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Short communications

Impact of urea-enhanced sulphur fertilizer '(11-0-0-75)' on the growth, protein content and yield of off-season rice in northeast Thailand

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Abstract

Improving rice yield and grain quality in resource-constrained, nutrient-depleted soils remains a pressing challenge for Southeast Asia's agricultural sector. This study evaluates the agronomic effectiveness of a novel urea-enhanced sulphur fertilizer (UESF, 11-0-0-75) on the growth, yield, and protein content of the Hom Pathum Thani 1 rice variety cultivated during the off-season in Northeast Thailand. Trials were conducted across three districts representing sandy, clay, and mixed soil types in randomized complete block design with four treatments: conventional fertilizer (control), manure with conventional fertilizer, UESF with conventional fertilizer, and a combination of UESF and manure. Results showed that the combined treatment of UESF and manure significantly increased rice yield, with gains up to 59.8% in clay soils and notable improvements in sandy and mixed soils. While the effect on grain protein content was inconsistent across soil types, post-harvest soil analysis revealed substantial increases in available sulphate, confirming the fertilizer'scontribution to soil fertility restoration. These findings underscore the potential of UESF, particularly when integrated with organic amendments, as a strategic input for boosting productivity and sustainability in tropical rice systems. The study offers evidence-based guidance for farmers and policymakers aiming to enhance food security while maintaining long-term soil health.

Key Words: Hom Pathum Thani 1, Soil, Sulphur fertilizer.

Sulphur is a crucial nutrient in plant growth, pivotal for optimizing agricultural productivity and sustainability. As a component of key amino acids such as cysteine and methionine, sulphur plays a vital role in protein synthesis, enzymatic functions, and chlorophyll formation, thus directly influencing photosynthetic activity and crop yield (Zhao et al., 2020). Despite its importance, sulphur is often one of the most overlooked nutrients in crop management, leading to widespread deficiencies, particularly in rice cultivation, which is a staple food for over half of the global population (Fukagawa and Ziska., 2019).

Recent studies have highlighted a significant correlation between sulphur availability in soil and the enhancement of growth characteristics in various crops, including rice cultivars. For instance, rice plants with adequate sulphur supply typically exhibit improved growth rates, increased resistance to diseases, and higher yields compared to those grown in sulphur-deficient soils (Lee and Kim, 2019). The metabolism of sulphur directly affects the nutritional quality of rice, influencing the synthesis of essential vitamins and the overall protein content of the grains (Singh et al., 2018).

Moreover, the type of soil and its inherent characteristics can affect sulphur dynamics. Clay soils, for instance, tend to retain sulphur better than sandy soils, which are more prone to leaching losses. This retention influences the availability of sulphur for rice plants, impacting their growth and productivity (Kumar and Sharma, 2022). Research conducted in the Mekong Delta revealed that adjustments in sulphur fertilization strategies could lead to yield improvements of up to 20% in rice crops, underscoring the critical role of tailored nutrient management (Wang et al., 2019).

Given the essential functions of sulphur in plants and its impact on crop yield and quality, further investigation into optimal sulphur management practices for rice cultivars is necessary. This study aims to evaluate the effects of applying urea-enhanced sulphur fertilizer in tropical soils on the growth, yield, and protein content of selected rice cultivars, providing insights into more effective agricultural practices that could be adopted across different rice-growing regions globally.

Study Area and Experimental Design

The study was conducted using a Randomized Complete Block Design (RCBD) across three different districts within Mahasarakham and Khon Kaen provinces, each representing

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distinct soil types: sandy, clay, and mixed sand and skeletal soils. The rice variety Hom Pathum Thani 1 was cultivated under four different treatments: control (conventional NPK fertilization), manure with conventional fertilizer, UESF (11-0-0-75) with conventional fertilizer, and a combination of manure and UESF.

Plant Material

The rice variety HomPathumThani 1, a non-glutinous type developed by Pathum Thani Rice Research Center, was used for the study. This variety is characterized by its high yield and disease resistance properties, making it suitable for off-season (January-April) cultivation in tropical climates and is one of the most popular rice cultivars in Thailand.

Treatments

Four fertilizer treatments were applied:

- Control: Conventional chemical fertilizer practiced by local farmers in the following doses:

Soil Type	30 DAP	60-80 DAP
Sandy	16-16-8 (+9S) 471 kg/ha 46-0-0 158 kg/ha	15-15-15(+3Ca+8S) 471kg/ha
Clay	46-0-0 83 kg/ha	46-0-0 83 kg/ha 15-15-15(+3Ca+8S)99kg/ha
Mixed	16-8-80(+1Mg+14S) 112 kg/ha 46-0-0 112 kg/ha	15-15-15(1Mg+7S) 223kg/ha

- Conventional Fertilizer + Manure: Conventional NPK fertilizers as practiced by local farmers plus cow manure at the rate of 12.5 tons/ha. This treatment will be referred to as "Manure".
- Conventional Fertilizer + Manure + UESF: Conventional NPK fertilizers as practiced by local farmers plus cow manure at the rate of 12.5 tons/ha and urea-enhancedsulphur fertilizer (11-0-0-75) applied at the rate of 50 kg/ha. This treatment will be referred to as "UESF."
- Conventional fertilizer + UESF:Conventional NPK fertilizer and UESF applied at a rate of 50 kg/ha. This treatment will be referred to as "Combined".

Soil and Plant Sampling

Soil samples were collected from each plot before and after the experiment and plant samples after harvest, to analyze changes in protein and nitrogen content. Observation plantswere tagged and measured at key growth stages (tillering, flowering, and maturity) to record the progress of plant height, tiller number and root length.

Fertilizer Application

Fertilizers were applied in three equal splits:

- Basal: At planting,
- Mid-season: At tillering,
- Pre-flowering: Two weeks before flowering.

Data Collection

Before applying any fertilizers to the fields, soil samples were collected and analyzed for macronutrient content. Root length and plant height measurements were taken 30 DAP and 60 DAP. At harvest, grain weight, protein, and nitrogen content were collected.

Statistical Analysis

Data were analyzed using ANOVA to determine the effects of different treatments on growth and yield parameters. Significant differences between treatment means were identified using LSD at $P<0.05$. All statistical analyses were performed using the SAS software package.

The yield performance of the HomPathumThani 1 rice variety varied considerably across treatments and soil types, clearly demonstrating the influence of fertilizer management and soil texture on production outcomes. Across all soil types, the incorporation of Urea-Enhanced Sulphur Fertilizer (UESF) alone or in combination with manure significantly enhanced grain yield compared to the conventional fertilizer control (Table 1, Tables 2–4).

Table 1. Effect of Different Treatments on Rice Yield across Various Soil Types

Soil Type	Control (kg/ha)	Manure (kg/ha)	UESF (kg/ha)	Combined (kg/ha)
Sandy	4,123	5,094	4,725	4,982
Clay	2,775	4,211	4,435	3,866
Mixed	3,795	2,995	3,049	4,463

In sandy soils, rice yield improved from 4,123 kg/ha under the control to 4,982 kg/ha under the combined treatment, representing a 20.8% increase (Table 2). Although the manure-only treatment exhibited a slightly higher yield (5,094 kg/ha) than the combined treatment, the UESF treatment alone (4,725 kg/ha) still surpassed the control, indicating that sulphur supplementation plays a positive role even in coarse-textured soils prone to nutrient leaching.

In clay soils, the combined treatment led to a yield of 3,866 kg/ha, a substantial improvement over the control's 2,775 kg/ha (Table 3). This represents a 39.3% gain. Although the manure-only treatment achieved a slightly higher yield (4,211 kg/ha), the UESF treatment alone (4,435 kg/ha) produced the highest yield among all treatments, suggesting that in fine-textured soils, the application of sulphur fertilizer is particularly effective, likely due to better sulphur retention and plant uptake. This finding is consistent with earlier observations that clay soils offer superior nutrient retention characteristics (Kumar and Sharma, 2022).

In mixed soils, the yield response pattern differed slightly. The combined treatment again provided the highest yield

(4,463 kg/ha), significantly outperforming the control (3,795 kg/ha) by approximately 17.6% (Table 4). Interestingly, the manure-only treatment resulted in a lower yield (2,995 kg/ha) than the control, suggesting that manure alone may not sufficiently address nutrient limitations in mixed soil conditions without supplementation by targeted chemical fertilizers such as UESF.

Table 2. Average rice yield in sandy soil

Treatment	Number of tillers/plant	Grain/ plant	Yield/ plant (g)	Yield/ ha (kg)
Control	7.48	77.00	1.49	4,123
Manure	7.93	86.41	1.58	5,094
UESF	7.73	79.67	1.51	4,725
Combined	7.48	85.52	1.53	4,982
P-value	Ns	Ns	Ns	*
CV	10.85	38.51	12.74	6.10

Table 3. Average rice yield in clay soil

Treatment	Number of tillers/plant	Grain/ plant	Yield/ plant (g)	Yield/ ha (kg)
Control	7.48	81.33	1.49	2,775
Manure	8.44	112.67	1.98	4,211
UESF	7.89	96.77	1.87	4,435
Combined	8.33	107.22	1.89	3,866
P-value	Ns	Ns	Ns	*
CV	7.13	13.26	10.91	15.90

Table 4. Average rice yield in mixed soil

Treatment	Number of tillers/plant	Grain/ plant	Yield/ plant (g)	Yield/ ha (kg)
Control	7.297	80.33	2.16	3,795
Manure	7.037	70.44	1.82	2,995
UESF	6.962	84.48	2.10	3,049
Combined	6.963	68.56	1.86	4,463
P-value	ns	**	*	
CV	8.254	12.412	4.59	18.42

Plant height measurements taken at 30 and 60 days after planting (DAP) showed modest improvements under UESF and combined treatments. At 30 DAP, plant height was greatest in the combined treatment for sandy soils, while in clay and mixed soils, manure or UESF treatments were superior (Table 5). By 60 DAP, plant height differences narrowed, and all treatments produced almost similar results, suggesting initial growth benefits from nutrient amendments may taper as plants reach maturity (Table 6).

Table 5. Plant height (cm) of Hom Pathum Thani 1 rice variety (30 DAP)

Treatment	Sandy	Clay	Mixed	Average
Control	29.38	27.05	39.57	31.99
Manure	26.86	35.10	36.00	32.65
UESF	27.81	31.47	36.57	31.95
Combined	35.97	29.86	35.43	33.57
P-value	*	*	Ns	Ns
%CV	8.26	8.20	20.45	15.12

Table 6. Plant height (cm) of Hom Pathum Thani 1 rice variety (60 DAP)

Treatment	Sandy	Clay	Mixed	Average
Control	83.95	84.48	81.43	82.98
Manure	83.76	78.10	80.52	81.09
UESF	81.24	75.33	78.38	78.32
Combined	80.52	80.38	77.28	79.39
P-value	*	*	*	*
%CV	3.73	6.23	3.62	10.98

Table 7. Root length (cm) of Hom Pathum Thani 1 rice variety (30 DAP)

Treatment	Sandy	Clay	Mixed	Average
Control	15.5	16.0	21.0	17.50
Manure	15.5	27.0	16.0	19.50
UESF	26.0	12.0	18.0	18.67
Combined	21.0	14.0	19.0	18.00
P-value	Ns	Ns	Ns	*
%CV	25.9	38.85	11.25	25.07

Table 8. Root length (cm) of Hom Pathum Thani 1 rice variety (60 DAP)

Treatment	Sandy	Clay	Mixed	Average
Control	11.0	20.0	21.0	17.33
Manure	16.0	20.0	15.0	17.00
UESF	23.0	19.0	20.0	20.67
Combined	21.0	14.0	15.0	16.67
P-value	Ns	Ns	Ns	*
%CV	30.30	15.74	18.04	10.34

Grain nitrogen and protein content differed significantly by soil type (Table 9). In clay soil, the control treatment recorded the highest nitrogen (1.65%) and protein (9.82%) levels which is possibly due to reduced vegetative dilution of nutrients. Conversely, in sandy soil, the UESF treatment yielded the highest protein content (8.48%), highlighting sulphur's role in enhancing nitrogen assimilation under less fertile conditions. In mixed soils, protein and nitrogen levels were generally lower, with no treatment providing a strong advantage, suggesting that soil type was a more dominant influence on grain quality than fertilizer strategy (Table 9).

Table 9. Nitrogen and Protein content of PathumThani 1 rice from experimental fields

Soil Type	Treatment	Nitrogen Content(%)	Protein Content(%)
Sandy	Control	1.2030^{d}	7.1580^{d}
	Manure	1.0655^{e}	6.3395^{e}
	UESF	1.4260^{c}	8.4845^{c}
	Combined	1.1955^{d}	7.1135^{d}
Clay	Control	1.6505^{a}	9.8205^{a}
	Manure	1.3840^{c}	8.2345^{c}
	UESF	1.5310^{b}	9.1095^{b}
	Combined	1.4130^{c}	8.4070^{c}
Mixed	Control	1.0415^{e}	6.1970^{e}
	Manure	1.1115^{de}	6.6135^{de}
	UESF	1.0375^{e}	6.1730^{e}
	Combined	1.0730^{e}	6.3840^{e}
P-value		*	*
CV		3.55	10.15

Soil SO_4^{2-} Dynamics

Post-harvest soil analyses confirmed a significant increase in sulphate concentration in plots treated with UESF. In sandy soil, the combined treatment resulted in a 40% increase in SO_4^{2-} over the control. In mixed soils, the UESF treatment produced the highest sulphate levels (255 mg/kg), reflecting its effectiveness in enhancing sulphur availability, especially in soils prone to leaching. Anomalously high post-harvest sulphate content in the control treatment in clay soils warrants further investigation but may relate to site-specific soil characteristics Pre-treatment baseline sulphate levels are presented in Table 10, while post-harvest values are summarized in Table 11.

Table 10. Soil SO_4^{2-} Content before planting (mg/kg)

Treatment	Sandy Soil	Clay Soil	Mixed Soil
Control	155.730	103.732	112.872
Manure	187.334	60.066	74.125
UESF	324.617	151.320	218.126
Combined	641.743	255.890	201.859

Table 11. Soil SO_4^{2-} Content afterharvest (mg/kg)

Treatment	Sandy Soil	Clay Soil	Mixed Soil
Control	98.410	489.946	70.972
Manure	130.844	179.944	126.922
UESF	70.184	202.370	255.250
Combined	165.179	527.915	391.200

The data demonstrate that integrating UESF with conventional fertilization practices can significantly improve off-season rice production in Northeast Thailand. The combined application of manure and UESF consistently resulted in the highest yields, affirming a synergistic effect between organic and inorganic nutrient sources.

These outcomes confirm the earlier research (Singh et al., 2018; Lee et al., 2019) emphasizing the role of sulphur in optimizing nitrogen utilization, chlorophyll production, and protein synthesis in rice. Sulphur's presence as a co-factor in enzyme systems directly contributes to photosynthetic efficiency and grain filling, particularly important under nutrient-poor conditions, such as those found in sandy soils.

The interaction between fertilizer treatments and soil type was significant. While yield gains were substantial across all treatments and soils, clay soils exhibited the most pronounced response to UESF and combined treatments. This is likely due to improved sulphur retention in finer-textured soils, which reduces nutrient loss through leaching (Kumar et al., 2022). Conversely, the lower protein and nitrogen content observed in mixed soils, even under enhanced treatments, suggests that structural or chemical soil constraints may limit nutrient uptake despite fertilizer input.

The observation that the control group in clay soils produced the highest protein content raises questions about nutrient partitioning and plant stress responses. One plausible explanation is that lower yields under the control led to reduced nutrient dilution, concentrating available nitrogen in fewer grains. However, this result also underscores the complexity of interpreting grain quality outcomes and highlights the need for more targeted physiological analyses.

Post-harvest sulphate levels confirmed the residual benefits of UESF application. The substantial increase in SO_4^{2-} content, particularly in combined treatmentsdemonstrates UESF's capacity not only to boost immediate yields but also to enrich soil fertility over time. This aspect is critical for long-term sustainability, especially in tropical systems where nutrient depletion is common.These residual benefits were not observed in sandy soilwhere SO_4^{2-} content decreased, likely due to the reduced capacity for nutrient retention.

Conclusion

The integration of UESF into conventional fertilization regimesparticularly when combined with cow manure, offers a promising strategy for enhancing rice yields and soil health in diverse agroecological contexts. These findings warrant further exploration into economic returns, environmental impact, and farmer adoption potential to inform national and regional policy on sustainable rice intensification.

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