faezah *et al.,* 2021). Racoma *et al.* (2017) claimed that applied fermented foliar fertilizers weekly for ten consecutive weeks exhibited the greatest potential as a nutrient source for organic hot pepper production. In a similar study, Denona *et al.* (2020) applied nitrogen-based Fermented Plant Juice (FPJ) weekly from the vegetative phase until one week before harvest. Their findings emphasized the consistent role of FPJ in supporting plant growth during early developmental stages. Furthermore, Diamante *et al.* (2022) investigated the effects of varying FPJ concentrations in pechay and reported that weekly applications from the vegetative phase up to one week before harvest demonstrated a direct relationship between FPJ concentration and enhanced plant growth. These results demonstrate that both chemical and frequent organic fertilizer applications can improve leaf development, with chemical fertilizer providing rapid effects, while organic liquid fertilizer contributes to sustained vegetative growth and improved plant canopy development (Brady and Weil, 2016; Magdoff and van Es, 2009).

Yield and yield components

Table 3 shows that the inorganic fertilizer significantly increased the number of filled spikelets per panicle and consistently produced the strongest response among nutrient treatments, reflecting its reliable role in assimilate partitioning and reproductive development. Similar responses have been reported by Ashraf *et al.* (2024), who attributed higher productive tiller numbers, filled grains per panicle and grain yield to improved nutrient availability under inorganic fertilization.

Daily foliar application of GSE and FES resulted in productive tiller number, filled spikelet percentage, filled spikelet weight per panicle and grain yield comparable to inorganic fertilization, indicating that frequent bio stimulant application can match conventional nutrient management in enhancing key yield components. In contrast, T_2 and T_3 produced moderate improvements, while the unfertilized control consistently recorded the lowest values across all yield parameters.

The unfertilized control (T0) produced the lowest grain yield (4.42 t ha^{-1}), below the average yield potential (5.1 t ha^{-1}), due to restricted vegetative growth, tillering and grain filling in the absence of external nutrient inputs. Similar reductions in productive tillers, filled spikelets and grain yield under unfertilized conditions have been reported by Lalichetti *et al.* (2024) and Mohammed *et al.* (2024), emphasizing the importance of nutrient supplementation in overcoming soil fertility constraints. Treatments T_2 and T_3 produced intermediate grain yields (5.0 t ha^{-1}), suggesting that although GSE and FES enhanced yield performance, their effectiveness was limited when nutrient supply did not fully meet crop demand during critical growth stages. Comparable trends were observed by Naikoo *et al.* (2025) under reduced nutrient input conditions.

Notably, daily application of GSE and FES (T_4) achieved a grain yield of 6.25 t ha^{-1}, statistically comparable to inorganic fertilization (T_1). This superior performance

Table 3: Yield and yield components of irrigated lowland rice as affected by the application of GES and FES as organic fertilizer.

Treatments	No. of productive tillers per hill at maturity	No. of filled spikelets panicle^{-1}	Percentage of filled spikelets panicle^{-1} (%)	Weight of filled spikelets panicle^{-1} (g)	Weight of 1,000 grain (g)	Grain yield (t ha^{-1})
Interval of application						
T_0 - No fertilizer	13.00c	72.00d	72b	2.49b	32	4.42c
T_1 - 120-90-90 kg ha^{-1} N, P_2O_5, K_2O Inorganic fertilizer	18.00a	96.00a	77ab	2.83a	35	7.25a
T_2 - 4 L ha^{-1} (FES) and (GSE) at weekly interval of application	15.00bc	80.00c	72b	2.50b	32	5.00bc
T_3 - 4 L ha^{-1} (FES) and (GSE) at 3 days interval of application	15.00bc	83.00c	73b	2.82a	32	5.00bc
T_4 - 4 L ha^{-1} (FES) and (GSE) at daily interval of application	17.00ab	89.00b	78a	2.83a	33	6.25ab
C.V. (b)%	9.10	2.22	3.25	2.66	8.25	9.61
SE	1.17	1.52	1.98	0.058	2.20	0.44
Pr (≥F)	0.0104	0.000	0.046	0.003	0.467	0.002

Means within column followed by the same letter are not significant different at 5% level, DMRT.

Table 4: Return on Investment (ROI) of irrigated lowland rice as affected by the application of GES and FES as organic fertilizer.

Treatment	Total yield (kg)	Gross income	Total cost	Net income	Return of investment (%)
T_0 - No fertilizer	4,420	79,560.00	21,300.00	58,260.00	273.52
T_1 - 120-90-90 kg ha^{-1}, N, P_2O_5, K_2O Inorganic fertilizer	7,250	130,500.00	69,710.00	60,790.00	87.20
T_2 - 4 L ha^{-1} (FES) and (GSE) at weekly interval of application	5,000	90,000.00	32,220	57,780.00	179.33
T_3 - 4 L ha^{-1} (FES) and (GSE) at 3 days interval of application	5,000	90,000.00	43,540.00	46,460.00	106.71
T_4 - 4 L ha^{-1} (FES) and (GSE) at daily interval	6,250	112,500.00	103,020	9,480.00	9.20

relative to T_2 and T_3 highlights the importance of application frequency, likely due to more consistent nutrient supply, improved uptake efficiency and enhanced assimilate translocation to grains, consistent with findings by Lalichetti *et al.* (2024). Consistent improvements in spikelet number and grain filling under inorganic and precision nutrient management have been widely reported (Ashraf *et al.*, 2024; Lalichetti *et al.,* 2024), supporting the present results. The 1000-grain weight showed minimal variation among treatments, indicating that yield differences were primarily driven by improvements in spikelet filling and yield component expression rather than individual grain weight.

Return on investment

Return on investment (ROI) differed markedly among fertilizer treatments (Table 4). The control (T_0, no fertilizer) recorded the highest ROI (273.52%), reflecting minimal input costs relative to yield. Application of inorganic fertilizer at 120-90-90 kg ha^{-1} N-P_2O_5-K_2O (T_1) resulted in a lower ROI (87.20%), indicating that yield gains did not sufficiently offset the high cost of inputs. Among organic-based treatments, weekly application of FES and GSE at 4 L ha^{-1} (T_2) produced a high ROI (179.33%), representing the most economically efficient fertilized treatment. Increasing application frequency reduced profitability, with 3-day interval application (T_3) yielding an ROI of 106.71%, while daily application (T_4) resulted in a very low ROI (9.20%), suggesting diminishing marginal returns due to excessive input costs. Organic treatments are expected to improve soil biological activity and nutrient cycling, supporting long-term soil fertility. In contrast, repeated inorganic fertilizer use may negatively affect soil quality over time. Although the control showed high short-term ROI, continuous nutrient omission may lead to soil nutrient depletion.

CONCLUSION

Fertilizer management significantly affected the growth and yield performance of lowland rice. Inorganic fertilizer applied at the recommended rate produced the highest growth parameters and grain yield. Foliar application of organic fertilizers (GSE and FES) improved yield compared with the unfertilized control, with daily application of GSE and FES) achieving yields comparable to inorganic fertilizer, indicating their potential as sustainable alternatives. However, economic analysis showed that weekly application (4L application of GSE and FES provided the best cost-return balance, while daily application was less economically viable due to higher labor costs, despite its agronomic and soil health benefits. Consequently, daily application may be more suitable for small-scale or urban farming systems, whereas weekly application is recommended for economically efficient production. Future research should focus on long-term effects of GSE and FES on soil fertility, nutrient dynamics and microbial activity, as well as optimizing application rates and combinations with reduced inorganic fertilizer to further enhance sustainability and profitability in rice farming.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal Care and Handling Techniques were approved by the University of Animal Care Committee.

Conflict of interest

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