

NANO FERTILISER IMPACT ON VITATO SWEET POTATO GROWTH: MORPHOLOGICAL INSIGHTS

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Abstract: This study assessed the influence of nano fertilisers on the growth and development of sweet potatoes (*Ipomoea batatas*). An experiment was conducted over a four-month period, from August to November 2023 to investigate the effects of nano fertilisers on the morphological characteristics of sweet potatoes of the VitAto variety. The sweet potatoes were treated with fertilisers based on organic matter in nanoparticles with different total volumes (50 ml, 100 ml, and 200 ml) for 14 weeks. The experiment was laid out using a Randomised Complete Block Design (RCBD) with three replications. The study results show that the use of 200 ml of nano fertiliser per application significantly increased the number of leaves, total leaf area, plant height, wet and dry weights, and plant water content ($p < 0.05$). Additionally, the average plant height increased in tandem with the increase in the volume of fertiliser used after two weeks of planting. The interaction between total fertiliser volume, type of fertiliser and fertiliser size on plant height, number of leaves, mean leaf area, and water content was significant. The study revealed that applying nano fertilisers improved the growth of VitAto sweet potato plants just two weeks after planting. However, the fertiliser had no observable or no effect on tuber growth whether in terms of tuber length dry and wet weights.

Keywords: Nanoparticle application, fertiliser, sweet potatoes, organic, *Ipomoea batatas*.

Introduction

Farmers in rural areas of developing countries face several challenges, including chemical toxicity caused by the excessive use of chemical fertilisers, long crop production times, and high costs that are beyond their means. The use of nanotechnology in agriculture has previously been well-documented (Khot *et al.*, 2012). Nanotechnology involves matter sizes ranging between 1 nm and 100 nm that exhibit unique characteristics (Park *et al.*, 2006). It has been suggested that fertiliser particles can be intelligently released in response to specific signals. Nano fertilisers show promise as a means of enhancing the efficiency of nutrient use, accelerating plant growth, and boosting agricultural production (Ram *et al.*, 2014). However, the adoption and use of nano fertilisers may impose a heavy financial burden on some farmers.

Su *et al.* (2022) noted that encouraging farmers to use nanotechnology-enabled fertilisers was a challenge due to the high costs and additional labour requirements needed for the successful application and use of such fertilisers, particularly in low-commodity pricing markets. To address this issue, synthesising nano fertilisers from organic matter has been proposed as a more cost-effective alternative. Organic fertilisers derived from recycled waste materials are more affordable and help mitigate the soil pollution caused by chemical fertilisers. Additionally, nano fertilisers produced from organic matter may further reduce labour costs, making them a more practical and sustainable option for farmers.

Sweet potatoes are the most significant tropical root crop due to its versatility. It may be grown and harvested at any time of the

year (Motsa *et al.*, 2015). Sweet potato plants can adapt to various environmental conditions, including soil types, temperatures, and altitudes. They can grow in various agroecological environments, making them appropriate for cultivation worldwide (Afza *et al.*, 2017). They have a short growth cycle and are easy to replicate, by all farmers need to do is plant the nonedible sections (Kays, 2018). Moreover, sweet potato plants have a loose growth style and do not require nutrient-rich soil.

Using the latest advances in nanotechnology and agricultural science, this study aims to evaluate the influence of nano fertilisers on sweet potato growth and thereby contribute valuable data to the growing body of research on innovative and environmentally friendly crop cultivation approaches. Organic fertiliser consisting of 30% nanoparticle matter derived from Anchovy Heads (AH) and 70% nanoparticle matter derived from Rice Husks (RH) was used to achieve the objectives of this study.

Materials and Methods

Preparation of Experiment Site

The University Malaysia Terengganu, Faculty of Science and Marine Environment, Biological Science greenhouse in Kuala Terengganu, Malaysia was chosen as the location for the experiment. The greenhouse and its enclosed planting area measuring 6 x 2.4 metres, protected the sweet potato plants from pests and being directly exposed to the weather especially the rain. Before the experiment, the greenhouse was cleared of all other plants and inappropriate items. The walls and fabric cover of the greenhouse were checked for any damage or holes to prevent insects from entering the greenhouse. The floor covering in the greenhouse was also cleaned to prevent wild plants from taking root after the planting process had started.

Plant Material Preparation

Shoot cuttings of the VitAto sweet potato plant was obtained from the Malaysian Agricultural

Research and Development Institute (MARDI) at Bachok in Kelantan. The VitAto shoot cuttings were grown in 40.64 cm x 40.64 cm polybags (Alif & Amira, 2023). The VitAto shoots were 30 cm to 35 cm long and harvested from healthy plants that were disease and pest-free (Afza *et al.*, 2021). Shoot cuttings are considered to be the best and most effective starting plant material as shoot cuttings are cost effective and can produce higher yields than the middle and base cuttings (Afza *et al.*, 2021). A total of 28 plants were planted an equal distance apart, with two stem nodes buried into the soil at a slightly slanted shoot position in the polybag and at between 1 feet and 2 feet between the plants.

Experimental Design

This study used a Randomised Complete Block Design (RCBD) with four replications for each treatment during cultivation. The final data analysis used only three replicates (21 polybags) due to natural deaths among the plants, leading to a reduced sample size. The sweet potato plants were randomly arranged to provide a fair and even lighting area for all the plants. In RCBD, the number of experimental units in each block equals the number of treatments and each treatment occurs exactly once in each group. When the experimental units are heterogeneous, part of the variability can be explained by grouping the experimental units so that the experimental units in each group are as homogeneous as possible (Shah *et al.*, 2018).

This study allows partial elimination of variation due to block differences from error variance. The data collected from the trial using RCBD would be classified bilaterally (Alif & Amira, 2023), according to the level of two components: Block and treatment. The arrangement of plant samples was randomised, with all types of treatments arranged in a mixed manner. The following is the layout of the samples in the greenhouse used in this study. The plants were arranged with four rows and seven columns, as shown in Figure 1.

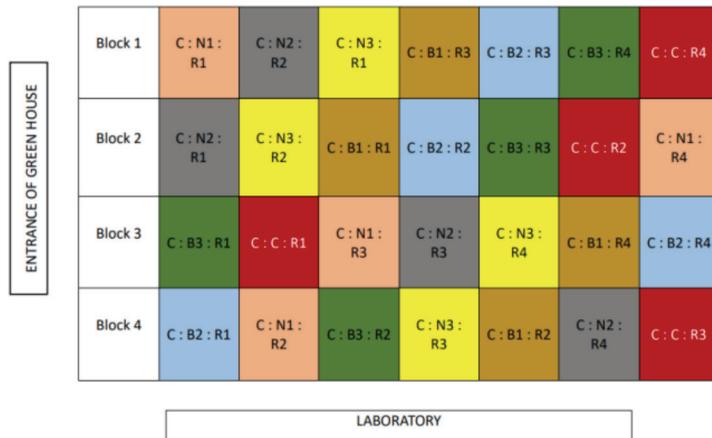


Figure 1: The layout of the sample position in the greenhouse. C represents the Control group, N represents the Nano Fertiliser, B represents the Non-nano Fertiliser, and R represents the Replicate

The experiment included three different volumes of non-nano fertiliser treatments (50 mL, 100 mL, and 200 mL) and three corresponding nano fertiliser treatments (50 mL, 100 mL, and 200 mL). The control group was treated with NPK fertiliser, a conventional source of essential nutrients such as nitrogen, phosphorus, and potassium. The selected fertiliser volumes were based on preliminary pilot studies (Tyasmoro *et al.*, 2024), which determined effective dosage ranges for assessing growth responses while minimising the risk of plant nutrient toxicity. These volumes were chosen to ensure an adequate supply of nutrients for optimal plant development while avoiding over-application, which could result in adverse effects such as nutrient leaching or environmental harm.

In the first week of planting, the control groups were given Agrobriidge green NPK fertiliser with a ratio of 15:15:15 (Olejeme *et al.*, 2023) and 4 g per sample. From the fourth week of planting until week 15, NPK fertiliser, Innotec NK, with a ratio of 15:3:20 was used to replace the initial fertiliser, given at a rate of 4 g per sample every three weeks.

Both nano and non-nano fertiliser treatments were administered according to the specified volumes for each treatment. However, starting from week 10 of planting, the total volume for

each treatment was doubled to 100 mL, 200 mL, and 400 mL and applied weekly. Fertilisers were not used on the first day of planting to allow the newly planted seedlings to adapt to the environment and reduce the risk of mortality due to transplant shock and stress (Nongbet *et al.*, 2022; Upadhyay *et al.*, 2023).

Weeding was done manually every three weeks. Watering was conducted daily in the evening at a rate of 1 L per plant, except on the day of fertiliser treatment to prevent fertiliser loss and ensure proper permeation into the soil. The watering rate remained consistent at 1 L per plant. Plants were grown until maturity using Beach Ridges Interspersed with Swales (BRIS) soil, the dominant soil type in the coastal areas of eastern Peninsular Malaysia. With its sandy texture and low bulk density, BRIS soil offers excellent drainage and aeration, promoting root penetration and tuber growth. Nurul Nahar *et al.* (2024) highlights that BRIS soil may improve moisture retention in soil, lowering drought stress and promoting vegetative and tuber growth in sweet potatoes. Figure 2 shows the experimental procedure for fertiliser treatments.

Preparation of Fertilisers

The nano fertiliser used in this research was made using pre-synthesised Anchovy Head (AH) and Rice Husk (RH) powders, all readily available

as nanoparticle compounds. The chemical composition and nitrogen content of nanoparticle powders were determined in the laboratory using a variety of analytical procedures, including nitrogen-specific analysis. The findings of these laboratory experiments are summarised in Table 1, which shows the chemical makeup of the nano fertiliser powders. These studies revealed the presence of nitrogen, among other significant elements, in the nanoparticle formulations. It is important to demonstrate that the laboratory studies on the AH and RH nanoparticle powders

were done independently to offer background information on the materials used rather than as part of the experimental framework of this investigation. The nano fertiliser was prepared using an analytical scale by weighing 30 g of AH nanoparticles and 70 g of RH. The weighed AH powder and RH powder were placed in a 500 ml glass container. Then, 350 ml of water was poured into the container. 5 ml of Effective Microorganisms (EM) that used lactic acid bacteria, *Lactobacillus plantarum*, and fungi *Aspergillus oryzae* were poured into the same



Figure 2: Experimental procedure for fertiliser treatments. Planting and Initial Fertiliser Application: Planting of seedlings and application of initial fertiliser treatments. Weekly Maintenance: Regular maintenance activities, including weeding, watering, and fertiliser application. Mid-term Adjustment: Adjustment of fertiliser volumes in the middle of the planting period. Continued Care Until Maturity: Ongoing care and plant growth observation until maturity

Table 1: Composition of chemical compounds in nano stock powder received

Compound	Value of Compound
Boron, B (mg/L)	ND
Calcium, Ca (mg/L)	56.45 mg/L
Copper, Cu (mg/L)	0.24 mg/L
Iron, Fe (mg/L)	5.89 mg/L
Magnesium, Mg (mg/L)	16.44 mg/L
Manganese, Mn (mg/L)	ND
Phosphorus, P (mg/L)	299.35 mg/L
Potassium, K (mg/L)	3226.80 mg/L
Sulphur, S (mg/L)	141.00 mg/L
Zinc, Zn (mg/L)	0.18 mg/L
pH level at 25°C	8.2 (Alkaline)
Test nitrogen (mg/L)	200.03 mg/L

ND = Non Determine

500 ml glass container using a measuring cylinder. The ingredients were stirred until fully dissolved and mixed. The container was then tightly and neatly closed and labelled. The fertiliser was stored for the fermentation process for up to one month for the fertiliser maturation process. After the fertiliser had matured, it was filtered with filter paper and diluted by adding 1 ml of fertiliser essence to 200 ml of water. The diluted fertiliser was kept in a 1.5 L bottle before applying it to the plant sample.

The non-nano fertiliser was prepared by weighing 30 g of AH powder and 70 g of RH powder in a 500 ml glass container. Then, 350 ml of water was poured into the container, followed by 5 ml of EM. The ingredients were stirred until mixed and dissolved. The container was then tightly and neatly closed and labelled. The fertiliser was stored for the fermentation process for up to one month to mature fully and then diluted in the same way as the nano fertiliser.

Growth Parameters Research

Measurement of Length of Plant

A method to determine plant length in sweet potatoes required using a measuring tape to acquire precise measurements of the plants' vertical development. Measurements were obtained from the shoot tip to the stem base at the soil level. The measuring technique was modified for plants examined in weeks 9 and after planting to allow for the sweet potato vines' increased length and spreading growth behaviour.

In this case, the plant's length was first marked with a long rope carefully aligned with its whole length. The marked rope was then carefully measured with a measuring tape in an open area outside the greenhouse to ensure enough room for accurate readings. This method allowed the cord to be fully extended, accurately measuring the plant's length. This strategy was used regularly to reduce variability and ensure accurate and reliable data collected throughout the study.

Measurement of Leaf Development

Number of leaves was counted manually. The area of the leaves was calculated using the Millimetre Graph Paper technique. A leaf was placed on a millimetre graph paper or 1-centimetre grid paper and its outline was sketched using a pen or pencil. Then, the contour plots were counted and the area was calculated based on the number of squares. The results were recorded and each contour and accompanying measurement were labelled with a name or number such as "Leaf No. 1". All individual measurements were added together to get the overall leaf area. The leaf area readings were calculated by using the equation:

$$1 \text{ square} = 1 \text{ cm}^2$$

Soil pH

The Takemura Soil pH and Moisture Tester DM15 measured the soil's pH level inside the polybag. Soil pH readings were taken three times: The first in the second week before the treatment was given, the second in the eighth week of planting, and the last recorded after the planting harvesting process. The Takemura DM15 tool was cleaned before use to ensure the accuracy of the data (Johar *et al.*, 2016).

The tool was then stuck into the ground and the soil was compacted around it until the embedded metal touched the ground. Readings were recorded in triplicate after one minute of burial to obtain the average soil pH reading. Collecting data on soil pH ensures that the soil maintains good pH levels throughout the cultivation period without affecting plant growth and development.

Fresh and Dry Weight

Both fresh and dried sweet potatoes were weighed in two separate ways. The fresh weight was measured first, followed by the dry weight after eliminating the moisture content. Firstly, the plants were carefully removed from the soil medium, so, they were not uprooted and separated from their original structure. Then, the sweet potato plants were washed to remove any

soil on its surface. The plants were then brought into the laboratory to be chopped into shoots, roots, and tubers, which were weighed on an analytical scale, and the readings were recorded. Readings were performed three times, with the third reading indicating the fresh weight of the sweet potato plant components.

To determine the dry weight, an oven was pre-heated between 65°C and 80°C while the sweet potato samples were sliced into uniform pieces with a thickness of 6.35 to dry faster (Amuron, 2023). The sweet potato slices were placed on a baking sheet with an aluminium foil base to prevent sticking.

After the oven was preheated, the temperature was increased to 204°C, and the tray with the sweet potato slices was placed on it for six hours to dry. After the sweet potato pieces had completely dried, they were taken out of the oven to cool to room temperature. The exact drying process was repeated for the stems and roots of the sweet potato plant. Dried sweet potato pieces and other plant parts were weighed on the same scale to obtain its dry weights.

Water content, which is commonly stated as a percentage, refers to the quantity of water included in a substance or material (Bingham, 1974). The following formula is widely used to determine water content:

$$\text{Water content (\%)} = \frac{\text{Weight wet} - \text{Weight dry}}{\text{Weight dry}} \times 100$$

Measurement of Tuber Development

Tuber length and weight were the two main characteristics evaluated as part of the approach for measuring tuber development. To ensure accurate measurements from one end of the tuber to the other, the length of the tuber was measured using a standard ruler. The length of the tuber was measured from tip to tip. To ensure accuracy, the weight of each tuber was measured using a calibrated digital weighing scale. These factors were noted for every tuber collected to analyse the development trends across the study period comprehensively. To reduce variability and ensure accurate and repeatable data for evaluating the impact of treatments on tuber growth and development, measurements were carried out under uniform conditions.

Results and Discussion

Effect of Nano Fertiliser on Plant Length

Figure 3 shows the graph of the mean length of sweet potato plants for every treatment applied to the plant over the cultivation period. The longest plant on week 11 was the N3 sample (200 ml of nano fertiliser) at 447 cm, followed by N1 (50 ml of nano fertiliser) measuring 422.33 cm, B3 (200 ml of non-nano fertiliser), which was at 398 cm, N2 (100 ml of nano fertiliser), which stood at 391.67 cm, B1 (50 ml of non-nano fertiliser), which measured 338.33 cm, B2

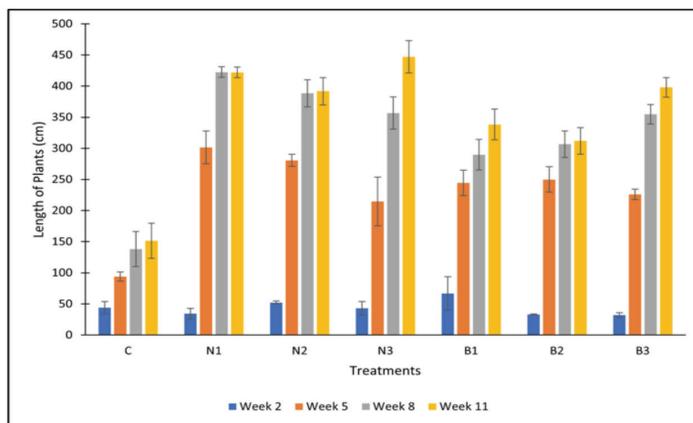


Figure 3: Total length of plants (cm) at different weeks of cultivation against the type of treatments (C: Control, N: Nano fertiliser, B: Non-nano fertiliser). Notes: Values are means ± standard error (n = 7)

(100 ml of non-nano fertiliser) at 312 cm, and C (control), which had the shortest length at 151.33 cm.

The treated plants' lengths were higher than their respective controls, which meant that the nano fertiliser treatment induced greater plant heights than plants treated with the non-nano fertiliser. Different changes were observed each planting week throughout the planting period, although all of the plants saw an increase in height over the planting period.

The effect of nano fertilisers on plant growth can be seen more clearly in week 11. Figure 4 shows the length of plants for each type of treatment given in the last week of planting. Treatment N3 recorded the greatest plant height reading for the nano fertiliser category (447 cm \pm 26.05 cm) and B3 recorded the greatest height for the non-nano fertiliser treatment type (398 cm \pm 15.69 cm).

The ANOVA single-factor findings showed a highly significant difference between the treatment groups. The F-value (304.2223) was much higher than the crucial F-value ($F_{crit} = 4.964603$) at $\alpha = 0.05$. This supports the occurrence of significant differences between treatment groups. Therefore, using fertilisers with different volumes can affect the growth rate of plants. The greater the volume of fertiliser given, the greater the length of the plant.

Furthermore, N3 is the treatment that had the most effect on the height of the sweet potato plant. This is because a high fertilisation rate can raise the nutrient content such as nitrogen, phosphorus, potassium, and other elements in plants. The absorption of these nutrients has a beneficial effect on the biological functions of plants such as stem growth.

Some studies have investigated the effect of fertilisation volume on plant nutrient absorption (Aminifard *et al.*, 2012; Seleiman *et al.*, 2020). Fertilisation volume has a profound effect on nutrient levels in the substrate solution. The discussion in this study was reinforced by the findings of Ali *et al.* (2021), who conducted nutrient release tests to assess the effectiveness of nano fertilisers. The researchers analysed the cumulative release of nutrients from the nano fertiliser over 30 days. The nano fertilisers used in their study comprised of organic nanoparticle components, indicating a regulated release of nutrients at varied rates. This controlled release capability was superior to traditional fertilisers, indicating their potential for long-term nutrient availability.

Furthermore, Ali *et al.* (2021) conducted plant growth promotion experiments and discovered considerable changes in plant development measurement. Using nano fertilisers significantly increased root length,

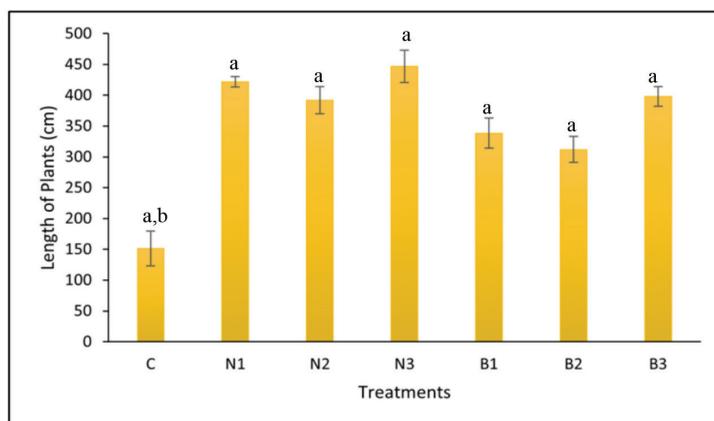


Figure 4: Total length of plants (cm) at 11 weeks of cultivation against the type of treatments (C: Control, N: Nano fertiliser, B: Non-nano fertiliser). Notes: Values means \pm standard error ($n = 7$). Different small letters represent significance in different values $p \leq 0.05$ (ANOVA)

plant biomass, and total crop output. These findings aligned with the results from the current study, demonstrating the efficacy of nano fertilisers in agricultural applications. The study also investigated the processes that supports nano fertilisers’ growth-promoting benefits, which included greater nutrient availability, improved interactions with beneficial bacteria in the rhizosphere, and higher tolerance to environmental challenges. These studies demonstrated nano fertilisers’ potential to transform agricultural practices by providing sustainable and efficient nutrient delivery methods while boosting plant health and production.

A study by Alhasany *et al.* (2021) showed that a nano fertiliser with a high concentration and volume can affect plant height. The study revealed that applying nano fertilisers significantly influenced various growth parameters and increased plant height, leaf area, and total biomass compared to the plants which received the control treatments.

Effect of Nano Fertiliser on Number and Area of Leaves

Figure 5 shows the number of leaves recorded during the pre-harvest period against the type of treatments. There was no significant difference

between the plants that received the nano fertiliser treatment and those in the control group. There was also no significant difference between the plants that received the non-nano treatment and those in the control group. However, all treatments, including those in the control group showed a significant difference in the number of leaves in weeks 2, 5, 8, and 11. This result shows changes in plant growth at every week of planting. However, the total number of leaves in weeks 8 and 11 increased significantly. This is likely because, on week 10, the volume of fertiliser applied increased to 100 ml for N1 and B1, 200 ml for N2 and B2, and 400 ml for N3 and B3 treatment.

Using fertilisers also affected the total number of leaves and their area. The leaf area for treatment N3 was the largest at week 11 of planting. The lowest area of leaves in week 11 was observed for the control group, with $118.89 \pm 11.20 \text{ cm}^2$. The area of leaves in weeks 2, 5, 8, and 11 was not significantly different from the control group, respectively.

Many factors cause the number of leaves and the total area of leaves to be insignificant compared to the control group when using one-way ANOVA. This study had a small number of samples and replicates (Columb & Atkinson, 2016), making it statistically more difficult to

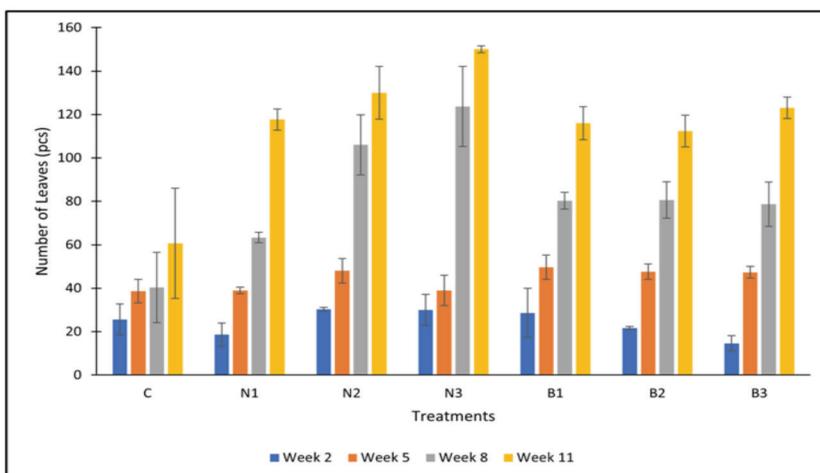


Figure 5: Total number of leaves (pcs) against the type of treatments (C: Control, N: Nano fertiliser, B: Non-nano fertiliser). Notes: Values are means ± standard error (n = 7)

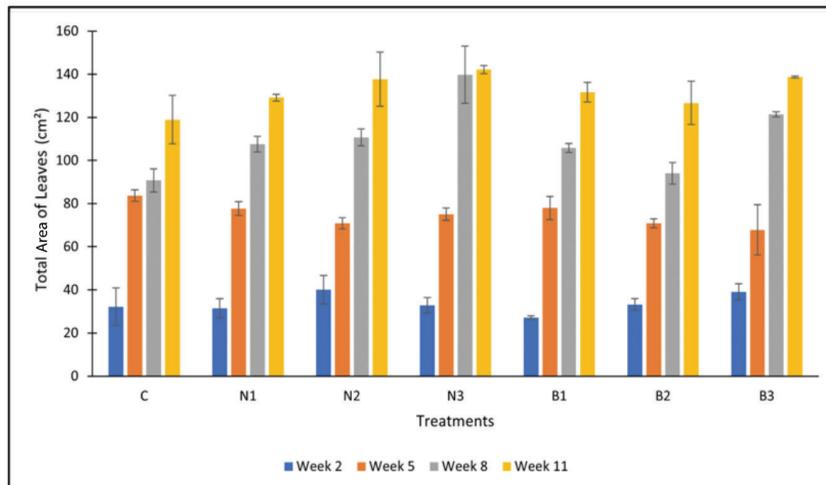


Figure 6: Total area of leaves (cm²) against the type of treatments (C: Control, N: Nano fertiliser, B: Non-nano fertiliser). Notes: Values are means \pm standard error (n = 7)

detect significant differences more accurately (Prajapati *et al.*, 2010). Another constraint of the experiment was the relatively limited greenhouse space, which increased the risks of technical errors in the study. Figure 6 shows the total area of leaves against the type of treatments.

The increase in leaf growth in terms of area and quantity has shown that using nano-fertilisers has morphologically affected the leaves. Nano fertilisers are designed to supply nutrients to plants more efficiently and precisely than traditional fertilisers (Thirugnanasambandan, 2018). The chemical components of nano fertilisers are key to triggering and encouraging leaf growth and development. The primary feature of nano fertilisers is their particle size. This compact size gives search fertilisers more surface area for contact with plant tissue (Al-Juthery *et al.*, 2021). The tiny nanoparticle enables improved penetration into plant tissues, such as leaves. This allows for more effective absorption of nutrients directly via the leaf surface (foliar uptake) (Jakhar *et al.*, 2022).

Nano fertilisers can be designed to supply nutrients directly to individual leaves. This accuracy of distribution guarantees that the nutrients reach the intended target sites of action. Nano fertilisers provide better-targeted distribution than conventional fertilisers

(Adhikari & Ramana, 2019). Nutrients are disseminated in the soil and root absorption relies on root spread. In addition, certain nano fertilisers have a gradual release mechanism. This enables the progressive and continuous release of nutrients, ensuring a consistent supply to promote long-term leaf growth and development.

For non-nano fertilisers, the release mechanism is far quicker (Niedziński *et al.*, 2021). The study emphasizes that non-nano fertilisers such as traditional fertilisers provide instant nutrient availability. They do not align well with plant growth phases and need numerous applications to fully satisfy crop demands. Nano fertilisers may distribute nutrients in a targeted and efficient manner, improving the total efficiency of nutrient use. This implies that leaves use nutrients better, which reduces waste and decreases the environmental impact.

Effect of Nano Fertiliser on Fresh and Dry Weights

Effect of Nano Fertiliser on Water Content

All plant parts, including shoots, stems, roots, and tubers were weighed after harvesting. There was a significant difference between the total fresh weight and the total dry weight, which proves that each treatment affects the water

content of the plant samples. Fresh weight includes the actual mass of biological material and water contained in the plant cells. The dry weight represents the mass of the material after the water has been removed from the plant cells.

The percentage of water content can be measured by the difference between the fresh and dry weight. Based on Table 2, the highest percentage of water content was from the 200 ml nano fertiliser treatment, with 89.44% of water content. At the same time, the control group recorded the lowest percentage of water content, only 70.38%, compared to other treatments. The ANOVA test revealed a significant effect of fresh and dry weight, $F = 52.66297, p < .001$. The obtained F-statistic of 52.66297 exceeded the critical F-value of 4.747225347, with a p -value of 1.01×10^{-5} , indicating a statistically significant difference among the groups.

Using nano fertilisers has proven effective in increasing the total percentage of water content. This is because nutrient absorption increases due to the use of nano fertilisers by plant cells (Solanki *et al.*, 2015). When nutrients can be absorbed well, it can increase cellular processes that control the water content in plant cells.

Efficient nutrient absorption refers to the ability of plants to absorb elements from applying fertilisers in the form of nanoparticles. The size and shape based on Arora *et al.* (2024),

plants may absorb nanoparticles ranging in size from between 7 nm and 200 nm, with smaller particles allowing for faster absorption via root hairs and other entrance sites. This emphasises the relevance of nanoparticle size in improving nitrogen absorption efficiency in plants. Nano fertiliser particles with a larger surface area also allow the interaction of nanoparticles with plant roots to become more active and increase nutrient efficiency (Preetha & Balakrishnan, 2017).

However, environmental factors also contribute to the percentage of water content in plant samples (Chia & Lim, 2022). In the present study, the harvest was carried out during the monsoon season on the East Coast of Peninsular Malaysia. This means that humidity in the air at the time of the harvest may have contributed to the water content percentage in the cells. A high humidity can contribute to a higher water absorption by plant material (Mortensen, 2000).

Effect of Nano Fertiliser on Tuber Development

This experiment was carried out during the post-harvest process. The results showed that the tuber length was not significantly changed between plants on the nano fertiliser treatments and those on the non-nano fertiliser treatments, with a P -value of 0.15. However, tubers from treatment B1 were the longest compared to tubers from other treatments. Meanwhile, the

Table 2: Total fresh weight (g) and dry weight (g) of plants at 11 weeks of treatment against the percentage of water content (%)

Treatment	Total Fresh Weight (g)	Total Dry Weight (g)	Water Content (%)
Control	33.94 ± 9.04	10.04 ± 1.11	70.38
Nano fertiliser (50 ml)	81.38 ± 4.15	11.41 ± 3.26	85.98
Nano fertiliser (100 ml)	92.98 ± 18.73	11.87 ± 0.81	87.22
Nano fertiliser (200 ml)	104.51 ± 15.05	11.30 ± 0.88	89.44
Non-nano fertiliser (50 ml)	60.55 ± 12.49	10.37 ± 1.40	82.87
Non-nano fertiliser (100 ml)	68.40 ± 11.32	11.09 ± 0.12	83.78
Non-nano fertiliser (200 ml)	78.60 ± 15.21	11.85 ± 1.04	84.91

Notes: Values are mean ± standard error (SE).

*Pooled standard error of means (Control, $n = 3$, Nano Fertiliser, $n = 9$, Non-nano Fertiliser, $n = 9$) represent significant value $p < 0.05$.

Table 3: The growth and development of sweet potato tubers at 15 weeks against the type of treatments

Treatment	Sample	Tuber Length (cm)	Tuber Wet Weight (g)
Nano fertiliser	N1		
	N2	5.00 ± 8.66	7.13 ± 12.34
	N3	4.33 ± 7.50	1.4 ± 3.42
Non-nano fertiliser	B1	15.00 ± 13.00	7.46 ± 8.44
	B2	8.66 ± 8.50	7.21 ± 8.24
	B3		
Control	C1		
	C2		
	C3		

Notes: Values are mean ± standard error ($n = 7$).

data analysis of the sweet potato fresh weight (wet weight) showed no significant difference between nano and non-nano fertiliser treatment. Nevertheless, the heaviest tuber was B1, at 7.46 g (Table 3).

However, the post-harvest test found that not all samples produced tubers throughout the planting period. It was observed that the growth of tubers was limited when planted in polybags. In addition, pre-ripe tubers were harvested before they were fully mature due to environmental factors such as weather and air humidity, which can affect the growth and development of sweet potatoes. Planting sweet potatoes at the end of the year, i.e., during the monsoon season can result in a lower rate of growth for the sweet potato plants (Mortensen, 2000). Afza *et al.* (2021) have stated that mature sweet potatoes can be harvested as early as week 13. Therefore, the planting period was extended until week 15 to give the sweet potatoes more time to grow. However, inclement weather such as prolonged heavy rain during weeks 14 and 15 of the planting period, meant that harvesting was done immediately to prevent the plants from being attacked by fungus, which was a very real and distinct possibility in a prolonged high-humidity environment.

The results of this experiment also showed that the growth of the tuber was not affected by the use of nano fertilisers. Tuber growth was significantly affected by environmental factors

and soil conditions during the planting period and may take a long time to mature. The use of hormones can produce better results when stimulating the growth of tubers. This proposal is supported by Malkawi *et al.* (2007), who found that gibberellic acid, jasmonic acid, and cis-zeatin riboside could stimulate potato tuber growth (*Solanum tuberosum* cv. "Katahdin"). Stolons and roots such as pencil and fibrous roots must first be stimulated to achieve tuber production. Aksenova *et al.* (2012) have proven the hormonal regulation of tuber formation in potatoes. Research by Vreugdenhil and Struik (1989) and Debast *et al.* (2011) have also proven that the correct use of plant hormones can directly affect the growth of tubers.

Based on the findings, N3 was the best treatment applied to sweet potatoes since it produced the highest length of plants, number of leaves, area of leaves, total fresh weight, and dry weight. N3 is the nano fertiliser treatment with the highest volume (200 ml) that contains nanoparticles of organic compounds AH and RH. However, in the long term and for more optimal commercial use of nano fertilisers, N1 (50 ml) and N2 (100 ml) are recommended for more stable plant growth. Moreover, an upcoming study should determine the best amount of appropriate fertiliser depending on the type of plant that may be used as a sample, plant breed, soil condition, and the environment of the planting area.

Conclusions

This study has proven that nano fertilisers effectively improved the growth of VitAto sweet potato plants, with N3 (200 mL of nano fertiliser) being the best treatment. Using nano fertilisers can thus help increase sweet potato plant growth. It is recommended that farmers in Malaysia use nano fertiliser to maintain better plant growth while reducing environmental pollution since fewer synthetic chemicals will be needed. It is recommended that future studies avoid using polybags due to their restrictive effect on tuber growth. Instead, planting directly into soil beds should be considered, as this provides ample space for optimal tuber expansion.

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Conflict of Interest Statement

The authors agree that this research was conducted in the absence of any self-benefit, commercial, or financial conflict and declare an absence of conflicting interests with the funders.

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