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Optimization of Dried Nutmeg Leaf Compost on the Growth and Productivity of Red Potatoes (*Solanum tuberosum* L.) in the Highlands

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ABSTRACT

The red potato (*Solanum tuberosum* L.) is a pivotal horticultural crop contributing to global food security. However, its sustainable production is challenged by overdependence on chemical fertilizers and the underutilization of local organic resources. In regions like North Maluku, Indonesia, nutmeg leaf waste remains largely unused despite its potential as an organic soil amendment. This study aims to assess the effect of various doses of compost fertilizer derived from dried nutmeg (*Myristica fragrans*) leaves on the growth and yield of red potato plants. The treatments included five compost doses: K0 (control, no compost), K1 (100 g/plant), K2 (200 g/plant), K3 (300 g/plant), and K4 (400 g/plant). Growth and yield parameters observed were plant height, number of shoots, number of tubers per sample and plot, and tuber weight per sample and plot. Results showed that dried nutmeg leaf compost significantly influenced plant performance, especially during weeks 7 and 8 after planting. The highest productivity was observed in treatment K4, with a plant height of 28.6 cm, increased shoot formation, an average of 84 tubers per plot, and a tuber weight of 840 g per plot. Statistical analysis supports the potential of dried nutmeg leaf compost as a sustainable, eco-friendly organic fertilizer that enhances red potato productivity.

Keywords: Compost; Dried Nutmeg Leaf, Growth, Red Potato, Sustainable Agriculture

Introduction

Red potato (*Solanum tuberosum* L.) is the fourth most important food crop globally after rice, wheat, and maize, due to its high yield potential and short growing cycle. [1,2,3]. It provides essential nutrients including carbohydrates, fiber, vitamins, and minerals, making it a valuable alternative carbohydrate source. [4,5,6]. In Indonesia, red potato is a strategic crop in efforts to strengthen food security, [9] particularly as climate change threatens rice production in certain regions. [10] In North Maluku, red potatoes are traditionally cultivated on a small scale to meet household consumption. [11] However, production remains limited due to the high cost and overuse of chemical fertilizers, which contribute to soil degradation and environmental harm. This creates an urgent need for sustainable, low-cost alternatives that improve both soil health and crop productivity. [12] North Maluku is known as the "Spice Islands" and is a major producer of nutmeg (*Myristica fragrans*). While the nutmeg fruit is widely used, the leaves are typically discarded or burned, creating waste and air pollution. [13,14] Composting dried nutmeg leaves provides a promising solution to convert organic waste into nutrient-rich fertilizer. Enriching compost with decomposer microbes and organic NPK has been shown to improve soil fertility and crop yield in other contexts. [15] Although the benefits of organic fertilizers are well documented, limited scientific research has explored the use of dried nutmeg leaf compost as a fertilizer, particularly for red potato cultivation on Andosol soils in highland agro-ecosystems. The lack of data on optimal application doses further limits its adoption. [16]

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Dried nutmeg leaf compost presents a promising solution to improve red potato productivity in North Maluku while reducing dependence on external inputs. [17] When processed with decomposing microorganisms, this compost improves soil physical, chemical, and biological properties, supporting nutrient availability and plant health. [18,19] Soil microbes further enhance nutrient cycling and disease suppression, contributing to sustainable crop production. Red potatoes, as nutrient-demanding tuber crops, require effective and environmentally friendly fertilization strategies. [20, 21] The use of organic fertilizers such as nutmeg leaf compost has shown potential to increase yield while promoting long-term soil health. [22] However, optimal dosage for its application remains unclear. This study aims to evaluate the effects of different doses of dried nutmeg leaf compost on the growth and yield of red potatoes, to support sustainable fertilization practices using locally available organic materials.

Materials and Methods

Study Area

Lada' Ake Hamlet, located in Jaya Village, North Tidore District, Indonesia, lies at an altitude of approximately 950 meters above sea level (Figure 1). Fieldwork took place between June and September 2024, during the region's relatively dry season. This highland area experiences a tropical climate with moderate rainfall and supports traditional farming systems, with potato cultivation as the primary agricultural activity.

Tools and Materials

Red potato tubers with shoots approximately 2 cm in length were used as planting material, dried nutmeg leaves, EM4 solution, brown sugar, and water as a solvent. The equipment used included a digital scale (accuracy ±0.01 g), an organic material chopper (300 W, stainless steel blade), a 250 mL measuring cup (graduated plastic), a 10 L plastic bucket (HDPE), a vernier caliper (precision 0.02 mm), a fine mesh filter cloth (100 µm), and a 20 L airtight plastic storage container (food-grade).

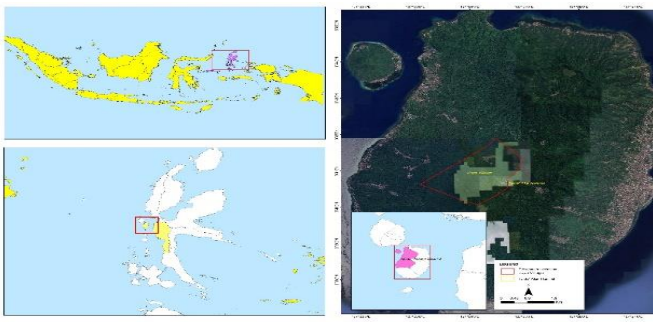

Figure 1: Research Location Map at Lada'Ake Hamlet, Jaya Village, North Tidore District

Dried nutmeg leaf compost fertilizer

Nutmeg leaves were collected in June 2024 from Jaya Village, Maluku, Indonesia (0°40′34′184″ N, 127°24′15″ E), a region known for its spice production. The species used was *Myristica fragrans*. [23] The collected leaves were dried in the shade, avoiding direct sunlight. After drying, the leaves were stored in airtight containers until further use. Dried nutmeg leaves totaling 5 Kg were mechanically ground into a fine powder. A fermentation activator solution was prepared by combining 200 mL of EM4, 150 mL of liquid brown sugar, and 1.5 L of purified water. This solution was gradually poured over layered powdered nutmeg leaves in a 20 L container until full. The composting process was conducted over approximately two weeks. The resulting compost was then applied to the planting beds as fertilizer for red potatoes.

Research Methods

The planting was carried out from June to September 2024, corresponding to a single planting season. The decision to conduct only one planting season was based on the objective of evaluating the short-term effects of compost application on the growth and yield of red potato (*Solanum tuberosum* L.). Limiting the study to a single season allowed for consistent environmental conditions, including temperature, rainfall, and soil characteristics, thereby increasing the internal validity of the experiment. The experimental design used was a Randomized Block Design with five treatment levels and three replications, resulting in a total of 15 experimental units. The study comprised five treatments using dried nutmeg (*Myristica fragrans*) leaf compost. The treatments consisted of control (K0) received no compost. Treatments K1, K2, K3, and K4 were supplemented with 100 g, 200 g, 300 g, and 400 g of compost per plant, respectively.

Observation Parameters

Plant height was measured weekly from two to eight weeks after planting (WAP) to monitor vegetative growth. The number of buds was recorded up to eight WAP to evaluate early development stages. At harvest, both the number and weight of tubers were determined per sample and per plot to assess yield and biomass production.

The observations recorded were subsequently analyzed using the following statistical model to evaluate the results accurately. The mathematical formula:

$$Yij = \mu + \pi i + \beta j + \text{Ɛij} \quad (1)$$

Description:

Yij = Observed value of i-th treatment and j-th replication
μ = General mean
πi = Effect of i-th treatment
βj = Effect of j-th group
Ɛij = Experimental error of i-th and j-th treatments

Data analysis

The data obtained were analyzed using analysis of variance (ANOVA) with SPSS version 20. If there was a significant effect on the treatment, further tests were carried out using the BNT (Bayesian Network Test) at the 95% confidence level (α = 0.05). [24]

Results and Discussion

Effect of nutmeg leaf compost on potato plant height

The application of dried nutmeg leaf compost fertilizer to the height of red potato plants at 7 WAP and 8 WAP is shown in Table 1. Table 1 shows the average height of red potato plants at seven and eight weeks after planting (WAP) following the application of dried nutmeg leaf compost. Higher compost doses, particularly K3 and K4, resulted in taller plants, indicating a positive response to increased nutrient availability.

Table 1: ANOVA analysis of red potato plant height with nutmeg leaf compost fertilizer treatment at the age of 7-8 WAP

Source of Variation	Mean square red potato plant height	
	7 WAP	8 WAP
Block	4.27.	0.73
Treatment	30.14*	34.98*
Error	4.90	7.07
Critical Value	3.91	9.31

Description: * indicates significant difference between treatments in the BNT test α = 0.05

Nutmeg leaves contain bioactive compounds and essential nutrients, making them a potential organic fertilizer that supports plant growth and offers protection against stress. [14] The ANOVA results (Table 1) showed significant differences in plant height, especially in treatments with nutmeg leaf compost, confirming its effectiveness in promoting growth. [25] Compost derived from *Myristica fragrans* enhances photosynthesis and vegetative development through key nutrients like nitrogen, phosphorus, and potassium, which are vital for chlorophyll formation and nutrient uptake. [26] The increased mean square values at 7 and 8 WAP reflect a strong growth response, particularly in the early growth phase. [27] Overall, the use of nutmeg leaf compost improves soil fertility, root development, and nutrient absorption, leading to taller and healthier potato plants. [28, 29] The composted leaves enrich the soil with nutrients, promoting optimal plant growth. The morphological characteristics of the root system have been demonstrated to play a pivotal role in enhancing nitrogen utilization efficiency. The impact of nitrogen on the vertical distribution of cotton roots has been identified as a critical factor influencing the photosynthetic capacity of leaves. [30] Inadequate irrigation has been shown to cause a decline in the potato leaf area index, resulting in diminished photosynthetic capacity and, consequently, reduced yields. [31] The graph of red potato plant height growth with nutmeg leaf compost at the age of 2 to 8 weeks after planting is shown in Figure 2.

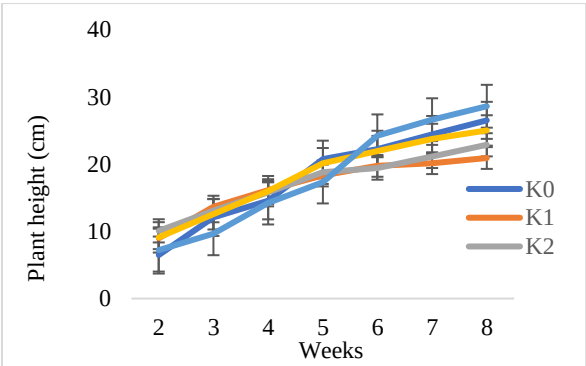

Figure 2: Graph of nutmeg leaf compost fertilizer on the height of red potato plants at the age of 2 - 8 WAP

Figure 2 illustrates the growth trend in plant height from 2 to 8 WAP. A consistent upward trend was observed, with the most pronounced increases in the K3 and K4 treatments. No significant treatment were found, and the results confirm that compost dosage positively correlates with plant height. The increased application of compost fertilizer demonstrated a significant impact, as evidenced by the observations recorded in trials K3 and K4, which exhibited the most optimal outcomes (Figure 2). Higher fertilizer doses have been demonstrated to enhance essential nutrient availability, thereby stimulating the overall plant growth process. The nitrogen present in compost plays a pivotal role in the process of protein formation, which in turn leads to an increase in biomass and tuber production. [32,33]

Effect of nutmeg leaf compost on the number of red potato shoots

The application of dried nutmeg leaf compost significantly affects the number of red potato shoots at all observation times, from three to eight WAP (Table 2), showing the consistency of the plant's physiological response to organic treatments during the vegetative phase. The dried nutmeg leaf compost treatment on the number of red potato buds at three untul eight WAP is shown in Table 2. The application of dried nutmeg leaf compost significantly increased the number of red potato shoots from 3 to 8 WAP. The highest shoot number was recorded in treatment K4, especially at week seven. Temporal trends showed a gradual increase in shoot numbers across weeks, indicating a continuous physiological response to compost treatment.

The growth of potato plants (*Solanum tuberosum* L.) is characterized by a series of distinct stages, beginning with the emergence of shoots and continuing through the development of roots and the formation of tubers. The process of photosynthesis, which is contingent upon sunlight and the availability of nutrients from the soil, facilitates optimal tuber development. The group mean square value for the number of shoots was comparatively minimal compared to the treatment values, suggesting that the variation in shoots was predominantly influenced by applying nutmeg leaf compost fertilizer rather than by the differences between the groups. The maximum observed variation among the groups occurred at six weeks of planting, with a value of 7.23, as indicated in Table 2. Conversely, the highest recorded treatment value was attained at seven weeks of planting, with a value of 100.53. This finding suggests a significant to statistically substantial effect since yhree weeks of planting. This finding further supports the hypothesis that nitrogen- and phosphorus-rich nutmeg leaf compost can stimulate shoot growth through increased soil nutrients and microbiological activity. [34] Furthermore, the soluble organic matter and minerals contained in organic fertilizers have been demonstrated to promote plant development [35] and stimulate the activity of soil microorganisms, thereby accelerating decomposition and nutrient absorption. [36] Compost fertilizers support these stages by ensuring sufficient nutrients are available for chlorophyll formation and cell elongation. [37,38]. The utilization of dried nutmeg leaf compost has been demonstrated to result in a substantial augmentation in the number of shoots and tubers, as well as an increase in the fresh tuber weight of potato plants. [39,40]

Effect of nutmeg leaf compost on the number of potato tubers

The dried nutmeg leaf compost treatment on the number of potato tubers is shown in Table 3. Yield analysis demonstrated that the application of dried nutmeg leaf compost significantly affected potato productivity. As presented in Table 3, the center-squared results illustrate the impact of the treatment on the number of tubers. The control group exhibited an average yield of 14.26 tubers per sample and 252.87 per plot, while the dried nutmeg leaf compost treatment yielded 344.59 tubers per sample and 1702.40 per plot. The low error values of 38.07 per sample and 43.20 per plot indicate variability not caused by random factors. The Critical Value value was higher for the number of tubers per sample (75.49) than per plot (12.42), indicating a significant effect of the nutmeg leaf compost fertilizer in increasing the number of tubers.

Table 2: ANOVA analysis of the number of red potato shoots aged 3-8 WAP with dried nutmeg leaf compost treatment

Source of Variation	The mean square of shoots at week after planting (WAP)					
	3	4	5	6	7	8
Block	0.66	2.24	3.31	7.23	0.07	1.30
Treatment	8.86**	18.99**	29.84**	7.19**	10.53**	40.63**
Error	0.86	1.30	2.57	10.28	7.95	6.41
Critical Value	0.79	0.75	0.91	1.49	1.15	0.90

Description: * indicates significant difference between treatments in the BNT test $\alpha = 0.05$

Table 3: ANOVA analysis of the red potato tubers with nutmeg leaf compost treatment at harvest time

Source of Variation	Mean square number of potato tubers at harvest	
	per sample	per plot
Block	14.26	252.87
Treatment	344.59**	1702.40**
Error	38.07	43.20
Critical Value	75.49	12.42

Description: * indicates significant difference between treatments in the BNT test $\alpha = 0.05$

Variance analysis confirmed that the treatment effect was statistically significant ($p<0.01$). This finding indicated that applying nutmeg leaf compost significantly increased tubers per sample. The observed increase in potato yield following the application of nutmeg leaf compost suggests the efficacy of organic matter in potato cultivation. Nutmeg leaf compost has been demonstrated to provide essential nutrients that directly affect plant growth and development. The presence of compost has been shown to enhance the availability of nitrogen, which is crucial for protein synthesis; phosphorus, which facilitates energy transfer and root development; and potassium, which contributes to tuber quality. [41] *Solanum tuberosum*, commonly known as the potato, has been observed to require a significant amount of potassium. It has been demonstrated that maintaining optimal potassium levels positively affects the size of potatoes, the amount of starch they contain, and their overall marketability. This makes potassium an essential nutrient in the production of potatoes. [42]

Compost fertilizer derived from nutmeg leaves has been demonstrated to enhance the nutritional quality of soil, thereby promoting plant development. [43] Additionally, it has been observed to facilitate increased nutrient absorption and augment

plant yield by stimulating beneficial microbial activity. [44] High microbial activity has been shown to accelerate the decomposition of organic matter, thereby making nutrients more readily available and strengthening growth and tuber formation. [45] provide further support for this claim. Specifically, they demonstrate that compost significantly increases the number of potato tubers, particularly by improving soil nutrient balance and stimulating microorganism activity.

The error value of 38.07 reflects variation among individual plants due to uncontrolled environmental or genetic factors. Despite a high coefficient of variation (75.49%), the yield increase from compost treatment remained statistically significant, indicating diverse biological responses. In contrast, the control group showed minimal variation, with a mean square value of 252.87 tubers per plot.

Treatment with nutmeg leaf compost produced a mean square value of 1,702.40, significantly increasing over the control ($p < 0.01$). The error value was 43.20, which was lower than the standard deviation of the sample level. This finding suggests that the treatment effect exhibited greater stability at the plot level. The coefficient of variation was determined to be 12.42%, indicating minimal variability and suggesting that fertilizer application resulted in a more uniform distribution of yield among plots.[46]

The results of the analysis of the application of dried nutmeg leaf compost to the number of potato tubers at harvest per sample and per plot are shown in Table 4. Dried nutmeg leaf compost significantly increased the number of potato tubers. Treatment K4 produced the highest yield (13 tubers per sample; 84 per plot), significantly different from other treatments (Table 4). K2 and K3 also outperformed the control (K0) and K1, which showed the lowest yields and were not statistically different. These results indicate that increasing compost dosage improves productivity up to the optimum level (K4), with BNT test results at the 5% level confirming significance.

A statistical analysis of the BNT test ($\alpha = 0.05$) revealed that treatments K2, K3, and K4 significantly increased the number of tubers compared to the control (K0) and K1. The findings suggest that medium to high doses of nutmeg leaf compost promote optimal tuber formation. Compost has been demonstrated to enhance soil structure and facilitate nutrient release. [47] This outcome aligns with the observations from the K3 and K4 treatments, which exhibited the most optimal tuber yield. The results of the study indicate that the application of nutmeg leaf compost fertilizer has the potential to enhance the productivity of potato plants in terms of both the quantity of tubers produced and the quality of their growth. This enhancement is achieved through the improvement of soil conditions and the enhancement of nutrient availability. Organic-based compost has been demonstrated to enhance potato productivity, particularly in the number of tubers produced. Compost has been shown to improve soil structure [48], augment water retention [49], and supply vital nutrients that facilitate tuber growth and development.

Table 4: Effect of application of dried nutmeg leaf compost on the number of tubers at harvest

Treatments	Number of potato tubers at harvest	
	per sample	per plot
K_0	5^a	31^a
K_1	4^a	28^a
K_2	9^b	56^b
K_3	10^b	66^b
K_4	13^c	84^c
BNT $\alpha = 0,05$	1,96	12,38

Description: superscript letters in the same column indicate highly significant differences between treatments (sig.<0.05) at the 95% confidence level according to the BNT test.

Compost utilization has been demonstrated to enhance crop yield by promoting improved vegetative growth and enhanced tuber quality. In addition to its agronomic benefits, compost is a sustainable alternative to reduce dependence on chemical fertilizers and prevent land degradation. At optimal doses, such as those employed in treatment K4, the analysis of dried nutmeg leaf compost revealed a substantial increase in yield, with an average of 13 tubers per sample and 84 tubers per plot, along with a total tuber weight of 840 g per plot. The findings indicate that the judicious application of compost fertilizer can enhance the productivity and quality of potato crop yields, directly influencing food security and agricultural productivity. [50] By this, research by Sosnowski et al. [51] has demonstrated that compost contains microelements such as auxins, which enhance the process of photosynthesis and chlorophyll formation, thereby supporting overall plant growth.

To support optimal potato productivity, it is essential to ensure the presence of nitrogen, phosphorus, and potassium in the growing medium. [52]. A nitrogen deficiency has been demonstrated to impede metabolic processes, thereby engendering suboptimal conditions. Nitrogen (N) is a pivotal element in photosynthesis in food crops. It is directly involved in synthesizing essential substances, such as chlorophyll and protein, thereby substantially influencing the growth and development of food crops. [53]. The utilization of nitrogen fertilizers has been demonstrated to enhance potato yields. [21]. Nutmeg leaf compost has been shown to contain soil phosphorus, a primary macronutrient source for plants. This element has been demonstrated to be effective in optimizing growth and maintaining efficient metabolic activity. [54,55]. Plants primarily obtain inorganic nitrogen (N) from NH_4^+. [2] This process elicits varied responses in various physiological processes, including root system development, photosynthesis, and N metabolism. Consequently, utilizing organic fertilizers comprising balanced NPK can enhance processes, thereby fostering the comprehensive growth of potato plants.[56]

Effect of nutmeg leaf compost on potato tuber weight

Red potato samples treated with dried nutmeg leaf compost fertilizer significantly impacted red potato sprouting bobo, as shown in Table 5. Applying dried nutmeg leaf compost fertilizer significantly affected tuber weight per plot. As presented in Table 5, compost application also significantly affected tuber weight per plot. Treatment K4 resulted in the highest tuber weight (840.00 g), followed by K3 (330.00 g), while the control treatment (K0) had the lowest (113.33 g). The LSD test (BNT) indicated that K3 and K4 treatments were significantly different from K0 and K1. The progressive increase in tuber weight over time highlights the long-term benefit of compost enrichment. These results suggest that higher fertilizer doses contribute to increased potato tuber production.

Table 5: ANOVA analysis of the red potato tubers treated with nutmeg leaf compost at harvest time

Treatments	Mean square weight of potato tubers at harvest (g)	
	Per sample	per plot
K_0	160.00^a	113.33^a
K_1	203.33^a	173.33^a
K_2	200.00^a	196.67^a
K_3	286.67^b	330.00^{ab}
K_4	118.00^b	840.00^b
BNT α 0,05	61.45	526.65

Description: superscript letters in the same column indicate highly significant differences between treatments (sig.<0.05) at the 95% confidence level according to the BNT test

Potatoes have the potential to serve as an alternative carbohydrate source, thereby supporting local food security. This is especially true when organic fertilizers are employed, as they can enhance the yield's quality and quantity. Optimal climatic conditions, characterized by effective moisture management, have been demonstrated to enhance the yield of potato plants. [57] Furthermore, the hormone auxin, present in plants, plays a pivotal role in enhancing plant productivity.[50] This is because leaves are the primary organ in photosynthesis.[58] The present study corroborates earlier findings that applying organic fertilizers, including nutmeg leaf compost, can enhance potato plants' leaf area and fresh weight, thereby enhancing photosynthetic efficiency. [59]

The utilization of dried nutmeg leaf compost fertilizer has been demonstrated to positively influence potato plants' agronomic parameters, including the number of fresh tubers. Compost that contains optimal levels of potato development has been shown to increase photosynthetic efficiency and support overall plant biomass. Plants engage in photosynthesis, which entails nitrogen absorption. [61, 62] This process involves converting light energy into organic matter, such as glucose [60]. The energy derived from this process is then utilized to facilitate the fixation of carbon dioxide (CO_2). Applying organic fertilizers can augment leaf area and plant fresh weight. [59] The concept of photosynthesis, thereby underscoring the significance of optimal leaf area in enhancing plant productivity. [58] Furthermore, environmental factors such as temperature and humidity are crucial in facilitating plant growth. The cultivation of plants under controlled climate conditions has yielded superior results, particularly regarding plant height, the number of shoots, and the fresh weight of the plants. [57]

Elevated carbon dioxide concentrations have been demonstrated to enhance photosynthetic performance, optimize water use efficiency, and augment potato tuber yield. However, the efficacy of these improvements is contingent upon the specific type or cultivar of potato being cultivated. [63] Consequently, the response to fluctuations in CO_2 conditions exhibits cultivar-specific variations. The present study's findings are consistent with the results of previous research, which demonstrated that the application of nutmeg leaf compost fertilizer enhances the agronomic parameters of potato plants. [64] Additionally, it was observed that utilizing organic matter leads to improved plant growth. [65] Nitrogen plays a pivotal role in photosynthesis, facilitating the distribution of energy derived from sunlight. Photosynthesis in potato plants is a biochemical process that produces the energy plants require. In this process, carbon dioxide (CO_2) and water (H_2O) are converted into glucose under the influence of light. Photosynthesis represents the most significant chemical process, providing the fundamental energy source for food crops and influencing crop yield and quality. [66] Photosynthesis occurs in the chloroplasts of leaves, which contain chlorophyll and function in the capture of light to produce energy. [67]

Conclusion

The application of dried nutmeg leaf compost significantly enhanced the growth and yield of red potato plants, demonstrating its effectiveness as an organic fertilizer. The compost stimulated vegetative development, as reflected by the increased number of shoots from 3 to 8 weeks after planting (WAP), and promoted greater plant height at 7 and 8 WAP compared to the control. Higher compost dosages, particularly at 400 g/plant (K4), resulted in the highest number and weight of tubers, with 84 tubers and 840 grams per plot. These findings confirm that increasing the dosage of nutmeg leaf compost correlates positively with improved plant growth parameters and productivity. Furthermore, the use of nutmeg leaf compost offers a promising alternative to synthetic fertilizers, supporting sustainable agriculture by utilizing organic waste and reducing environmental impact.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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