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INFLUENCE OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH AND YIELD OF POTATO *(SOLANUM TUBEROSUM* L.*)* IN NYABIHU DISTRICT OF RWANDA

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ABSTRACT: The objective of this study was to evaluate the response of different organic and inorganic nutrients on physical growth and yield of potatoes in Nyabihu District. The experiments were conducted in farmer's fields in Nyabihu District during the agricultural seasons 2022 B (March - June 2022) and 2023 A (September 2022 – January 2023). The experiment was laid out in Randomized Complete Block Design (RCBD) with six treatments: T1 (Control), T2 (NPK), T3 (Compost), T4 (FYM), T5 (Compost + NKP), and T6 (FYM + NPK) in three replications. Physical growth and yield of the potato were evaluated. The collected data were subjected to ANOVA at 5 % level of significance and mean separation with Least Significant Difference (LSD). There was a significant difference in potato growth and yield at *P<0.05*. Compost combined with NPK had the highest influence on physical growth and yield followed by farm yard manure combined with NPK in both seasons. The least was control preceded by NPK alone. Crops performed better in season 2023 A than 2022 B. Therefore, combination of organic and inorganic fertilizer synergically influence potato yield than when applied individually and it should be given special attention to increase potato yield.

KEYWORDS: Inorganic fertilizer, organic fertilizer, potato, yield increment

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most used vegetables. It belongs to the large family of vegetables Solanaceae (Burke, 2016; CIP, 2023). It is grown and eaten in many countries than any other crop and it is grown in all continents except Antarctica (Burke, 2016). It originated in the highlands of South America before Spanish explorers brought the plant to Europe in the late 16th century and thereafter spread in the entire planet (FAO, 2020). It ranks the third most important food crop in the world after rice and wheat in terms of human consumption (CIP, 2023). Rwanda is the first producer of potato in East Africa and the third in Sub-Sahara Africa (USAID, 2016). More than a billion people worldwide eat potatoes, and global total crop production exceeds 374 million metric tons (CIP, 2023). Potato has gained an important consideration in human food due to its nutrients content.

Potato is essentially a food security crop with good prospects for increased domestic urban demand. It is mainly grown for source of food in many households and as a major source of income. It is among priority crops in Rwanda. Since its introduction, the Rwandan government has given it a substantial importance. Its production

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increased dramatically from 2,24,000 tons in 2013 to 6,000,000 tons in 2019 (Agriterra, 2020). Increase in potato production is linked to the increase in land utilized in potato production (Agriterra, 2020). Moreover, farmers supported by Agriterra noticed drastic increase in production per unit area from 10 t/ha in 2017 to 30 t/ha in 2020 (Agriterra, 2020). However, it was reported that average of productivity is still low being 8.6 t/ha in season A and 6.2 t/ha in season B of 2022 (NISR, 2022). This low productivity is related to different constraints in this sector which need to be dealt with in order to increase productivity of potato in all farmers.

Potato production in Rwanda is dominated by the use of inorganic fertilizers. During its introduction, mineral fertilizer was advocated to increase soil fertility and crop yield. It releases nutrients more rapidly which leads to the rapid development of the plant (Sharma and Chetani, 2017). However, in recent years mineral fertilizer was reported to increase soil acidity and cause nutrients imbalance (Atanaw and Zewide, 2021). Inorganic fertilizer has been reported that it can leach in soil, pollute water streams, water ponds and other water bodies (Sharma and Chetani, 2017). It can also leach away from the root zone, accumulate into the plant and harm people during consumption of food it contains (Sharma and Chetani, 2017). Accumulation of inorganic fertilizer was linked to high risk of cancer in humans (Sharma and Chetani, 2017). Consistent application of inorganic fertilizer leads to decline in soil micronutrients, depletion of organic matter, increase in acidity, degradation of physical property of soil and increase in erosion (Sharma and Chetani, 2017). Excessive application of nitrogen was linked to the reduction in quality of potato, environmental pollution, jeopardize public health, and leads to economic loss (Atanaw and Zewide, 2021). Nowadays consumers and environmentalists are reluctant on the use of inorganic fertilizers and there is a need to seek for alternative of reducing inorganic fertilizer.

Inorganic fertilizer can be reduced by shifting to the organic fertilizer. Organic fertilizers derived from organic sources and are used to enrich soil nutrients in food production. Both chemical and organic fertilizers were reported to contribute morphological, physiological and biochemical performance of the crop (Sharma and Chetani,2017). The use of organic fertilizer in soil amendment was reported to be environmentally friendly (Sharma and Chetani, 2017). Organic fertilizer prevents moisture loss, maintains soil temperature, facilitates microbial growth, prevents soil erosion and compaction; thus, maintaining soil fertility (Atanaw and Zewide, 2021). Organic fertilizer can be recommended for its healthy soil and moisture conservation potentiality. The benefits of organic fertilizers are enormous and this study aims at investigating its influence in potato production.

MATERIALS AND METHODS

Experimental site

The experiments were conducted in farmer's fields in Nyabihu District, Gisesero Cell during the agricultural seasons 2022 B and 2023 A. Nyabihu District is located in the western province of Rwanda. It is located on a volcanic mountain range whose altitude varies between 1800 and 2450 meters above sea level, 1°29′ of Latitude S and 29°39′ of Longitude E. The relief in Nyabihu is characterized by 90% rugged mountains with slopes of more than 55% creating a high risk of erosion. Soils comprise sandy and clay, laterite, and volcanic. Precipitation is almost uniform over every month and close

to 1400 mm per year. It has a climate with an average temperature of 15°C (Nyabihu District, 2019).

Experimental design and treatments

Experiment was laid out in Randomized Complete Block Design (RCBD) in two agricultural seasons 2022 B and 2023 A with six treatments replicated three times. The elementary plots had a dimension of 4 × 3 m, spaced 1m in the blocks and 2 m between the blocks. The sowing density was 80 × 30 cm between and within rows, respectively, which gave a total of 50 planting holes per elementary plot, and 41,667 plants/ha. The potato seeds of the Kinigi variety were obtained from a certified seed multiplier in Musanze District. The first and second plowings took place from January through February of 2022 B and from August through September of 2023 A, and planting was undertaken at the beginning of the rainy season when there was enough rainfall for planting (Mid-March 2022 B, and Mid-September 2023 A seasons).

Treatment rates were:

- T1: Control (untreated),
- T2: (Farmer practice, 150 kg of NPK/ha),
- T3: (Compost, 3,000 kg/ha),
- T4: (Farm yard manure, 3,000 kg/ha),
- T5 : [(Compost (3,000 kg/ha) + NPK (150 kg/ha)],
- T6: [Farm yard manure (3,000 kg/ha) + NPK (150 kg/ha)].

Data collection

In all seasons, randomly 5 plants were selected from each plot excluding border plants, and were used to measure various growth and yield parameters. The data on vegetative growth (plant biomass (number), plant height (cm), and plant diameter (cm) were collected at the period interval of 15 Days After Planting (DAP) starting at 45 DAP to 105 DAP. Yield data was taken after harvesting. Technical data collection sheets, rulers, and weighing scales were availed for that purpose. All data on the physical growth and yield were collected at the same sampled plant from all plots.

Statistical data analysis

Data were subjected to analysis of variance (ANOVA) appropriate to the RCBD in Microsoft Excel, and the treatment means were separated into homogeneous groups using the Least Significant Difference (LSD) at 5 % levels of significance.

RESULTS AND DISCUSSION

Plant leaf development (number)

Number of leaves of different treatments was significantly different at $P<0.05$ as presented in Tables 1 and 2. The number of leaves increased gradually from 45 DAP to 75 DAP in all sites and reduced at 90 DAP. In both seasons compost with NPK had the highest number of leaves and control was the lowest. Season 2022 B had the highest number of leaves than season 2023 A. Ratna *et al.* (2016) reported that the number of leaves was higher where NPK and compost were used together which is aligned with the results of this study. It was followed by the use of NPK alone while the control where no fertilizer was used was the least preceded by the use of combination of cow dung and poultry manure (Ratna *et al.*, 2016). Similarly, leaf index area followed the same trend of number of leaves (Ratna *et al.*, 2016). Organic manures were reported to increase the number of leaves (Suh *et al.*, 2015). The increase in number of leaves was also reported by Mama *et al.* (2016) due to combination of farm yard manure and nitrogen. Combination of organic manure

Table 1: Plant leaf development from 45 DAP to 90 DAP in season 2022-B

Treatments	45 DAP	60 DAP	75 DAP	90 DAP
Compost	41.1^{bc}	41.8^{f}	108.2^{a}	55.9d
Compost + NPK	47.5^{a}	55.2^{e}	116.7^{a}	62^{cd}
Control	23.9^{f}	69.8^{d}	86.4^{d}	68.3^{bc}
FYM	34.3d^{e}	75.8^{c}	92.5^{cd}	77.7^{a}
FYM + NPK	38.1^{c}	78.8^{b}	111.7^{a}	81.2^{a}
NPK	32.3^{e}	84.8^{a}	98.8^{bc}	86.2^{a}
General Mean	36.1	67.7	102.3	71.8
CV (%)	6.3	1.9	6.6	9.4
LSD (5%)	3.01	1.74	8.95	8.95

Means followed by the same letter(s) in a column are not significantly different by LSD at a 5 % level of significance, CV=Coefficient of variation, LSD=Least Significant Differences, DAP=Days After Planting

Table 2: Plant leaf development from 45 DAP to 90 DAP in season 2023-A

Treatments	45 DAP	60 DAP	75 DAP	90 DAP
Compost	38.9^{bc}	71.9^{c}	92.2^{a}	74.2^{a}
Compost + NPK	45.3^{a}	80.9^{a}	100.7^{a}	82.7^{a}
Control	21.7^{f}	37.9^{f}	70.4^{d}	52.4^{d}
FYM	32.1^{de}	65.9^{d}	76.5^{cd}	58.5^{cd}
FYM + NPK	35.9^{c}	74.9^{b}	95.7^{a}	77.7^{a}
NPK	30.1^{e}	51.3^{e}	82.8^{bc}	64.8^{bc}
General Mean	34.0	63.8	86.3	68.3
CV (%)	6.71	2.07	7.85	9.92
LSD (5%)	3.01	1.74	8.95	8.95

Means followed by the same letter(s) in a column are not significantly different by LSD at a 5 % level of significance, CV=Coefficient of variation, LSD=Least Significant Differences, DAP=Days After Planting.

and NPK was reported to influence cell division, cell growth and proliferation of auxiliary branches (Atanaw and Zewide, 2021). Number of leaves increases gradually as the crop grows and it is influenced by the applied fertilizer. Combination of NPK and compost dominated other treatments in increasing number of leaves.

Plant height (cm)

Plant height of different treatments was significantly different at *P<0.05* as depicted in Tables 3 and 4. Plant height increased gradually from 45 DAP to 90 DAP and reduced afterwards. Compost with NPK had the highest height and the least was for the control. Season 2022 B had the highest plant height than season 2023 A. The effect of organic and inorganic fertilizer on plant height was also reported by Ratna *et al.* (2016) where combination of poultry manure and NPK resulted in the tallest plants 30 DAP to 75 DAP. Similarly, the least was for the control where no fertilizer was used preceded by the use of organic fertilizer alone (Ratna *et al.*, 2016). Moreover, plant height was also reported to be influenced by integration of cow dung and NPK compared to the control (Suh *et al.*, 2015). A combination of farm yard manure with NPK was reported to have a better increase in plant height than farm yard or NPK applied individually (Mama *et*

Table 3: Plant height (cm) from 45 to 90 DAP in season 2022-B

Treatments	45 DAP	60 DAP	75 DAP	90 DAP
Compost	47.5[a]	87.7[a]	101.2[a]	102.2[a]
Compost + NPK	48.1[a]	96.2[a]	109.7[a]	110.7[a]
Control	37.1[d]	65.9[d]	79.4[d]	80.3[d]
FYM	44.3[b]	72[cd]	85.5[cd]	86.5[cd]
FYM + NPK	47.3[a]	91.2[a]	104.7[a]	105.7[a]
NPK	41[c]	78.3[bc]	91.8[bc]	92.8[bc]
General Mean	44.2	81.8	95.3	96.3
CV (%)	3.85	8.29	7.11	7.04
LSD (5%)	2.25	8.95	8.95	8.95

Means followed by the same letter(s) in a column are not significantly different by LSD at a 5% level of significance, CV=Coefficient of variation, LSD=Least Significant Differences, DAP=Days After Planting

Table 4: Plant height (cm) from 45 to 90 DAP in season 2023-A

Treatments	45 DAP	60 DAP	75 DAP	90 DAP
Compost	43.6[a]	80.2[a]	89.23[a]	96.01[a]
Compost + NPK	44.1[a]	88.7[a]	97.7[a]	104.4[a]
Control	33.1[d]	58.3[d]	67.36[d]	74.14[d]
FYM	40.4[b]	64.4[cd]	73.49[cd]	80.2[cd]
FYM + NPK	43.4[a]	83.7[a]	92.7[a]	99.4[a]
NPK	37.1[c]	70.8[bc]	79.84[bc]	86.6[bc]
General Mean	**40.3**	**74.3**	**83.3**	**90.1**
CV (%)	4.23	9.12	8.14	7.52
LSD (5%)	2.25	8.95	8.95	8.95

Means followed by the same letter(s) in a column are not significantly different by LSD at 5% level of significance, CV=Coefficient of variation, LSD=Least Significant Differences, DAP=Days After Planting

al., 2016; Atanaw and Zewide, 2021). Organic manure and inorganic fertilizer synergically increase plant height and optimum ratios should be use for a better growth.

Plant stem diameter (cm)

Plant stem diameter was significantly different in both seasons for all treatments at $P<0.05$ as shown in Tables 5 and 6. There was a steady increase in plant diameter from 45 DAP to 75 DAP for season 2022 B and reduced at 90 DAP while for the season 2023 A there was a steady increase in number of leaves up to 90 DAP. Initially, in season 2022 B compost and NPK had the highest diameter of 2.2 cm which reduced to 1.3 cm at 90 DAP. On the contrary, control was the least initially with 1.0 cm at 45 DAP which increased to 2.3 cm at 90 DAP. Overall, the highest increase was for farm yard manure for 1.7 to 2.5 after 45 and 90 DAP respectively. For season 2023 A, compost with NPK was the best throughout and control was the least. The study conducted in clay soil of Cameroon showed no significant influence of organic, inorganic fertilizers nor their combinations on the stem diameter of potato (Suh *et al*., 2015). On the other hand, Mama *et al*. (2016) evaluated effect of different rates of farm yard manure and nitrogen and it was reported that the combination of the two influenced positively the increase in diameter of potato

Table 5: Plant stem diameter (cm) from 45 to 90 DAP in season 2022-B

Treatments	45 DAP	60 DAP	75 DAP	90 DAP
Compost	1.8^{c}	2.3^{c}	2.3^{c}	2.1^{c}
Compost + NPK	2.2^{a}	1.5^{f}	1.5^{f}	1.3^{f}
Control	1.0^{f}	2.5^{b}	2.5^{b}	2.3^{b}
FYM	1.7^{e}	2.7^{a}	2.7^{a}	2.5^{a}
FYM + NPK	2.0^{b}	2.2^{d}	2.2^{d}	2^{d}
NPK	1.7^{d}	2.2^{e}	2.2^{e}	2^{e}
General Mean (GM)	1.7	2.2	2.2	2.0
CV (%)	3.9	3.0	3.0	3.3
LSD (5%)	0.09	0.09	0.09	0.09

Means followed by the same letter(s) in a column are not significantly different by LSD at a 5% level of significance, CV=Coefficient of variation, LSD=Least Significant Differences, DAP=Days After Planting

Table 6: Plant stem diameter (cm) from 45 to 90 DAP in season 2023-A

Treatments	45 DAP	60 DAP	75 DAP	90 DAP
Compost	1.8^{bcd}	2.3^{bacd}	2.2^{bcd}	2.2^{bacd}
Compost + NPK	2.2^{a}	2.7^{a}	2.6^{a}	2.6^{a}
Control	1.0^{e}	1.5^{e}	1.4^{e}	1.4^{e}
FYM	1.7^{d}	2.2^{d}	2.1^{d}	2.1^{d}
FYM + NPK	2.1^{a}	2.5^{a}	2.5^{a}	2.4^{a}
NPK	1.7^{cd}	2.2^{cd}	2.1^{c}	2.1^{cd}
General Mean	1.75	2.25	2.15	2.13
CV (%)	3.9	3.10	3.0	3.2
LSD (5%)	0.28	0.28	0.28	0.28

Means followed by the same letter(s) in a column are not significantly different by LSD at a 5% level of significance, CV=Coefficient of variation, LSD=Least Significant Differences, DAP=Days After Planting

stem. Increase in stem diameter of potato due to combination of organic and inorganic fertilizer was also reported by Atanaw and Zewide (2021) where combination gave better results than when they were applied separately. Organic fertilizer in combination with inorganic fertilizer have positive influence on stem diameter.

Yield of potato (t/ha)

Yield is important to evaluate effect of different treatments. There was a significant difference in yield for both seasons in all treatments at $P<0.05$ as presented in Table 7. Compost with NPK was the highest with yield of 61.83 t/ha and 69.33 t/ha in season 2022 B and 2023 A respectively. It was followed by compost with 55.28 t/ha and 62.78 t/ha for 2022 B and 2023 A respectively. The lowest in both seasons was control. Ratna *et al.* (2016) studied effect of organic and inorganic fertilizers on yield of potato and they reported that combination of poultry manure and NPK had the highest yield followed by NPK alone, while the lowest yield was obtained from combination of cow dung and poultry manure and the control. The effect of organic fertilizer on potato productivity was also reported by Suh *et al*. (2015) where combination of cow dung and foliar gave the highest productivity

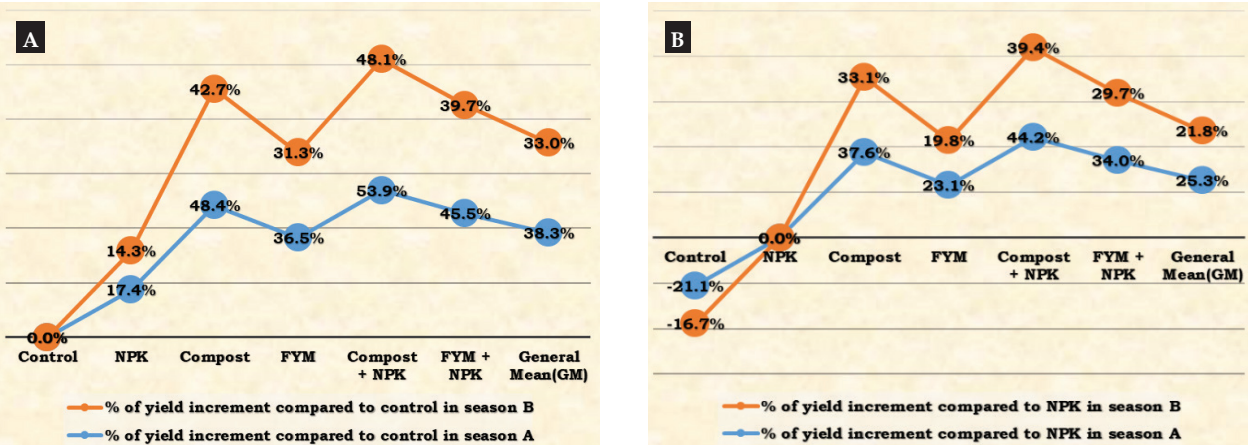

Fig.1. Percentage of Yield increment in seasons 2022 B and 2023 A compared to the control (A) and NPK (B)

Table 7. Comparative response of different organic and inorganic nutrient sources on the yield (t/ha) in the seasons 2022-B and 2023-A.

Treatment	Yield (t/ha) Season 2022-B	Yield (t/ha) Season 2023-A
Compost	55.28^{bc}	62.78^{bc}
Compost + NPK	61.83^{a}	69.33^{a}
Control	28.50^{f}	36.00^{f}
FYM	44.88^{d}	52.38^{d}
FYM + NPK	52.25^{c}	59.75^{c}
NPK	34.51^{e}	42.00^{ef}
General Mean (GM)	46.21	53.71
CV (%)	0.07	0.06
LSD (5%)	0.10	0.14

Means followed by the same letter(s) in a column are not significantly different by LSD at a 5% level of significance, CV=Coefficient of variation, LSD=Least Significant Differences, DAP=Day After Planting

in comparison to where inorganic fertilizer was used either alone or in combination with organic fertilizers. Similarly, control had the lowest yield compared to other treatments (Suh *et al*., 2015). Therefore, potato yield can be maximized by combination of organic and inorganic fertilizers in specific ratios.

Yield increment

Organic fertilizers influenced yield increment in both seasons as presented in figure 1. When compared to the control, the average of yield increment was 33.0% in season 2022 B and 38.3% in season 2023 A. when control was taken as baseline, the highest increment was obtained when compost was used together with NPK and the lowest when NPK was used alone. On the other hand, when NPK was used as the baseline, the average of yield increment was 21.8% for season 2022 B and 25.3% for season 2023 A. Similarly, the highest increment was obtained when compost was used together with NPK, while control had (Atanaw and Zewide, 2021). Increment of potato yield due to combination of organic and inorganic fertilizer was also reported by other authors (Suh *et al*., 2015; Ratna *et al*., 2016). Combination of organic and inorganic fertilizer can be given much attention for effective increase in potato yield.

CONCLUSION

The study on the response of different organic and inorganic nutrients on the physical growth and yield of potatoes *(Solanum tuberosum* L.*)* in Nyabihu District in agricultural seasons 2022 B and 2023 A revealed that organic fertilizers can increase significantly the physical growth and yield of potatoes. The combination of NPK with organic manure showed a better plant growth with a better yield. Compost with

NPK had the highest yield followed by farm yard manure with NPK in both seasons. Control had the lowest yield preceded by the application of NPK alone. Organic fertilizer when applied individually had a better yield than inorganic but still lower than combination of organic and inorganic fertilizers. Organic and inorganic fertilizers when applied together synergically increased potato yield. Therefore, to obtain a high yield, NPK should be applied with organic compost at specified ratios.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

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