Research article

Evaluation of Developed Novel Hybrid Granular Fertilizers for Sustainable Agriculture in Sri Lanka

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Abstract This study developed and evaluated novel hybrid granular fertilizers by blending urea with locally available organic materials using molasses as a binder. Six treatments (T1-T6) were prepared with varying ingredient ratios and granulated using a small concrete mixer. Granule uniformity and size distribution (2.01-4.75 mm and 4.76-8.00 mm) were determined by hand sieving, indicating their suitability for bulk production and industrial application. Water stability was assessed using an aggregate analyzer for over two hours. Nutrient dissolution experiments were conducted to measure the initial release of nitrate and potassium. The results showed low uniformity indices, indicating consistent granule size and production scalability. Molasses alone did not dictate granule formation; a balanced mix of organic materials was essential for this process. Molasses enhanced water stability, but compost (T4) was the most effective for granule stability, outperforming chicken manure. Compost is recommended as a core organic component for stable slow-release granules. One-way ANOVA confirmed a highly significant treatment effect on nutrient release ($P < 0.001$). T5 and T6 were optimal for crops requiring rapid early season nutrition (leafy vegetables), whereas T4 was suitable for perennials or leaching-prone soils. Biochar-rich T1 and T2 treatments are recommended for soils requiring long-term nutrient cycling. Further optimization is required to tailor the formulations to specific agronomic requirements. These findings contribute to the development of slow-release hybrid fertilizers, thereby supporting sustainable agriculture in Sri Lanka.

Keywords hybrid fertilizer, nutrient loss, water resistance, Sri Lanka

INTRODUCTION

Sri Lanka's commercial agriculture has long relied on chemical fertilizers to achieve high crop yields, primarily because of their high nutrient content, rapid nutrient release, and ease of application. However, a substantial proportion of these nutrients is lost through leaching, runoff, and volatilization, resulting in economic inefficiency and environmental pollution. These losses contribute to water contamination, soil degradation, and adverse effects on human health (United Nations, 2022). The incorporation of organic matter into agricultural systems has been shown to enhance soil quality and fertility by increasing soil organic carbon, improving nutrient retention, and enhancing soil structure (Kim and Mihara, 2022).

Despite these benefits, the overreliance on chemical fertilizers in Sri Lanka has led to a significant decline in soil organic matter, further diminishing the soil structure and nutrient retention capacity. The National Agriculture Policy (2021) explicitly promotes the integration of organic components into farming systems as a balanced approach to ensure sustainable agricultural production. Despite these government efforts, the adoption of organic fertilizers by farmers remains low in China. A field survey conducted by the authors in 2023 in the Anuradhapura District revealed that only a minority of paddy farmers incorporate organic matter into their soils, with most citing slow nutrient release and the large quantities required as major barriers to its adoption. Consequently, most farmers continue to rely on chemical fertilizers for immediate and manageable nutrient supply, underscoring the urgent need for practical, cost-effective solutions that bridge the gap between conventional and organic farming approaches. There is growing interest in hybrid fertilizers that combine the rapid nutrient release of chemical fertilizers with the soil health benefits of organic amendments, such as compost. High production costs and technological complexity in the production methods of commercially formulated organic-chemical blended fertilizers have limited their adoption in Sri Lanka.

Therefore, this study aimed to develop a simple and low-cost production technique for hybrid fertilizers using locally available organic materials and urea, with molasses as a binding agent. The results are expected to provide valuable insights into improving hybrid fertilizer production and adoption in Sri Lanka and other developing countries facing similar agricultural challenges.

OBJECTIVES

The objectives of this research were:

- to formulate hybrid granular fertilizers from locally available organic materials and urea
- to evaluate the stability of these fertilizers under field-like conditions and
- to assess the nutrient release of the developed hybrid fertilizers

METHODOLOGY

Materials Selection for Making Hybrid Granular Fertilizers

The selection of materials for hybrid granular fertilizers was based on a critical literature review, nutrient content analysis, and practical considerations related to Sri Lankan agriculture. Leafy compost, cow manure, and chicken manure were chosen as organic fertilizers due to their balanced nutrient composition and organic matter content. Biochar has been used for its ability to improve soil physicochemical properties (Herath et al., 2013). Molasses served as a binder to aggregate the ingredients. Urea was included as a readily available source of nitrogen to complement the slow release of nutrients from organic sources.

All materials utilized in this study were procured locally within Japan from certified agricultural supply firms, but closely resembled those commonly available in Sri Lanka, ensuring the relevance of the results for Sri Lankan conditions. The chemical composition of the ingredients is presented in Table 1.

Table 1 Chemical properties of the ingredients

Component	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Total potassium (mg/kg)
Urea	460,000	-	-
Leafy compost	10,000	3,000	10,000
Cow dung	10,000	5,000	10,000
Chicken manure	30,000	30,000	20,000
Rice husk biochar	3,000	1,000	15,000
Molasses	1,200	200	40,000

Preparation of Hybrid Granular Fertilizers

Urea and organic materials (except molasses) were ground to less than 1 mm in size. Six treatments (T1-T6) were developed (Table 2), based on oven-dry mass basis ratios (dried at 105 °C for 24 hours). According to the ratios, the ingredients were mixed in a small-scale concrete mixer operated at a rotation speed of 16 rpm and a 30-degree inclination angle. These parameters were determined based on preliminary optimization trials to promote a gentle mixing.

Distilled water was evenly sprayed during mixing to promote wet granulation. Granules were collected and air-dried for 2 to 4 days at a controlled temperature of 24°C and used for subsequent experiments. A schematic of the granulation process is shown in Fig. 1.

Table 2 Mixing ratios of ingredients (%)

Treatment	Urea	Compost	Cow manure	Chicken manure	Rice husk biochar	Molasses
T1	10	50	10	10	16	4
T2	10	48	10	10	16	6
T3	15	51	10	10	10	4
T4	15	61	10	-	10	4
T5	10	51	25	10	-	4
T6	10	49	25	10	-	6

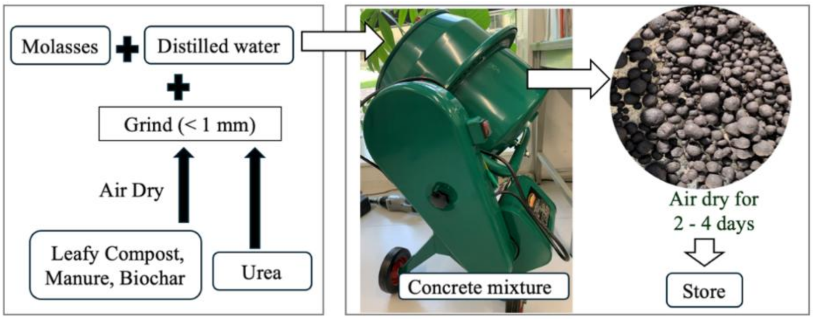

Fig. 1 Schematic diagram of the granulation process

Determination of Granule Uniformity

Following granulation, the uniformity of the granules for each treatment was determined by hand sieve analysis using standard laboratory sieves. Sieves with aperture sizes of <0.5 mm, 0.51-2 mm, 2.01-4.75 mm, 4.76-8 mm, and >8 mm were arranged in descending order. The samples were placed on the top sieve and gently shaken by hand for 15 min to ensure proper particle separation. The mass retained on each sieve was recorded, and the particle sizes at which 10% (D_{10}) and 95% (D_{95}) of the sample (by mass) passed through the sieves were determined by interpolation. The uniformity index (UI) was calculated for each treatment using Eq. (1) (Ohio State University Extension 2025; Ivell and Nguyen 2014). Assessing the uniformity of the bulk sample ensured that the fertilizer was spread evenly, minimizing product loss.

$$UI = (D_{95}/D_{10})*100 \tag{1}$$

Where, D_{95} size of sieve opening that retains 95% of the sample, and D_{10} size of sieve opening that retains 10% of the sample

Determination of granule size distribution

The granule size distribution was determined by sieving the air-dried fertilizer granules into defined size fractions relevant to industry standards: 2.01-4.75 mm, 4.76-8.00 mm, and >8.00 mm (Fig. 2).

Granules within the 2.01-4.75 mm range are most suitable and commonly used for field applications because of their optimal handling and spreading characteristics (Kasmadi et al., 2019). Granules sized 4.76-8.00 mm were used to a medium extent, whereas those >8.00 mm were rarely used. This classification ensured that the produced fertilizer granules were aligned with commercial fertilizer quality standards.

Fig. 2 Different granular size ranges

Evaluating Water Stability of Granular Fertilizers

Evaluating the water stability of fertilizer granules is essential for assessing their ability to retain physical integrity under wet conditions and to regulate nutrient release. To analyze the water stability, an aggregate analyzer was used, as shown in Fig. 3. The samples were placed on the top sieve and continuously stirred in water for two hours. After agitation, the material retained on each sieve was collected and oven-dried to determine its quantity.

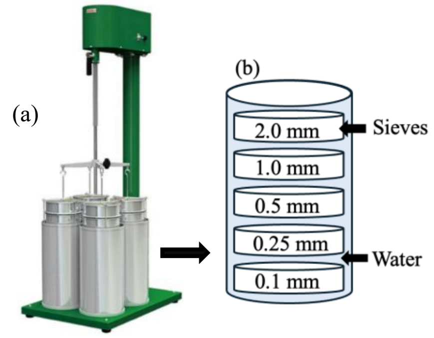

Fig. 3 Aggregate analyzer (a) with sieves (b)

Determination of Initial Nutrient Dissolution

Granules of 2.00-4.75 mm size were analyzed for initial nutrient release analysis. Triplicate samples of each granule were mixed with distilled water at a 1:10 solid-to-liquid ratio in 50 mL centrifuge tubes (Violamo centrifuge tube, Sigma-Aldrich, USA). The samples were then shaken using a reciprocating shaker at 150 rpm for 30 min at 24°C to ensure uniform nutrient extraction. Subsequently, the suspensions were filtered and analyzed for nitrate (NO_3^-) and potassium (K^+). This method provided an assessment of nutrient release under controlled conditions, mimicking the initial field interactions between fertilizer and soil moisture. This procedure was chosen for its practicality and alignment with the commonly used practices in nutrient release studies.

RESULTS AND DISCUSSION

Granule Uniformity

The calculated UI values for treatments T1, T2, and T3 were 24, while the remaining had a value of 25, exhibiting uniformity index values well below 40. The industry standard considers UI values within 40-60 to indicate a uniform particle size; values below 40 are not explicitly defined in the reference (Ohio State University Extension, 2025). However, the observed lower UI values suggest that the developed granular fertilizers possess even more uniform particle sizes and distributions. Therefore, all treatments ensured that the bulk production would spread evenly and minimized product loss.

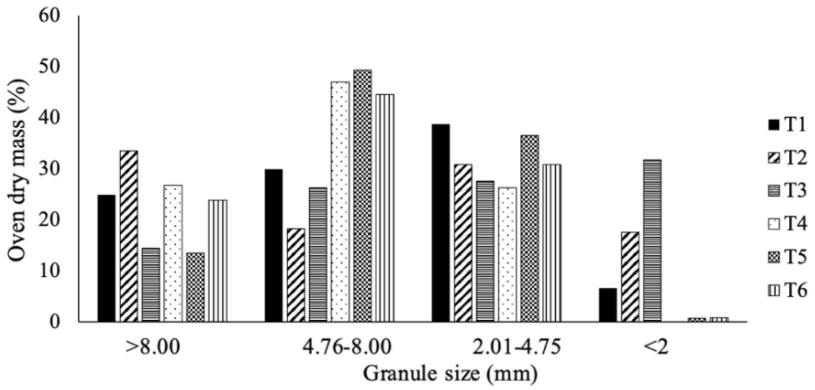

Fig. 4 Granular size distribution of developed fertilizers

Granule Size Distribution

Figure 4 shows that the granule size distribution varied among the treatments. Increasing the molasses content from 4% to 6% did not consistently improve the granule size distribution, suggesting that molasses alone is not the sole factor affecting granule formation. Instead, a balanced combination of organic materials is important for optimal granule size and reducing fines. Notably, T4, T5, and T6 produced minimal fines (<2 mm), likely due to differences in their compost, cow dung, and manure contents. For example, T4 contained high compost and no chicken manure, T5 contained higher cow dung and no biochar, and T6 contained higher cow dung and molasses. In industrial production, excessive fines and oversized particles are undesirable and can lead to wastage. Therefore, further formulation and optimization are recommended to achieve the most uniform granule size distribution possible.

Water Stability of Granular Hybrid Fertilizers

The results in Table 3 show that molasses increased granule stability (T2>T1, T6>T5). However, T4, with higher compost and no chicken manure, was the most stable of all, surpassing even those with higher molasses. This demonstrated that the absence of chicken manure and high compost content were the primary factor for T4's water stability, as the fibrous nature of chicken manure could reduce granule stability. This suggested that compost was an effective organic fertilizer for strong, water-stable granules, while chicken manure was less effective for binding.

Table 3 Mass percentage left on the sieve after 2 hours of shaking

	Mass percentage left on the sieve after shaking for 2 hours					
Sieve (mm)	T1	T2	T3	T4	T5	T6
2.0 mm	93.19	96.47	95.80	99.35	94.83	97.91
1.0 mm	5.77	2.47	1.81	0.29	2.12	0.78
0.5 mm	0.52	0.49	1.08	0.10	1.65	0.62
0.1 mm	0.53	0.57	1.30	0.26	1.40	0.70

Nutrient Dissolution

Figure 5 shows the initial nutrient release from the developed fertilizers. One-way ANOVA revealed that the release of NO_3^- and K^+ from hybrid fertilizer granules (2.01-4.75 mm) varied significantly across treatments. Treatments T5 and T6, which contained higher amounts of cow manure, exhibited the highest nitrate and potassium release, while T4, with no chicken manure, showed the lowest nutrient release. These results suggest that cow manure, as a readily mineralizable organic nitrogen source, and molasses, as a microbial energy substrate, synergistically promote rapid nutrient release. In contrast, compost's stabilized organic matter content contributes to its slow-release characteristics. Biochar-rich treatments demonstrated moderate nutrient release, likely due to the porous structure and nutrient retention capacity of biochar.

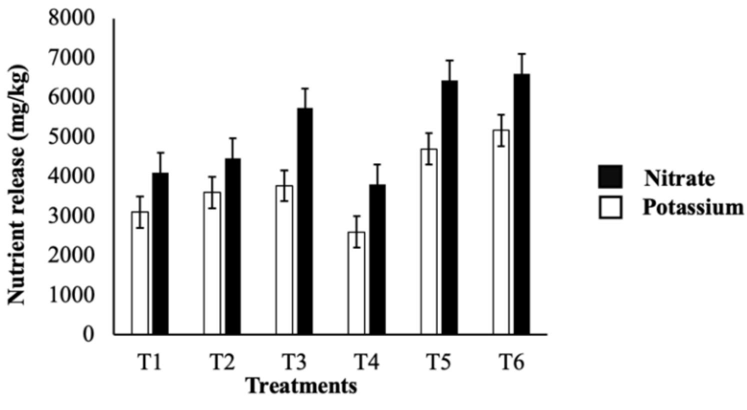

Fig. 5 Nutrient release from developed fertilizers

As a recommendation, T5 and T6 are particularly suitable for crops requiring rapid early-season nutrition, such as leafy vegetables. Treatment T4, with its slow-release properties, is ideal for perennial crops or soils prone to nutrient leaching, where sustained nutrient availability proves critical. Biochar-rich treatments (T1 and T2) are recommended for degraded soils requiring improved water retention and long-term nutrient cycling.

CONCLUSION

The hybrid granular fertilizers developed in this study, using locally available organic materials and urea with molasses as a binder, demonstrated improved nutrient release and stability compared to urea alone. The granules exhibited uniformity, ensuring better handling, especially for smallholders. Slow-release properties minimize nutrient leaching and runoff, enhancing nutrient use efficiency and water stability. This study focused on short-term nutrient release in laboratory conditions. The nutrient release dynamics observed in this study may differ under field conditions because of factors such as soil microbial activity, weather, and plant uptake. Further field trials are required to validate these findings in real agricultural scenarios. Studies linking nutrient release kinetics to plant growth and soil microbial diversity would further strengthen the practical relevance of these results.

REFERENCES

Herath, H.M.S.K., Camps-Arbestain, M. and Hedley, M. 2013. Effect of biochar on soil physical properties in two contrasting soils: An Alfisol and an Andisol. Geoderma, 209-210, 188-197, Retrieved from DOI https://doi.org/10.1016/j.geoderma.2013.06.016

Ivell, D.M. and Nguyen, V.T. 2014. The evolution of screening systems for optimum granular fertilizer product quality. Procedia Engineering, 83, 328-335, Retrieved from DOI 10.1016/j.proeng.2014.09.024

Kasmadi, B., Nugroho, B., Sutandi, A. and Anwar, S. 2019. Filter cake utilization as filler of 15-15-15+5S compound fertilizer: Particle size distribution and granule crushing strength properties. Reaktor, 19 (4), 145-151, Retrieved from URL http://ejournal.undip.ac.id/index.php/reaktor/article/view/25843

Kim, M.L. and Mihara, M. 2022. Effect of adding agricultural and organic lime on soil properties and survival rate of pathogenic bacteria (Coliform and E. coli) in farmland soils of Kampong Cham Province, Cambodia. International Journal of Environmental and Rural Development, 13 (2), 61-68, Retrieved from DOI https://doi.org/10.32115/ijerd.13.2_61

Ministry of Agriculture. 2021. National agriculture policy. Ministry of Agriculture, Sri Lanka, Retrieved from URL https://www.agrimin.gov.lk/web/images/20.10.20221/Final%20English%20Document%2007.02.2022%20pdf.pdf

Ohio State University Extension. 2025. Physical properties of granular fertilizers and impact on spreading. FABE-5501, Ohio State University, Retrieved from URL https://ohioline.osu.edu/factsheet/fabe-5501

United Nations. 2022. Environmental and health effects of fertilizer use. Retrieved from URL https://wedocs.unep.org/20.500.11822/40363