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Effect of NPK Fertilizer on Growth of *Amaranthus gangeticus* through Fertigation using Burnt Paddy Husks

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ABSTRACT

Amaranthus gangeticus (red spinach) is a nutrient-rich leafy vegetable widely grown in Asia, and fertigation offers an efficient approach to deliver nutrients directly to crops. In Malaysia, burnt paddy husks serves as a cost-effective soilless medium, but the impact of different nitrogen, phosphorus and potassium (NPK) fertilizer levels on A. gangeticus growth under fertigation remains underexplored. This study aimed to investigate the effects of different concentrations of water-soluble NPK (20-20-20) fertilizer on the growth of A. gangeticus using fertigation with burnt paddy husks as the medium. Leaf count, plant height and plant weight were measured as important growth indicators. Experiments looked at how A. gangeticus reacted to a fertigation application of an NPK (20-20-20) compound fertiliser under the local agroecological conditions at MARDI Alor Setar. Here, instead of using soil, the substrate used were burnt paddy husks. No NPK was used in one sub-plot 0 g (control) and 10, 15, 20, 25 and 30 g of NPK were used in the remaining sub-plots. The number of leaves and plant height (cm) were recorded weekly over a four-week period. Repeated measures ANOVA showed that both NPK concentration ($F = 28.01$, $p = 0.0001$) and time ($F = 60.38$, $p = 0.0001$) had significant effects on plant height and leaf count, while their interaction was not significant ($F = 0.517$, $p = 0.613$), indicating consistent influence across traits. Pearson correlation analysis showed moderate positive relationships between NPK levels and plant growth, with $r = 0.393$ for leaf number, $r = 0.416$ for height, and $r = 0.598$ for weight. These results also suggest that applying up to 25 g of NPK under fertigation can significantly enhance plant growth and productivity, serving as a valuable guideline for farmers aiming to optimize yield in terms of foliage, height, and weight.

Keywords: Fertigation, Red spinach, NPK fertilizer, Burnt paddy husk

1. INTRODUCTION

Amaranthus gangeticus, commonly known as red amaranth or Chinese spinach, is a leafy vegetable that plays a vital role in people's diet across various regions around the world. This plant is particularly valued not only for its nutritional content but also for its medicinal properties. *A. gangeticus* has been embraced for its versatility in culinary applications. It is commonly used as a vegetable in soups, salads, and stir-fries in many Asian and African cuisines (Pandit et al., 2013). The plant thrives well in various climatic conditions, making it accessible and popular among local communities for home gardening and small-scale farming, with reported consumption patterns highlighting its use in both rural and urban settings (Bang et al., 2021). Among the high potential growing method for *A. gangeticus* is by fertigation.

Using fertigation, farmers can be more productive and less damaging to the environment because it improves the use of fertiliser, reduces fertiliser inputs and ensures a higher return on investments in fertiliser (Hagin et al., 2003). One way is to provide needed nutrients to crops by irrigation system (Bar-Yosef, 1999). It allows precise control over the timing, quantity, and concentration of fertiliser applied. In this method, an injection pump delivers water-soluble

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fertilisers into the irrigation system, distributing the nutrient solution through a network of pipes directly to the plants (Kant & Kafkafi, 2013).

Altogether, instead of traditional soil, many fertigation systems use different growing media for plants. Though many use rock wool, perlite and vermiculite, importing them and their price make them impractical for some regions. Since burnt paddy husks are the waste product in Malaysia, they are generally favoured. These materials are easy to find in places like Kedah and Perlis which produce a lot of rice. Even though burnt paddy husks are now used in industrial sectors in Europe and North America, it is not widely used commercially in many developing countries (Mohd et al., 2015).

The use of NPK (nitrogen, phosphorus, potassium) fertilizers through fertigation has become increasingly prominent in modern agricultural practices, particularly in improving crop yields and nutrient management efficiency. Fertigation combines the water and fertilizers' application, allowing the plant's root zone obtain precise nutrient delivery directly. This method facilitates optimal nutrient uptake and enhances both the growth and yield of various crops (Maršić et al., 2012).

Arshad et al. (2014) studied the effects of NPK fertiliser on cucumbers in greenhouses where they found that varying amounts had a good effect on both the growth and the number of cucumbers harvested. While the findings from Katrina et al. (2024) on *A. tricolor L*. similarly demonstrate that NPK application enhances key growth parameters such as plant height, leaf number, leaf area, and biomass. However, unlike Arshad et al. (2014) that focused on fruit yield, Katrina et al. (2024) observed the greatest benefit in vegetative growth, which is critical for leafy vegetables such as spinach. Unfortunately, limited studies have looked into how *A. gangeticus* reacts to NPK fertiliser using burnt paddy husks for growing. Therefore, this study aims to investigate five levels of NPK fertiliser on the growth of *A. gangeticus* when grown in burnt paddy husks using a fertigation system.

2. MATERIALS AND METHODS

2.1 Chemicals and Materials

A. gangeticus seeds, NPK fertilizer (20-20-20), magnesium sulphate, iron chelate, zinc sulphate, boric acid, calcium nitrate, monopotassium phosphate, sodium molybdate, copper sulphate and manganese sulphate were bought from Sigma Aldrich (M) Sdn. Bhd.

2.2 Fertigation Setup and Experimental Design

The experimental site for this study was located at the Malaysian Agricultural Research and Development Institute (MARDI) station in Alor Setar, Kedah. The fertigation experiments were conducted in a designated area equipped with a rain-shelter roof and an automated drip irrigation system to ensure controlled water application. The site consisted of 10 rows of polybags arranged in straight lines. Each row was fitted with a drip irrigation system comprising a single submain connected to the fertilizer mixing and water tank, branching into microtubes attached to individual drippers. Each dripper was inserted into a polybag. A total of 18 polybags were filled with burnt paddy husks, each filled to approximately three-quarters of its volume. An additional three polybags were filled with soil medium and served as the control.

2.3 Preparation of Basic Fertilizer and NPK Fertilizer

MARDI formulated the fertilisers based on the nutritional requirements of the plants (Mahamud et al., 2007; Suhaimi et al., 2011; Suhaimi et al., 2012). All fertiliser components used were fully water-soluble. The nutrients were prepared separately in two tanks, designated as Tank A and Tank B (Figure 1). Tank A contained a mixture of 11500 g of calcium nitrate and 190 g of iron chelate. Tank B contained 6600 g of potassium nitrate, 2220 g of hydrated monopotassium phosphate, 4030 g of magnesium sulphate, 17 g of manganese sulphate, 33 g of boric acid, 2 g of copper sulphate, 15 g of zinc sulphate, and 2 g of sodium molybdate. This formulation was prepared for 10,000 litres of water. The fertiliser solution from the central tank was supplied directly into the submain pipeline, which distributed it to the crops. The nutrient concentration of the solution was routinely monitored using an electrical conductivity (EC) meter to ensure it remained within the desired range of 1.8 to 2.4. To prepare the NPK treatments, five concentrations of NPK fertiliser (10, 15, 20, 25, and 30 g) were each mixed with 0.5 litres of water before being applied to the plants.

Figure 1: Tank A (Mixture of Ca, Iron chelate) and Tank B (Mixture of KNO_3, KH_2PO_4, $MgSO_4$, $MnSO_4$, H_3BO_3, $CuSO_4$, $ZnSO_4$, Na_2MoO_4)

2.4 Irrigation Frequency

Drip-irrigation system was used to supply all the basic fertilizers and water twice daily; once in the morning, once in the evening, for a duration of 5-10 minutes each time. In addition, six equal doses of water-soluble NPK compound fertiliser were applied to the plants weekly by spraying. The six sub-plots received different treatments: one sub-plot served as the control and received no NPK, while the remaining sub-plots were supplied with 10, 15, 20, 25, and 30 g of NPK fertiliser, respectively.

2.5 Seeds Sowing and Transplanting

Peat moss was filled in each hole of the seeding trays with one seed was placed in each. The seeds were ready for transplantation once they had formed 2 or 3 leaves (Figure 2 and Figure 3).

Figure 2: Seedling tray containing peat moss with baby plants

Figure 3: Lines of polybags filled with burnt paddy husks

2.6 Plant Harvesting and Measuring

The duration of the growing stage varied between 20 and 30 days, depending on the crop variety and temperature conditions. After harvesting and cleaning, the plants were graded based on height, length, and weight. Data collection involved recording the number of leaves, plant height (cm), and plant weight (g) for each sample.

3. STATISTICAL ANALYSIS

Repeated measures ANOVA were used to analyse the data with a mixed model to investigate the differences in plant growth based on time and growth type, along with their interaction. To investigate the relationship between NPK levels and their effects on the number of leaves, weight, and height of *A. gangeticus,* Pearson's Correlation Coefficient was used. This statistical analysis was performed using IBM SPSS Statistics 20.

4. RESULTS AND DISCUSSION

The experimental results indicate that varying the concentrations of NPK fertilizer have a significant influence on the number of leaves, plant height, and plant weight in *A. gangeticus*, as shown in Figures 4, 5, and 6. According to Campbell et al., (2018) and Kipkosgei et al., (2003), these impacts can be largely caused by the physiological roles of NPK in plant development, with nitrogen being the most important in promoting vegetative growth.

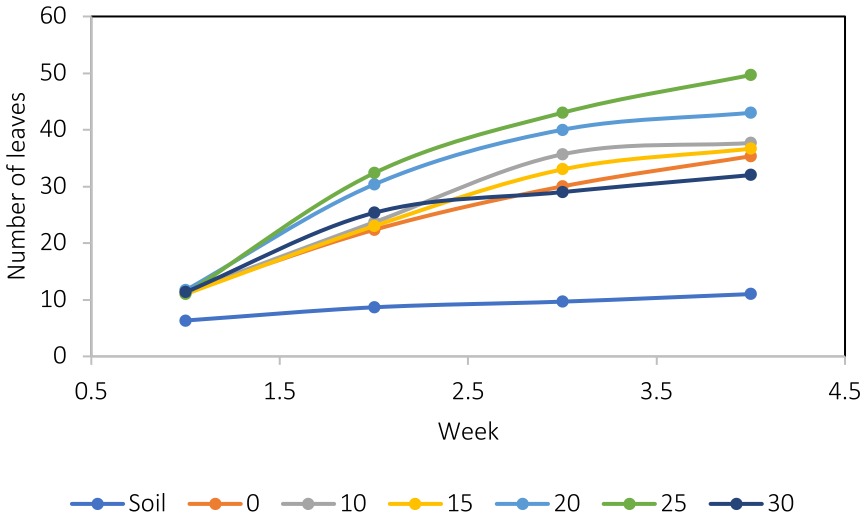

Figure 4: The number of leaves based on the different level of NPK (0g, 5g, 10g, 20g, 25g and 30g)

In Figure 4, it was seen that NPK application caused the number of leaves to increase consistently, reaching the highest value for 25 g of NPK application. This observation suggests that nitrogen served a crucial role in synthesizing chlorophyll and forming protein through amino acid production essential for leaf initiation and expansion. This finding is in line with that obtained by Kipkosgei et al., (2003), who demonstrated enhanced leaf production and overall plant yield from nitrogen supplementation. Nevertheless, the maximum number of leaves was recorded at 50 using 25 g, while the minimum reading of 32 was observed using 30 g in week 4, indicating that excessive fertilizer may hinder growth from possible nutrient toxicity or physiological stress. These outcomes are consistent with those obtained by Kulkarni & Goswami, (2019), stating that overusing fertilizer can cause nutritional imbalances, reduced development, and heightened vulnerability to disease susceptibility in plants. Finally, plants treated with NPK presented quicker growth compared to those cultivated in soil without using NPK.

Figure 5 shows a similar upward trend in plant height with increasing NPK concentrations, where the tallest plant (38.7 cm) was observed when using 25 g NPK, and the shortest (7.9 cm) in soil medium. This trend highlights the importance of phosphorus, which is involved in energy transfer and root development, and thus indirectly supports vertical growth. Enhanced root function allows greater nutrient uptake, leading to taller and more vigorous plants (Bechtaoui et al., 2021). Although plant height still increases at 30 g NPK, the improvement was smaller compared to the

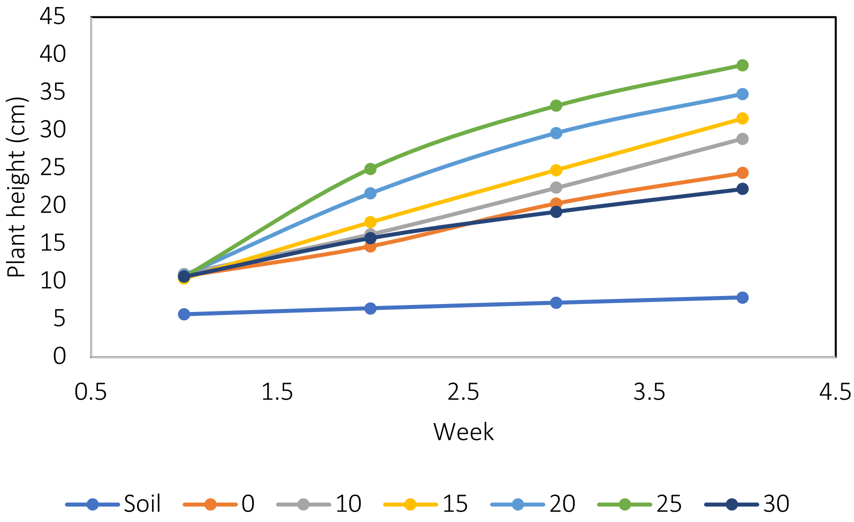

Figure 5: Plant height based on the different level of NPK (0g, 5g, 10g, 20g, 25g and 30g)

growth seen between 15 and 25 g, showing a plateau effect. This means that adding more fertilizer after a certain point does not help the plant grow much taller. Sun et al., (2022) also found that plant height increased with NPK levels up to a limit, after which extra fertilizer had little effect. These findings support the idea that using too much fertilizer can be wasteful and may not lead to better plant growth, highlighting the need to apply the right amount for best results.

The relationship between NPK level and plant weight (Figure 6) reveals a distinctly non-linear pattern. Plant weight increases progressively from 0 to 25 g NPK, reaching a peak at 25 g. This stage reflects optimal nutrient uptake and utilization, where essential macronutrients are effectively converted into plant tissue. The positive impact of moderate fertilizer application on yield was supported by Ayeni et al., (2010), who found a significant yield increase in maize with proper NPK levels. However, a drastic reduction in plant weight at 30 g suggests nutrient toxicity or physiological stress. Over-fertilization can lead to osmotic imbalances, salt accumulation, and reduced nutrient uptake efficiency (Havlin et al., 2014) ultimately hampering growth despite increased inputs.

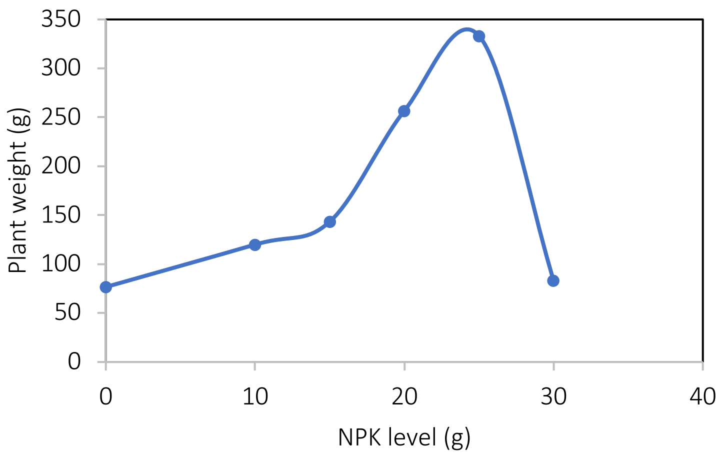

Figure 6: Plant weight based on the different NPK level

Overall, these findings emphasize that while NPK fertilizer enhances growth parameters in *A. gangeticus*, there exists a critical threshold that is 25 g in this study, beyond which plant development may be negatively affected. Optimizing nutrient input is thus essential not only for maximizing plant performance but also for ensuring resource efficiency and environmental sustainability.

The analysis of repeated ANOVA results in Table 1 highlights the significant effects of NPK level and time on plant growth parameters specifically on plant height and leaf count.

Table 1: The effects of NPK level, time, and their Interaction on plant height and leaf count

Effects	DF	F	P-value
NPK level and soil	36	28.01	0.0001*
Times	36	60.38	0.0001*
NPK level and soil *type of plant growth	40	0.517	0.613

*Significant different at the 0.05 level (2 tailed)

The effect of NPK concentration was statistically significant (F = 28.01, p = 0.0001), indicating that varying levels of NPK fertilizer had a measurable influence on overall plant development. Similarly, the effect of time was highly significant (F = 60.38, p = 0.0001), suggesting that the growth duration significantly impacted plant height and leaf number, likely due to progressive physiological development over time. In contrast, the interaction between NPK concentration and type of plant growth (height vs. leaf count) was not statistically significant (F = 0.517, p = 0.613). This implies that the influence of NPK concentration on growth does not vary between plant height and leaf number showing that NPK affects both parameters in a consistent manner. These findings suggest that while both NPK application and time independently enhance plant growth, their interactive effect across different growth traits remains uniform. This is consistent with Ayeni et al. (2010), which emphasize that the individual application of NPK significantly affects vegetative growth, and also supports the concept that optimal fertilizer management and timing are critical for maximizing growth outcomes across multiple plant traits.

The correlation and regression analysis reveal valuable insights into the influence of NPK fertilization on plant growth parameters in *A. gangeticus*. For the number of leaves, a statistically significant relationship was observed (p = 0.039), with a moderate positive correlation (r = 0.393) and an R-square value of 0.155, indicating that 15.5% of the variation in leaf count can be explained by NPK level (Table 2).

Table 2: Pearson's Correlation between different levels of NPK with number of leaves, plant height and weight of *A. gangeticus*

Type of plant growth	Measure	Value
Plant number of leaves	P-value	0.039*
	r	0.393
	R-square	0.155
Plant height (cm)	P-value	0.028*
	r	0.416
	R-square	0.173
Plant weight (g)	P-value	0.156
	r	0.598
	R-square	0.358

*Correlation is significant at the 0.05 level (2-tailed).

Plant height similarly showed a significant correlation ($p = 0.028$), with a slightly higher correlation coefficient ($r = 0.416$) and R-square of 0.173, suggesting that NPK application moderately affects vertical growth. Although there was a positive correlation between NPK concentration and plant weight ($r = 0.598$), the regression result was not statistically significant ($p = 0.156$). This lack of significance may be due to the sharp drop in plant weight at the highest NPK level (30 g), which increased variability and reduced the overall consistency of the relationship.

The relatively low R-square values across all three parameters suggest that while NPK fertilization plays a role in promoting growth, other factors significantly influence *A. gangeticus* development. Environmental conditions such as light intensity, soil structure, temperature, and water availability also contribute to growth variability (Campbell et al., 2018; Ncise et al., 2020). Additionally, factors like genetic variation, micronutrient availability, and pest pressure may further explain the unexplained variance. For example, Abou El- Magd et al., (2006) emphasized that NPK alone does not determine yield outcomes without considering other factors.

The Pearson correlation values observed ($r = 0.393–0.598$) are considered moderate, particularly in agricultural field studies where multiple variables interact. These moderate correlations suggest that while there is a clear positive association between NPK concentration and growth traits, the relationship is not perfectly linear due to the dynamic nature of plant-environment interactions. Similar moderate correlations have been reported in leafy vegetables and *Amaranthus spp*., highlighting that nutrient uptake efficiency and growth response can vary based on crop type, growth stage, and soil condition (Jonathan et al., 2012). Therefore, the findings align with established literature, confirming that NPK is an important but not sole driver of plant development in *A. gangeticus*.

5. CONCLUSION

This study contributes useful information on the effect of different NPK concentrations and time on *A. gangeticus* growth by emphasizing careful nutrient timing and management in fertigation systems. The findings showed that NPK fertilizer greatly improves plant height, number of leaves, and weight to an optimal concentration of 25 g, after which growth performance declined indicating nutrient saturation or toxicity. Furthermore, the modest relationships identified between NPK levels and growth demonstrated the need for planned fertilizer application in reducing waste and environmental stress. This study further shows that burnt paddy husks have significant potential for serving as a low-cost and effective alternative growth medium for green agricultural produce. Overall, this study offers a sustainable model for producing vegetables through fertigation and increasing the yield of *A. gangeticus*. For future studies, examining the long-term effects of continuous fertigation, nutrient interactions with microelements, as well as scalability across various crop kinds and climatic conditions would be recommended.

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