Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 25 No. 1
January 2025
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2024; 25(1): 25661-25682 https://doi.org/10.18697/ajfand.138.24645

Date	Submitted	Accepted	Published
	5th March 2024	1st November 2024	29th January 2025

ASSESSMENT OF THE COMBINED EFFECTS OF ORGANIC MANURE AND NPK (17-17-17) ON GROWTH AND YIELD OF CARROTS IN RWANDA

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
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January 2025
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ABSTRACT

Carrot (*Daucus carota L.)* is one of the most important vegetable crops grown in many parts of Rwanda. However, its yield and growth are still low among many smallholder farmers partly due to limited knowledge on proper fertilizer use and application. To address this issue, the study was conducted to assess the effect of combined application of organic manure with different rates of NPK (17-17-17) on growth and yield of carrots in Rwanda. Understanding the impact of organic manure and NPK fertilizers on carrot growth and yield can help farmers optimize production, and enhance food security and economic development in the region. A field experiment was undertaken in season 2022-2023 in three agro-ecological zones (AEZs) in three different provinces of Rwanda namely, Huye (Southern province), Bugesera (Eastern) and Rubavu (Western) districts. Eight treatments were arranged in a randomized complete block design (CRBD) with three replications. Each of the eight treatments received a uniform application of 25 tons per hectare of organic manure. Additionally, inorganic fertilizers (specifically NPK 17-17-17) were introduced in varying quantities, except for the control plot(T_0), which did not receive any NPK. The treatments (T) were arranged as follows: T_0 (Control) = 0 kg/ha, T_1= 50kg/ha, T_2= 100 kg/ha, T_3=150 kg/ha, T_4=200 kg/ha, T_5=250 kg/ha, T_6=300 kg/ha and T_7= 350 kg/ha. Data collected from the experiment were subjected to analysis of variance (ANOVA) using R Studio. The analysis aimed to evaluate the impact of the different treatments on the growth and yield of carrots in the three agroecological zones (AEZs) represented by the Huye, Bugesera, and Rubavu districts. Results showed variations in carrot growth and yield based on fertilizer rates across all AEZs. Among the treatments, Treatment T7, receiving 350 kg/ha of NPK, exhibited a significant increase in the number of leaves and plant height compared to other treatments. Conversely, the control plots (T_0) exhibited the lowest plant height and number of leaves across all AEZs. Similarly, the T_7 also resulted in the highest carrot yield of 7.1 kg, outperforming all other treatments. In contrast, the control group (T0) exhibited the lowest yield of 3.3 kg. These findings suggest that combining 25 t/ha of organic manure with 350 kg/ha of NPK can significantly boost carrot production in various regions of Rwanda. The use of organic manure combined with NPK fertilizers can provide essential nutrients to the carrots, promoting their growth and yield. This information can be valuable for carrot farmers in the three AEZs of Rwanda, as it offers a practical approach to improving carrot production and increasing yields.

Key words: Carrot, agro-ecological zone, fertilizer, growth and yield, Rwanda

https://doi.org/10.18697/ajfand.138.24645

INTRODUCTION

Carrots (*Daucus carota L.)* are an important vegetable which serve as good source of nutrients such as vitamins A, C, and K, as well as potassium and fiber, which are essential for maintaining a healthy diet [1, 2]. Carrots grow well in Rwanda's agro ecological zones, making them a suitable vegetable for farmers to cultivate. The crop can be grown in a variety of soils, including sandy and loamy soils, and can tolerate a range of temperature [2, 3]. The plant roots are versatile and can be used in a variety of dishes, such as stews, salads, and soups [4].

In Rwanda, carrots are grown in several parts including the Eastern, Northern, and Southern provinces. The largest carrot producing areas are the districts of Bugesera, Kayonza, Gicumbi, and Nyagatare. Most of the carrot production in Rwanda is carried out using conventional farming methods, with farmers applying mineral fertilizers, pesticides, and herbicides to control pests and diseases as well as weeds to improve yields [4].

Carrots are often used in traditional dishes such as dishes made with mashed plantains, and bean stew [7]. Moreover, carrots have economic importance in Rwanda, as they are a valuable crop for smallholder farmers to sell at local markets across the country, while some are exported to neighboring countries such as the Democratic Republic of Congo, Burundi, and Uganda. The main buyers are usually small-scale traders and retailers who sell the carrots in urban and rural markets [5, 6]. This provides an important source of income for rural communities and can contribute to poverty reduction [5, 8]. Hence, the importance of carrots among other vegetables in Rwanda lies in their nutritional value, versatility, ease of cultivation, and economic importance [4].

The average yield of carrots in Rwanda was about 16.4 tons per hectare in 2019 which is low compared to 20-30 tons per hectare from other carrot producing countries [3, 6, 9]. With regards to aforementioned importance of carrots and their production, the country has made significant strides in increasing yields in recent years [4, 5]. One of the main factors to improve production of carrot is improved agricultural practices, such as better seed varieties, use of fertilizers, and better pest and disease management practices [10]. In addition, increased investment in irrigation and other infrastructures has helped to increase yields by reducing the impact of drought and other weather-related challenges. The Rwandan government has also implemented several policies aimed at promoting agricultural productivity and food security, including subsidies for fertilizers and other inputs, and investments in rural infrastructures [3, 10].

However, with regards to the previous research, appropriate rate of fertilizers is important for improving marketable yield of carrot, contributing to food security, and reducing costs associated with spoilage and waste [11]. In the farm, also recent research has shown that fertilizer application can have a significant impact on both crop yields and storage of the harvested produce [4]. Some of the impacts are in the concept that fertilizer application can improve crop yields by providing essential nutrients to the plants [7, 12, 13].

Different types of fertilizers contain varying amounts of nitrogen, phosphorus, and potassium, which are all essential for plant growth. When applied correctly, fertilizers can increase the availability of these nutrients in the soil, leading to increased crops yields and ultimately greater profits for farmers and better-quality produce for consumers [3]. The impact of fertilizer application on crop yield depends on several factors, including the type and amount of fertilizer used, soil quality, and weather conditions [12, 13].

However, most farmers have inadequate knowledge and skills regarding fertilizer use and application. Consequently, many farmers either apply excessive or insufficient amounts, leading to low yields, reduced profit margins, and environmental harm. This study was therefore designed to investigate the effects of applying different mineral fertilizer rates in combination with organic manure on the growth and yield of carrots in Rwanda. Combining mineral fertilizers with organic manure is crucial because, while mineral fertilizers provide an immediate nutrient supply for rapid plant growth, organic manure enhances soil structure, increases water retention, and promotes microbial activity, ensuring long-term soil fertility. This approach improves nutrient efficiency, reduces nutrient leaching, and fosters sustainable crop production, making it a more balanced and effective strategy than using inorganic fertilizers alone.

MATERIALS AND METHODS

Study Area

The study was conducted from January 2022 to June 2023 in three distinct agroecological zones managed by the Rwanda Agriculture Board (RAB). The research sites included farms in Bugesera District (Musenyi Sector) with sandy loam soil at an altitude of approximately 1,300 meters, Huye District (Rubona) with sandy silt soil at an altitude of about 1,800 meters, and Rubavu District (Tamira Sector) with volcanic ash soil at an altitude of around 1,500 meters above sea level. Carrots of the Nantes variety, which originated in the Netherlands, were used for the study and sourced from Holland Green Tech Rwanda. The Nantes variety was selected due to its adaptability to a range of soil types and its proven performance in various climatic conditions, including those found in different regions of Rwanda. This variety is known for its consistent quality and high yield potential across diverse growing environments. The NPK (17-17-17) fertilizer was purchased from Green Farm Ltd, and the cow manure was obtained from local village farms.

Soil sampling techniques

Soil sampling from the experimental fields was undertaken prior to planting and analysis was conducted by the University of Rwanda. Soil samples from each site were randomly collected in 0-30cm of depth by a soil auger using diagonal methods in five locations, including one from the middle and the rest 4 from the corners. Thereafter, those primary samples were mixed for obtaining composite samples for analysis.

Experimental design and layout

Each experimental field was ploughed at 40 cm depth to remove weeds and roots, and to enable favorable growth of the carrot roots. Field experimental design was completely randomized block design with 8 treatments namely, T0: Application of organic fertilizers at 25t/ha, T1: mixture of 25t/ha of organic fertilizer+50kg/ha of NPK; T2: Application 25t/ha of organic fertilizer +100kg/ha of NPK, T3: Application of 25t/ha of organic fertilizer +150kg/ha of NPK; T4: Application 25t/ha of organic fertilizer +200kg/ha of NPK; T5: Application 25t/ha of organic fertilizer +250kg/ha of NPK; T6: Application 25t/ha of organic fertilizer +300kg/ha of NPK, T7: Application 25t/ha of organic fertilizer +350kg/ha of NPK. The 25t/ha rate of organic manure was selected because it is commonly recommended in Rwanda for enhancing soil structure and nutrient availability, particularly in vegetable crops like carrots. It aligns with sustainable agricultural practices in similar agro-ecological zones.

Each treatment was 2× 1 square meter and one-meter spacing between blocks and 50 cm between plots, replicated three times. The experimental field measured 22m × 10m. After land preparation, organic manure was applied, followed by sowing. Lines of about 1.5 cm depth were made and seeds were sown in line. After sowing, the seeds were covered with loose soil. One day after sowing, the plots were covered to protect the seeds from direct sunshine. Seedling emergence occurred 8 to 10 days after sowing in all agro-ecological zones (AEZs), and the seedling emerging rate was assessed on the tenth day after sowing. Thinning was done following seedling emergence to keep a spacing of 20 cm × 10 cm. Irrigation was applied every 3 to 5 days throughout all AEZs, delivering roughly 20 to 25 mm of water per application. Total water consumption ranged from 440 to 550 liters each round for 22m x 10m field in all AEZs combined. "Inorganic fertilizers were applied 30 days after sowing.

Data collection

Data collection for this study focused on key growth and yield parameters of carrot plants and was conducted systematically throughout the growth period. Parameters assessed included plant height, measured from the base to the tip of the highest leaf, and the number of leaves per plant. These were recorded on days 30, 45, 60, and 90 after planting (DAP). At harvest, carrot root diameter and length were measured, with length assessed from the crown to the root tip and diameter at the thickest point. Marketable yield was determined based on the total weight of carrots meeting market quality standards, considering factors such as cracking, deformation, and other damage affecting marketability. Yield was calculated per hectare for each treatment.

Sampling was carried out using a stratified random sampling method across three agro-ecological zones: Huye, Bugesera, and Rubavu. In each zone, five locations were randomly selected for soil and plant sampling; one from the center and four from the corners of the field to ensure comprehensive representation. Each zone included 24 samples (8 treatments × 3 replicates), resulting in a total of 72 samples across all zones.

Carrot root diameter and length, marketable yield, non-marketable yield were recorded at harvesting. The young leaves were countered and twenty plants per plot were randomly selected from the middle rows and tagged for data collection. Twenty plants per plot were randomly selected from the middle rows and tagged for data collection. A meter rule was placed at ground level to the top of the shoot and their values recorded in centimeters. At harvest, carrot roots harvested in each plot were weighed in using the scale and recorded in Kilograms.

Furthermore, the same plants were measured using rope and measurement obtained was circumference and divided by Pi (3.14) to obtain diameter. Roots diameter, also measured for length using ruler and recorded in centimeters. Finally, the best carrot roots were selected and weighted in each plot and considered as marketable yield while non selected carrot roots were considered as non-marketable yield.

Data management and utilization

In this research data were collected using appropriate Microsoft excel and the R studio was used for all statistical analyses. The collected data was entered into computer, analyzed R studio.

RESULTS AND DISCUSSION

Effect of organic and inorganic fertilizers on growth of carrot in three agro-ecological zones

Effect of organic and inorganic fertilizers on number of leaves

The application of different fertilizer treatments significantly impacted the number of leaves produced by carrot plants. At 30 days after sowing (DAP), there was no significant difference between treatments. However, by 45 DAP, plants receiving higher rates of NPK (17-17-17) showed a notable increase in leaf number. Specifically, treatment T7 (25t/ha organic manure + 350kg/ha NPK) yielded the highest number of leaves across all zones, with values of 4.1 leaves per plant in Rubona, 3.9 in Musenyi, and 4.4 in Tamira. This was statistically significant compared to T0, which had the lowest number of leaves (3.5, 2.9, and 2.7, respectively) (Tables 1, 2, 3).

By 60 DAP, the trend continued with T7 showing the highest leaf number of 5.7 leaves, significantly more than T0 which had only 3.1 leaves. The increase in leaf number with higher NPK application is attributed to the essential nutrients provided by the fertilizers, which support leaf development and overall plant vigor (Tables 1, 2, 3). At 75 DAP, the trend continued with T7 showing 6.2 leaves, while T0 had just 3.3 leaves. By 90 DAP, the number of leaves decreased across all treatments, but T7 still led with 5.5 leaves, compared to T0 with 3.0 leaves.

The significant increase of plant growth by increasing rate of NPK (17-17-17, is due to inorganic fertilizers providing specific ratios of essential nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), which are crucial for plant growth [15, 16]. Carrots require these nutrients for various processes, including leaf development, root formation, and overall plant vigor [17, 18].

Inorganic fertilizers can provide readily available nutrients that promote rapid growth and higher yields [1, 10, 19, 20]. Inorganic fertilizers allow for precise control of nutrient levels in the soil [21, 22]. Inorganic fertilizers generally contain nutrients in forms readily absorbed by plant roots [10, 23]. This allows carrot plants to take up the necessary nutrients quickly, especially when compared to organic fertilizers that require decomposition and mineralization by soil microorganisms before nutrients become available. Rapid nutrient uptake can support efficient growth and development of carrot plants [23, 24]. Those results are consistent with the results observed by Agbede *et al.* [1], and Roshni *et al.* [25] that inorganic fertilizers have a positive effect on carrot growth including leaf development.

Effect of organic and inorganic fertilizers on plant height

Data presented in Tables 4, 5 and 6 showed that the height of carrot have been statistically found significant meaning that height is influenced by organic and inorganic fertilizers at all measurements dates at all agro ecological zones. Statistically significant differences (p-value = 2e-16) were noted, indicating the substantial impact of NPK on plant height. At 30 DAP did not reveal significant differences among the treatments. However, by 45 DAP, T7 plants were notably taller, averaging 24 cm in Rubona, 25 cm in Musenyi, and 26 cm in Tamira, compared to the control treatment, T0, which measured 15 cm, 16 cm, and 17 cm, respectively. At 75 DAP, T7 plants reached an average height of 30 cm in Rubona, 31 cm in Musenyi, and 32 cm in Tamira, whereas T0 plants were shorter, at 20 cm, 21 cm, and 23 cm. By 90 DAP, T7 maintained the tallest plants with heights of 35 cm in Rubona, 34 cm in Musenyi, and 36 cm in Tamira, compared to T0 heights of 22 cm, 21 cm, and 23 cm. This was because, Inorganic fertilizers are formulated to provide specific ratios of essential nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), which are crucial for plant growth.

Similarly, it is known that inorganic fertilizers contain nutrients in forms readily absorbed by plant and result to take up the necessary nutrients quickly which support efficient growth and development of carrot plants [26, 27]. Carrots require these nutrients for various processes, including leaf development, root formation, and overall plant vigor. Furthermore, inorganic fertilizers can have an acidifying effect on the soil. This can be beneficial for carrots, as they prefer slightly acidic soil conditions with a pH range of 5.5 to 6.8. Inorganic fertilizers can help maintain or adjust the soil pH within this optimal range [26]. Similarly, it is known that inorganic fertilizers contain nutrients in forms readily absorbed by plants and result in easily absorb required nutrients for the plants which support efficient growth and development of carrot plants [13, 26].

Effect of organic and inorganic fertilizers on yield parameters

As it is shown in the Tables (7, 8, 9), yield parameters, including root length, root diameter, yield per plot, and marketable yield, were also significantly affected by fertilizer treatments. T7 consistently produced the longest and widest roots, followed by treatments T6, T5, T4, and T3, while the control (T0) resulted in the shortest and narrowest roots. The highest yields per plot and the most marketable yields were also observed in T7 across all agro-ecological zones, with significant differences between the treatments. The p-values for root length, root diameter, yield per plot, and marketable yield were 4e-10, 2.26e-07, 0.0035, and 0.0308, respectively. These results indicate that the availability of essential nutrients from NPK fertilizers leads to better root development and overall improved yield performance. Similarly, inorganic fertilizer is known to supply balanced nutrients which promote root development in carrots [28].

Inorganic fertilizers typically provide nutrients in forms that are readily absorbed by plant roots. This allows carrot plants to efficiently take up the necessary nutrients, leading to rapid growth and development [29, 30, 31]. Quick nutrient uptake can contribute to higher carrot yields, especially when nutrient availability is crucial during critical growth stages. Inorganic fertilizers can provide a balanced supply of essential nutrients, ensuring that carrot plants receive the appropriate proportions of N, P, and K, as well as other essential micronutrients [32, 33]. This balanced nutrient ratio is essential for overall plant health and productivity, leading to improved yield outcomes [34, 35]. Properly applied inorganic fertilizers can enhance overall plant vigor, increase leaf growth, stimulate root development, and improve fruit formation, all of which contribute to higher carrot yields. When nutrient deficiencies are corrected and optimum nutrient levels are maintained, carrot plants are better equipped to reach their full yield potential [35, 36]. Similarly, inorganic fertilizer is known to enhance overall plant vigor, stimulate root development, and improve fruit formation, all of which contribute to higher carrot yields [2, 9, 31]. Additionally, inorganic fertilizer is known to provide uniform nutrient supply leading to more uniform root size, shape, and quality which is particularly important for commercial production and marketability [26, 38, 39, 40].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

In conclusion, the application of organic fertilizers in combination with varying rates of NPK (17-17-17) significantly improved the growth and yield characteristics of carrots across all agro-ecological zones. The treatment with 25t/ha of organic manure and 350kg/ha of NPK (T7) provided the best results in terms of leaf number, plant height, and yield. However, T3 (25t/ha of organic manure + 150kg/ha of NPK) achieved nearly the same yield as T7 with a lower fertilizer dose, suggesting it as a cost-effective alternative. Therefore, farmers are encouraged to adopt T3 for optimal productivity and cost-efficiency.

ACKNOWLEDGEMENTS

This work was supported by the University of Rwanda through its research and innovation directorate under the collaboration of Sweden development agency (SIDA), competitive grant given to University of Rwanda fresh PhD graduate. Much appreciation is given to the management of University of Rwanda for their technical supports during the execution of this research.

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SCHOLARLY, PEER REVIEWED
Volume 25 No. 1
January 2025
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Number of leaves as influenced by organic and inorganic fertilizers at Rubona zone, Huye district, Southern Province

Treatments	Number of leaves plant^{-1}				
	30 DAP*	45 DAP	60 DAP	75 DAP	90 DAP
25t/ha organic manure (T0)	2.6	2.8	3.1	3.0	2.0
25t/ha organic manure + 50kgs/ha NPK (T_1)	3.0	3.8	4.1	4.1	3.0
25t/ha organic manure + 100kgs/ha NPK(T_2)	2.9	3.8	4.5	4.1	3.3
25t/ha organic manure + 150kgs/ha NPK (T_3)	3.1	4.6	5.6	5.0	4.0
25t/ha organic manure + 200kgs/ha NPk (T_4)	2.9	4.6	5.6	5.0	4.0
25t/ha organic manure + 250kgs/ha NPK (T_5)	2.9	4.7	5.6	5.0	4.0
25t/ha organic manure + 300kgs/ha NPK (T_6)	3.1	4.8	5.6	5.0	4.0
25t/ha organic manure + 350kgs/ha NPK (T_7)	3.2	5.0	5.9	5.3	4.1
S.E.M	0.07	0.06	0.2	0.5	0.41
Level of sign	0.02	2e-16	2e-16	2e-16	2e-16

DAP* - Days after Planting

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ISSN 1684 5374

Table 2: Number of leaves as influenced by organic and inorganic fertilizers at Tamira zone, Rubavu district, Western province and Musenyi zone, Bugesera district, Eastern Province

Treatment	Number of leaves plant^{-1}				
	30 DAP*	45 DAP	60 DAP	75 DAP	90 DAP
25t/ha organic manure (T_0)	2.6	2.9	3.1	3.0	2.9
25t/ha organic manure + 50kgs/ha NPK (T_1)	2.9	3.1	4.1	3.8	3.4
25t/ha organic manure + 100kgs/ha NPK(T_2)	3	3.1	4.8	3.8	3.6
25t/ha organic manure + 150kgs/ha NPK (T_3)	3.2	3.6	5.2	4.0	4.0
25t/ha organic manure + 200kgs/ha NPk (T_4)	3	3.6	5.4	4.2	4.0
25t/ha organic manure + 250kgs/ha NPK (T_5)	2.9	3.7	5.2	4.4	4.0
25t/ha organic manure + 300kgs/ha NPK (T_6)	2.7	3.8	5.4	4.2	4.2
25t/ha organic manure + 350kgs/ha NPK (T_7)	2.7	3.9	5.4	4.5	4.6
S.E.M	0.03	0.041	0.15	0.45	0.39
Level of sign	0.6	2e-16	2e-16	2e-16	2e-16
Number of leaves as influenced by fertilizers at Musenyi zone, Bugesera districts, Eastern Province					
25t/ha organic manure (T_0)	2.5	2.7	3.1	3.1	2.8
25t/ha organic manure + 50kgs/ha NPK (T_1)	2.0	2.9	4.1	4.0	3.1
25t/ha organic manure + 100kgs/ha NPK(T_2)	1.9	3.0	4.4	4.0	4.0
25t/ha organic manure + 150kgs/ha NPK (T_3)	2.2	3.9	5.3	4.9	4.4
25t/ha organic manure + 200kgs/ha NPk (T_4)	2.0	4.1	5.3	4.9	4.6
25t/ha organic manure + 250kgs/ha NPK (T_5)	2.2	4.3	5.2	5.0	5.0
25t/ha organic manure + 300kgs/ha NPK (T_6)	2.1	4.1	5.4	4.9	4.0
25t/ha organic manure + 350kgs/ha NPK (T_7)	2.2	4.4	5.4	5.1	4.5
S.E.M	0.02	0.05	0.2	0.4	0.41
Level of sign	0.8	2e-16	2e-16	2e-16	2e-16

DAP* - Days after Planting

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SCHOLARLY, PEER REVIEWED
Volume 25 No. 1
January 2025
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 3: Variation of plant height due to different rate of fertilizers at Rubona zone, Huye district, Southern Province

Treatment	Plant height (cm)				
	30 DAP*	45 DAP	60 DAP*	75 days	90 DAP*
25t/ha organic manure (T_0)	13.9	14.5	19.4	19.4	15.5
25t/ha organic manure + 50kgs/ha NPK (T_1)	13.4	15.2	25.2	24.5	15.0
25t/ha organic manure + 100kgs/ha NPK(T_2)	13.1	15.5	25.9	24.8	15.1
25t/ha organic manure + 150kgs/ha NPK (T_3)	13.6	17.7	29.5	28.2	20.8
25t/ha organic manure + 200kgs/ha NPk (T_4)	13.3	17.7	29.8	28.5	20.8
25t/ha organic manure + 250kgs/ha NPK (T_5)	12.6	17.8	29.9	28.0	20.6
25t/ha organic manure + 300kgs/ha NPK (T_6)	12.4	17.9	30.4	28.7	21.0
25t/ha organic manure + 350kgs/ha NPK (T_7)	13.0	18.1	30.6	28.1	21.2
S.E.M	0.17	0.43	1.43	1.54	1.68
Level of sign	0.02	2e-16	2e-16	2e-16	2e-16

DAP* - Days after Planting

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Volume 25 No. 1
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ISSN 1684 5374

Table 4: Variation of plant height due to different rate of fertilizers at Musenyi zone, Bugesera district, Eastern Province

Treatment	Plant height (cm)				
	30 DAP*	45 DAP	60 DAP*	75 days	90 DAP*
25t/ha organic manure (T_0)	12.5	13.4	14.2	14.2	13.0
25t/ha organic manure + 50kgs/ha NPK (T_1)	12.3	14.6	23.3	22.5	14.0
25t/ha organic manure + 100kgs/ha NPK(T_2)	12.3	14.6	23.5	22.8	14.2
25t/ha organic manure +150kgs/ha NPK (T_3)	12.6	16.8	28.6	26.0	19.2
25t/ha organic manure + 200kgs/ha NPk (T_4)	12.0	16.9	28.8	26.0	20.2
25t/ha organic manure +250kgs/ha NPK (T_5)	12.5	16.8	29.2	27.1	20.0
25t/ha organic manure +300kgs/ha NPK (T_6)	12.6	16.9	29.4	27.4	20.0
25t/ha organic manure +350kgs/ha NPK (T_7)	12.4	16.9	29.4	27.1	20.2
S.E.M	0.12	0.41	1.40	1.51	1.7
Level of sign	0.2	2e-16	2e-16	2e-16	2e-16

DAP* - Days after Planting

Table 5: Variation of plant height due to different rate of fertilizers at Tamira zone, Rubavu district, Western Province

Treatment	Plant height (cm)				
	30 DAP*	45 DAP	60 DAP*	75 days	90 DAP*
25t/ha organic manure (T_0)	12.2	12.5	19.4	19.4	18.0
25t/ha organic manure + 50kgs/ha NPK (T_1)	12.2	16.2	26.2	24.5	19.0
25t/ha organic manure + 100kgs/ha NPK(T_2)	12.1	16.6	26.4	24.5	19.2
25t/ha organic manure + 150kgs/ha NPK (T_3)	12.1	19.6	30.4	28.2	20.2
25t/ha organic manure + 200kgs/ha NPk (T_4)	12.3	19.7	30.5	28.4	20.6
25t/ha organic manure + 250kgs/ha NPK (T_5)	12.4	19.8	30.5	28.5	20.6
25t/ha organic manure + 300kgs/ha NPK (T_6)	12.3	19.8	30.4	28.5	21.3
25t/ha organic manure + 350kgs/ha NPK (T_7)	12.2	19.8	30.6	28.4	21.5
S.E.M	0.17	0.43	1.42	1.52	1.65
Level of sign	0.2	2e-16	2e-16	2e-16	2e-16

DAP* - Days after Planting

https://doi.org/10.18697/ajfand.138.24645

Table 6: Variation of yield parameters due to different rate of fertilizers at Rubona zone, Huye district, Southern Province

Treatment	Root length (cm)	Root diameter (cm)	Yield /plot (kg)	Marketable yield (kg)
25t/ha organic manure (T_0)	5.0[d]	1.2[b]	5.0[c]	3.3[b]
25t/ha organic manure + 50kgs/ha NPK (T_1)	9.4[c]	2.1[ab]	7.0[bc]	5.9[a]
25t/ha organic manure + 100kgs/ha NPK(T_2)	12.6[bc]	2.3[a]	7.5[ab]	6.1[a]
25t/ha organic manure + 150kgs/ha NPK (T_3)	14.7[ab]	2.5[a]	8.2[ab]	6.7[a]
25t/ha organic manure + 200kgs/ha NPk (T_4)	15.7[ab]	2.5[a]	8.4[ab]	6.8[a]
25t/ha organic manure + 250kgs/ha NPK (T_5)	15.6[ab]	2.6[a]	8.5[ab]	6.8[a]
25t/ha organic manure + 300kgs/ha NPK (T_6)	19.3[a]	2.8[a]	8.5[ab]	7.0[a]
25t/ha organic manure + 350kgs/ha NPK (T_7)	20.1[a]	2.8[a]	8.7[a]	7.1[a]
S.E.M	1.762	0.175	0.538	0.430
Level of sign	4e-10	2.26e-07	0.0035	0.0308

Table 7: Variation of yield parameters due to different rate of fertilizers at Tamira zone, Rubavu district, Western Province

Treatments	Root length (cm)	Root diameter (cm)	Yield /plot (kg)	Marketable yield (kg)
25t/ha organic manure (T_0)	4.0[d]	1.1[b]	4.0[c]	3.1[b]
25t/ha organic manure + 50kgs/ha NPK (T_1)	8.1[c]	2.1[ab]	7.0[bc]	4.8[ab]
25t/ha organic manure + 100kgs/ha NPK(T_2)	11.6[bc]	2.6[a]	7.6[ab]	5.2[ab]
25t/ha organic manure + 150kgs/ha NPK (T_3)	15.7[ab]	2.6[a]	8.7[a]	6.4[a]
25t/ha organic manure + 200kgs/ha NPk (T_4)	15.7[ab]	2.6[a]	8.7[a]	6.5[a]
25t/ha organic manure + 250kgs/ha NPK (T_5)	15.8[ab]	2.8[a]	8.7[a]	6.5[a]
25t/ha organic manure + 300kgs/ha NPK (T_6)	15.8[ab]	2.8[a]	8.8[a]	6.3[a]
25t/ha organic manure + 350kgs/ha NPK (T_7)	15.9[ab]	2.9[a]	8.8[a]	6.5[a]
S.E.M	1.662	0.163	0.514	0.427
Level of sign	3e-10	2.16e-07	0.0031	0.031

ajfand Since 2001 AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 25 No. 1
January 2025
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 8: Variation of yield parameters due to different rate of fertilizers at Musenyi site, Bugesera district, Eastern Province

Treatments	Root length (cm)	Root diameter (cm)	Yield /plot (kg)	Marketable yield (kg)
25t/ha organic manure (T_0)	6.2^{d}	2.8^{b}	4.3^{c}	4.2^{b}
25t/ha organic manure + 50kgs/ha NPK (T_1)	9.3^{c}	3.3^{ab}	7.4^{bc}	4.9^{ab}
25t/ha organic manure + 100kgs/ha NPK(T_2)	12.2^{bc}	4.6^{a}	7.7^{ab}	5.4^{ab}
25t/ha organic manure + 150kgs/ha NPK (T_3)	18.8^{ab}	4.6^{a}	9.1^{a}	7.1^{a}
25t/ha organic manure + 200kgs/ha NPk (T_4)	18.9^{ab}	4.6^{a}	9.2^{a}	7.3^{a}
25t/ha organic manure + 250kgs/ha NPK (T_5)	19.2^{ab}	4.7^{a}	9.0^{a}	7.0^{a}
25t/ha organic manure + 300kgs/ha NPK (T_6)	19.4^{ab}	4.7^{a}	9.2^{a}	7.3^{a}
25t/ha organic manure + 350kgs/ha NPK (T_7)	19.4^{ab}	4.8^{a}	9.2^{a}	7.3^{a}
S.E.M	1.24	0.114	0.496	0.375
Level of sign	2e-10	2.16e-07	0.002	0.028

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