Effectiveness of zeolite and humic acid-based granular NPK fertilizer on durian (*Durio zibethinus*) growth

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Abstract. Improving NPK fertilizer efficiency can be achieved by incorporating zeolite and humic acid to slow nutrient release. This experiment evaluated the effects of a granular NPK fertilizer (6:6:12) enriched with zeolite and humic acid compared to a standard commercial NPK fertilizer (15:15:15) on durian (*Durio zibethinus*) growth and determined optimal dosing. A two-factor Randomized Block Design (RBD) was used: the first factor was fertilizer type (enriched NPK vs. commercial NPK), and the second was fertilizer dose (300 g, 500 g, and 700 g per plant every three months). The study, conducted on Musang King and Bawor durian varieties, measured growth parameters (plant height, stem diameter, and number of primary branches) and soil chemical properties (pH, CEC, base saturation, organic-C, and nutrient availability). Results showed no significant growth difference between plants fertilized with enriched and commercial NPK fertilizers. Optimal doses were 500 g and 300 g per plant per three months for Musang King and Bawor, respectively. Despite its lower NPK content, the enriched fertilizer improved nutrient efficiency through better retention and gradual release. These findings highlight its potential as a sustainable alternative for durian cultivation.

1 Introduction

Agricultural productivity often suffers from the inefficiency of applied fertilizers, as plants absorb only a fraction of the nitrogen remains around 50%, with significant losses happening due to volatilization and leaching [1]. Phosphorus use efficiency (PUE) around 10–15% is low due to limited availability in soils, necessitating the use of fertilizers. Potassium use efficiency (KUE), while relatively better at 50–70%, is still influenced by soil conditions that can lead to nutrient immobilization or leaching [2]. Inefficient fertilizer use contributes to

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significant environmental degradation, including water pollution and greenhouse gas emissions [3].

Slow-release fertilizers (SRFs) play a crucial role in enhancing nutrient availability while minimizing losses, therefore promoting sustainable agricultural practices. These fertilizers are designed to release nutrients gradually, aligning with plant uptake needs and reducing environmental impacts [4]. Innovations in fertilizer production enable the creation of granules with controlled dissolution rates, optimizing nutrient release according to plant needs. Granulated fertilizers allow for precise nutrient application, reducing losses and enhancing plant uptake [5].

Zeolites are alumina-silicate minerals that can absorb and release water and nutrients, making them effective in slow-release fertilizers. Zeolite has been shown to reduce nutrient solubility rates, indicating its potential to enhance NPK fertilizers [6]. Humic acid enhances soil structure and nutrient retention, promoting microbial activity and improving plant health [7]. Research on slow-release fertilizers has primarily focused on the use of zeolite in NPK formulations.

Meanwhile, studies on slow-release fertilizers made from zeolite and humic acid have mainly examined their application in urea-based fertilizers [8]. For example, urea fertilizer in the form of a slow-release combination of zeolite and humic acid is applied to soil media to reduce the rate of nitrate release, a higher humic acid concentration was given on fertilizer causes a nitrogen release become ammonium and nitrate more slowly [9]. However, research on zeolite and humic acid-based slow-release fertilizers for NPK formulations is still limited. Other research has demonstrated that combining humic acid with zeolite in fertilizers has been shown to increase the production of crops like rubber and kopyor coconut by improving nutrient release and uptake [10].

Currently, a slow-release granular NPK fertilizer (6:6:12) made from zeolite enriched with humic acid is being developed by a team from Department of Soil Science and Land Resources, Faculty of Agriculture and PT Cigula Bumi Mineral. This fertilizer produced in Karangnunggal, an area abundant in zeolite deposits. Before production and commercialization, the fertilizer needs to be tested on various plantation crops. One high-value crop with potential for development in the area is durian. According to the Central Statistics Agency (BPS), Tasikmalaya's durian production in 2023 reached 16,910 quintals. Durian requires optimal nutrients for its production needs. During its early vegetative growth phase, durian requires sufficient nutrients to enhance growth. Nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are essential for plant development and growth, making the application of an appropriate NPK fertilizer crucial for durian cultivation.

Therefore, this study to evaluated the effects of a granular NPK fertilizer (6:6:12) enriched with zeolite and humic acid compared to a standard commercial NPK fertilizer (15:15:15) on durian (*Durio zibethinus*) growth and determined optimal dosing.

2 Materials and methods

2.1 Location, equipments, and materials

The field experiments were carried out in Karangmekar Village, Karangnunggal District, Tasikmalaya Regency. Soil analysis was subsequently conducted at the Soil Chemistry and Fertility Laboratory, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University. The research location is situated in a lowland area with an elevation ranging between 100 to 266 meters above sea level. The area has an average temperature of 20°C to 34°C and receives annual rainfall of approximately 3000 to 3500 mm.

The equipment utilized in this study was categorized into field and laboratory tools. Field activities used instruments such as soil forks, pruning shears, calipers, and measuring tapes, which were essential for facilitating fertilizer application and measuring plant growth. Laboratory activities, on the other hand, required equipment such as a pH meter, an electrical conductivity (EC) meter, and an Atomic Absorption Spectrophotometer (AAS) to analyze the chemical properties of the soil.

The materials used in this research included two types of fertilizers: (1) NPK Granule Plus, formulated with a nutrient composition of 6:6:12 and enriched with zeolite and humic acid, and (2) conventional NPK fertilizer with a nutrient composition of 15:15:15. Additionally, various chemical reagents were used for analyzing the physical and chemical properties of the soil.

2.2 Experimental design

This study used a Randomized Block Design (RBD) to reduce experimental error and account for natural variations in the field. The experiment consisted of two treatment factors. The first factor was the type of fertilizer, which included NPK Granule Plus and conventional NPK fertilizer. The second factor was the fertilizer dosage, consisting of three levels: 300 g, 500 g, and 700 g per plant. Each treatment was repeated three times, producing a total of 18 experimental units.

The research was conducted on two types of durian plants, Musang King, and Bawor, both of which were approximately 3 years old. The two fields were located about 1 kilometer apart. The Musang King field had a more diverse range of surrounding vegetation, including rambutan, coconut, banana, cassava, and pineapple, while the Bawor field had fewer surrounding plants.

2.3 Production of NPK Granul Plus fertilizer, soil sampling, and analysis

The production of NPK Granul Plus fertilizer involved grinding the individual components, namely urea, SP36, and KCl, to a fine particle size of 100 mesh. The ground materials were mixed with zeolite (50%) and humic acid (1%) using a mixer machine. The homogeneous mixture was processed using a granulator to produce NPK Granul Plus fertilizer with a final nutrient composition of 6:6:12.

Soil samples were collected twice during the study: before fertilization and after fertilization. Sampling was conducted at a depth of 0–20 cm in each experimental plot. Soil samples were taken from five points within each plot and composited to obtain a representative sample.

The collected soil samples were analyzed to determine both chemical and physical properties. The chemical properties analyzed included pH, electrical conductivity (EC), organic carbon, total nitrogen, available nitrogen (NH_4 and NO_3), available phosphorus, available potassium, cation exchange capacity (CEC), and base saturation. The physical property analyzed was soil texture. The analyses were conducted following standard laboratory methods.

2.4 Plant growth measurement and data analysis

Measurements of plant growth parameters were conducted monthly for four months following the first fertilization. Three growth parameters were observed: plant height, stem diameter, and the number of primary branches. Plant height was measured from the soil surface to the highest leaf [11] using a measuring tape, while stem diameter was measured at

1.3 meters above ground level using a caliper [12]. The number of primary branches was recorded based on the emergence of new branches from the main stem.

The data obtained were analyzed statistically using Analysis of Variance (ANOVA) to determine the effects of treatments on plant growth and soil properties. When significant differences were detected, the Tukey test was performed at a 5% significance level to compare treatment means. All statistical analyses were carried out using SPSS software.

3 Results and discussions

3.1 Initial soil characteristics

The initial soil analysis showed differences between the Musang King and Bawor fields in pH, exchangeable calcium (Exch-Ca), and base saturation. The Musang King field was categorized as very acidic with pH 4.1, while the Bawor field had neutral soil conditions with pH 7.3. Other soil characteristics, such as organic-C, total-N, and cation exchange capacity (CEC), were within acceptable ranges for durian growth, although both fields had low available phosphorus (P_2O_5) and potassium (K) levels.

Table 1. Soil characteristics in Musang King and Bawor durian plantations before treatment.

Parameter	Unit	Musang King		Bawor	
		Value	Criteria	Value	Criteria
pH	-	4.1	Very acid	7.3	Neutral
EC	dS/m	0.27	-	0.20	-
Organic-C	%	1.96	Low	2.12	Moderate
Total-N	%	0.29	Moderate	0.23	Moderate
NH_4-N	ppm	90	-	60	-
NO_3-N	ppm	30	-	30	-
P_2O_5	ppm	1.50	Very low	2.80	Very low
Available-K	ppm	125	-	97	-
CEC	me/100 g	26.41	High	30.20	High
Exchangeable-Ca	me/100 g	10.49	Moderate	12.01	High
Exchangeable-Mg	me/100 g	1.12	Moderate	0.53	Moderate
Exchangeable-K	me/100 g	0.19	Low	0.13	Low
Exchangeable-Na	me/100 g	0.06	Very low	0.05	Very low
Base saturation	%	37.63	Low	42.26	Moderate
Texture					
Sand		8.30		13.33	
Dust	%	18.86	Clay texture	21.85	Clay texture
Clay		72.85		64.82	

3.2 Post-treatment soil chemical properties

The chemical characteristics of the soil in the Musang King and Bawor durian fields after treatment are presented in Table 2 and Table 3. After treatment, a clear advantage was observed for NPK Granule Plus 6:6:12 enriched with zeolite compared to standard commercial NPK fertilizer 15:15:15. In the Musang King field, applying 700 g NPK Granule Plus resulted in higher ammonium (NH_4^+) levels at 410 ppm than the same dosage of standard NPK fertilizer at 60 ppm, despite the lower overall nitrogen content in the enriched formulation. This outcome aligns with previous findings [10], indicating zeolite's capacity to adsorb ammonium ions, prolonging their availability and delaying their conversion to nitrate (NO_3^-).

A similar trend was noted for available potassium, with the 700 g NPK Granule Plus treatment providing the highest K content at 616 ppm, while the same dose of the commercial product yielded only 101 ppm. These results demonstrate the efficiency of zeolite-enriched fertilizers in retaining essential nutrients, particularly in acidic soil conditions like those in the Musang King field. The findings align with [13], who demonstrated that zeolite-rich tuffs improve nitrogen retention in olive plantations while reducing nitrogen input by 50% without compromising crop yield.

Table 2. Soil chemical characteristics in Musang King durian plantation after treatment

Fertilizer treatment	Dosage (g/tree/3 months)	Total-N (%)	P_2O_5 (ppm)	Available-K (ppm)	NH_4-N (ppm)	NO_3-N (ppm)
Granule NPK fertilizer (6:6:12)	300	0.27	4.6	119	90	150
	500	0.23	2.2	134	30	90
	700	0.38	5.5	616	410	60
Standard commercial NPK fertilizer (15:15:15)	300	0.15	3.1	171	170	90
	500	0.10	1.3	171	30	90
	700	0.11	1.2	101	60	120

In the Bawor field, shown in Table 3, enriched NPK maintained higher NH_4^+ levels and improved available K compared to standard NPK treatments. At a 700 g dosage, the enriched fertilizer combined nitrogen retention of 150 ppm of NH_4-N with 291 ppm of available K, surpassing the commercial NPK in both parameters. These findings underscore the importance of zeolite's porous structure and high cation exchange capacity in binding ammonium and potassium ions, then minimizing leaching losses. Nitrogen-enriched zeolites demonstrated better nitrogen recycling in acidic sandy-loam soils by balancing nitrate production and ammonium retention [14].

Table 3. Soil chemical characteristics in Bawor durian plantation after treatment

Fertilizer treatment	Dosage (g/tree/3 months)	Total-N (%)	P_2O_5 (ppm)	Available-K (ppm)	NH_4-N (ppm)	NO_3-N (ppm)
Granule NPK fertilizer (6:6:12)	300	0.29	3.3	115	90	150
	500	0.25	2.5	182	30	120
	700	0.22	4.8	291	150	90
Standard commercial NPK fertilizer (15:15:15)	300	0.26	3.9	111	60	90
	500	0.15	1.3	129	60	90
	700	0.22	3.6	63	60	120

Therefore, NPK Granule Plus, enriched with zeolite, therefore improved nutrient efficiency by retaining ammonium and potassium in the soil for a longer duration than the standard commercial NPK fertilizer. This retention is expected to promote a more stable nutrient supply for plant uptake, especially in high-rainfall or acidic environments that are prone to nutrient leaching.

3.3 Growth response of durian

Table 4 shows how different treatments and dosages affected the growth of Musang King durian, measured by plant height, stem diameter, and number of primary branches over four months following fertilization. While statistical analysis indicated no significant differences among treatments, all showed consistent increases in plant height, stem diameter, and the number of primary branches over time, demonstrating a positive growth response.

At the 700 g dosage, the standard commercial NPK fertilizer 15:15:15 increased plant height from 11.0 to 60.0 cm, a net gain of 49 cm. Over the same period, NPK Granule Plus 6:6:12 at 700 g still rose from 6.2 to 26.2 cm, for a net increase of 20 cm. However, at 500 g of NPK Granule Plus, the height gain moved from 6.0 to 48.7 cm, while the same dose of standard NPK only went from 8.6 to 32.8 cm. Although no statistical difference was found, these data show that a slow-release formulation may achieve comparable or even better height gains at a lower or moderate dosage. A 500 g dose of NPK Granule Plus nearly doubled the height increase obtained with 500 g of standard NPK, pointing to a potential reduction in fertilizer costs without compromising growth.

The results of this study align with findings from [15], which emphasized the critical role of nitrogen and potassium availability during the vegetative growth phase of durian plants. They observed that nutrient uptake and leaf nitrogen concentrations peak during early vegetative stages and gradually decline as the plant matures. In this study, the higher nutrient retention observed with NPK Granule Plus, particularly ammonium (NH_4^+) and potassium (K), supported consistent growth during the early vegetative phase, especially in acidic soils like those found in the Musang King field.

Table 4. Effect of treatment on growth increase in Musang King durian plants

Fertilizer treatment	Dosage (g/tree/3 months)	Plant height (cm)				Stem diameter (mm)			
MAF		1	2	3	4	1	2	3	4
Granule NPK fertilizer (6:6:12)	300	18.3 a	26.3 a	29.3 a	34.0 a	0.8 a	1.8 a	2.5 a	4.3 a
	500	6.0 a	19.0 a	35.6 a	48.7 a	0.8 a	2.2 a	3.4 a	4.7 a
	700	6.2 a	12.5 a	20.5 a	26.2 a	0.5 a	1.9 a	3.0 a	3.6 a
Standard commercial NPK fertilizer (15:15:15)	300	8.8 a	13.2 a	20.5 a	36.7 a	0.3 a	1.9 a	3.3 a	4.2 a
	500	8.6 a	13.8 a	20.0 a	32.8 a	0.7 a	2.3 a	3.9 a	5.7 a
	700	11.0 a	26.7 a	45.0 a	60.0 a	0.2 a	2.5 a	4.7 a	7.0 a

Note: MAF=month after fertilizer application

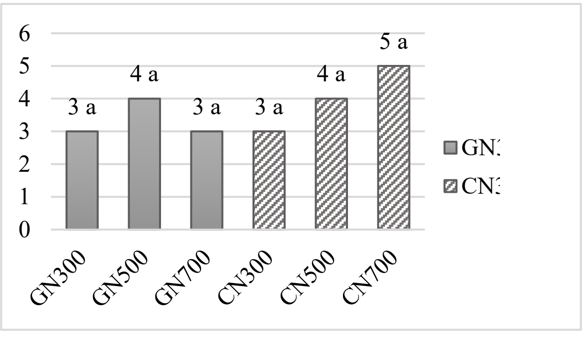

Fig. 1. Number of primaries branches of Musang King durian plants at 4 MAF

A comparable pattern was observed in the Bawor variety, shown in Table 5. This reinforces the possible advantages of NPK Granule Plus for durian cultivation. In Bawor durian, the 300 g dose of standard NPK reached 39.8 cm in plant height by the fourth month, starting from 12.3 cm. The 700 g dose of NPK Granule Plus produced a net increase from 11.3 to 36.0 cm. These results again do not show statistical differences, but they suggest that incremental improvements in growth are achievable under various dosages and fertilizer types. Notably, the 300 g standard NPK treatment recorded five primary branches, which was slightly higher than other treatments by the fourth month, yet the enriched NPK consistently maintained steady increases in height, stem diameter, and branching. In short, NPK Granule Plus 6:6:12 has the potential to match the performance of the standard NPK fertilizer 15:15:15, particularly when factoring in long-term nutrient retention and reduced application rates.

Table 5. Effect of treatment on growth increase in Bawor Durian plants.

Fertilizer treatment	Dosage (g/tree/3 months)	Plant height (cm)				Stem diameter (mm)			
MAF		1	2	3	4	1	2	3	4
Granule NPK fertilizer (6:6:12)	300	4.3 a	9.5 a	12.3 a	18.5 a	1.7 a	2.7 a	3.0 a	3.5 a
	500	12.2 a	17.7 a	28.7 a	32.3 a	0.8 a	1.9 a	2.3 a	3.3 a
	700	11.3 a	19.7 a	23.8 a	36.0 a	0.5 a	1.3 a	1.6 a	2.3 a
Standard commercial NPK fertilizer (15:15:15)	300	12.3 a	26.3 a	30.8 a	39.8 a	1.0 a	2.7 a	2.7 a	4.0 a
	500	4.3 a	9.5 a	12.3 a	18.5 a	1.7 a	2.7 a	3.0 a	3.5 a
	700	12.2 a	17.7 a	28.7 a	32.3 a	0.8 a	1.9 a	2.3 a	3.3 a

Note: MAF=month after fertilizer application

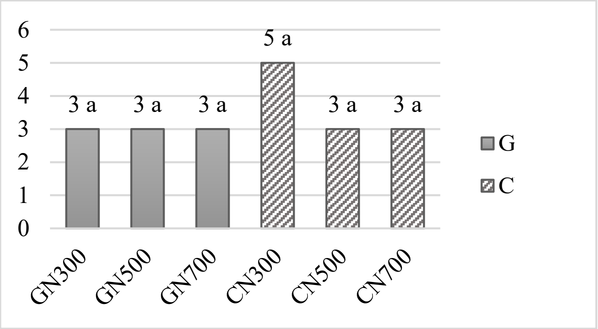

Fig. 2. Number of primaries branches Bawor durian plants at 4 MAF

Overall, the enriched NPK Granule Plus 6:6:12 showed considerable promise for increasing nutrient-use efficiency and sustaining durian growth, especially in acidic or high-rainfall soils where leaching is likely to occur. By binding ammonium and potassium through zeolite's cation exchange capacity, it reduced nutrient losses over time. Although no statistically significant differences were observed, the notable numeric growth increases at moderate doses highlight cost-effectiveness and environmental benefits, which aligns with findings of prolonged nutrient availability in slow-release formulations. Longer-term evaluations are encouraged to confirm potential yield and quality improvements, thereby strengthening the position of NPK Granule Plus as a more sustainable alternative to conventional NPK fertilizer 15:15:15 in acidic or leaching-prone durian plantations.

4 Conclusion

Musang King durian achieves optimal growth with a lower dosage of NPK Granule Plus at 500 g per tree every three months, while Bawor durian shows its best growth at 300 g per tree every three months. Despite its lower $N:P_2O_5:K_2O$ ratio of 6:6:12, NPK Granule Plus matches the performance of conventional NPK 15:15:15. Although no statistically significant differences were observed, the numeric growth improvements at moderate dosages highlight its cost-effectiveness and environmental benefits, making it a sustainable alternative for durian cultivation.

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