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GROWTH AND YIELD RESPONSE OF POTATO (*SOLANUM TUBEROSUM* L*)* TO ORGANIC AND BLENDED FERTILIZERS

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ABSTRACT: Appropriate nutrition management of the potato crop is crucial during the entire growth period as part of a successful agronomic strategy. In places of mid and high altitude where present yields of potato (Solanum tuberosum L.) are less than 10 t ha^{-1}, where production is severely hampered by inadequate soil fertility, Ethiopia has a significant potential to boost potato production and productivity. A field experiment was conducted to determine the effects of integrated application of blended NPS fertilizer and compost on growth, yield parameters and yield of potato (Solanum tuberosum L.), variety 'Belete' under irrigation at Efrata Gidim District, North Showa, Ethiopia in 2022 cropping season. The treatments consisted of four Nitrogen-Phosphorus-Sulfur (NPS) blended fertilizer levels (0, 50,100 and 150 kg ha^{-1}) and three compost levels (0, 10 and 20 t ha^{-1}). The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times. Data were collected and statistically analyzed using SAS version 9.2 software. The findings revealed that the highest marketable tuber number per plant (14.1), total tuber number per plant (17.6), marketable tuber yield (13.0 t ha^{-1}) and total tuber yield (15.48 t ha^{-1}) were obtained from combined application of 150 kg ha^{-1} NPS blended fertilizer and 20 t ha^{-1} compost. The integrated application of nutrients might have benefited the crop to access the essential elements for growth and development. The result can be temporarily recommended for potato producers around the study areas and similar agroecologies.

KEYWORDS: Compost; NPS fertilizer; Marketable tuber; Steam number; Tuber yield

INTRODUCTION

The potato (*Solanum tuberosum* L.), a member of the Solanaceae family and the genus Solanum (Reddy *et al*., 2018) is the 4th most significant food crop in the world after rice, wheat, and maize (Mangal *et al*., 2022) but it ranked 1st among the non-cereal crops (Muhie, 2022b). By giving small-holder farmers direct and immediate access to nutritious food, raising household income, and lowering their vulnerability to fluctuates in food prices, potato cropping methods serve to promote resilience, especially among small-holder farmers (Mitiku *et al*., 2019).

The potato is a crop with a significant potential for guaranteeing food security in Ethiopia because of its high nutritional content, high - yielding potential, quick growth, and broad range of plasticity (Tewodros *et al*., 2014). As one of the essential crops mentioned in the Millennium Development Goals for guaranteeing food security and the elimination of poverty, potatoes were designated as the crop of the year by the United Nations in 2008. Since the price of potatoes is more impacted by local supply and demand than by the global market, it might still help provide food security. The early maturity of potatoes and their short growing cycle are further advantages of potatoes over many other crops. In the primary cropping season of Ethiopia, over 1.04 million households produced 1,141,871.7 t of potatoes on an estimated 85, 988 hectares of land. However, the productivity of this crop in the country is rather poor when compared to the global average yield of 19 tha^{-1} (13.28 t ha^{-1}) (CSA, 2021).

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Potatoes are extremely dependent on the nutrient status in the soil due to their short, coarse, and underdeveloped root structure. The crop generates much more dry matter in less time than most soils can typically provide, exhausting a large amount more nutrients per unit of time (King *et al*., 2020). Use of organic manure and inorganic fertilizers may have a major impact on the production of the potato crop. Organic manures and their extracts have been shown to increase soil fertility, soil structure, and plant resistance to pests and diseases (Muhie, 2022c; Raghunandan *et al*., 2019). Research on organic manure is required because of worries about soil drowsiness and nutritional imbalances created by excessive and careless application of inorganic fertilizers, even though these mineral fertilizers such as NPS can be used to replenish soil nutrients and boost agricultural yields. However, because of its limited availability, poor nutrient content, high application rates, and labor-intensive nature, using organic fertilizer alone might not completely meet crop nutritional needs (Osterholz *et al*., 2017). Producers should apply novel approaches and practices for sustainable production of high value crops thereby improve their livelihood (Muhie, 2022a). Integrated application of organic fertilizers (compost, vermicompost, manure) and inorganic fertilizers (blended) could substantially influence the yield of potato.

These integrated use of these blended fertilizers with compost have not been studied due to previous research on fertilizer determination being restricted to the two common macronutrients, N and P. Under irrigation and rain-fed circumstances, local farmers grow potatoes for both food and profit. Nevertheless, there isn't a thorough prescription for NPS fertilizers for the local irrigation systems. This continues to discourage local farmers from looking into more effective methods of growing potatoes. In light of these worries, it was aimed that experiments about integrated use of organic and blended fertilizers would shed some light on the effects of various fertilizer concentrations on productivity and related factors, such as potato growth, tuber yield, size distribution, and related yield qualities. Therefore, direct investigation of the response of potato to integrated application of blended inorganic fertilizer (NPS) and organic fertilizer (compost) was required to come up with optimum fertilizer recommendations rates so as to improve productivity of the potato crop.

MATERIALS AND METHODS

Description of the Study Area

The experiment was carried out in Ethiopia's Efrata Gidm district's North Shewa zone during the 2022 growing season under irrigation. The region lies 273 kilometers from Addis Ababa in the north-eastern region of Ethiopia. Geographically, the region is located at 10° 33' N latitude, 39° 35' E longitude, and 1470 meters above sea level (masl) elevation (Figure 1).

The area's agroecology includes kola (low land), woyna dega (mid land), and dega (high land). The area's minimum and highest temperatures are 12 and 30 degrees Celsius, respectively. The average annual rainfall is 1004 millimeters. The soil at the test site has a typically clay loam texture. The major horticultural crops grown in the study area are potato, onion, paper, tomato and cabbage (Efrata Gidim Woreda ARDO, personal communication).

Experimental Materials

The potato cultivar "Belete" from the Debre-Birhan Agricultural Research Center (located at latitude 9º 67□□ and longitude 39º 53□) was used as a test crop. It is intended

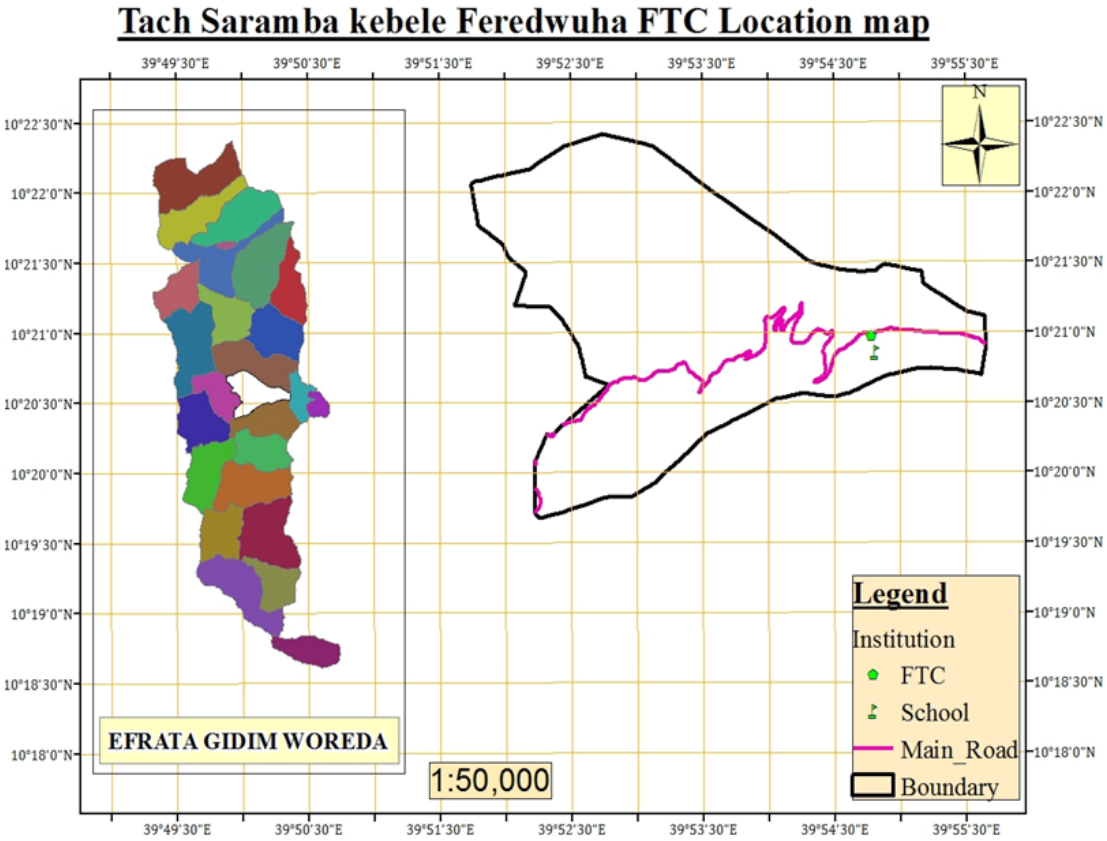


Figure 1. Map of study area

for altitudes of 1600 to 2800 masl. It is the cultivar that is most regularly farmed in North Showa, Ethiopia. For planting, medium-sized, equally-sized tubers that had a healthy sprout were utilized.

Experimental treatments, design and procedures

The treatments consisted of four level of NPS blended fertilizer application rates (0, 50, 100 and 150kg ha^{-1}) and three level of compost rates (0, 10 and 20t ha^{-1}), which were assigned randomly to each plot. The experimental design was laid out in a Randomized Complete Block Design (RCBD) in three replications with path width of 1 meter between plots and 1.5 meter between blocks. The gross size of experimental plot was 3 m x 3 m (9 m^2) accommodating 4 rows of potato at a spacing of 75 cm between rows and 30 cm between plants.

Soil Properties before Planting

As shown in Table 1, the soil's physical and chemical characteristics in the experimental field. The experimental site's soil textural class was sandy clay loam. Hazelton & Murphy, (2016) rated the soil of the experimental field as having a slightly acidic pH (6.5), very low levels of organic carbon (0.50%), very low levels of organic matter (0.86%), low levels of total nitrogen (0.12%), and extremely low levels of available phosphorus (7.56 mg kg^{-1}). The soil's Cation Exchange Capacity (CEC) was 39.84 cmol kg^{-1} (Table 1). CEC normally increases as pH, clay, and organic matter levels rise because clay and organic particles have the capacity to draw and hold cations.

Table 1. Soil physical and chemical properties of the experimental site before planting at Efrata Gidim in 2022

Physical properties				Chemical properties					
Particle size Distribution (%)				pH	OC (%)	OM (%)	Total N (%)	Available P (Mg kg^{-1})	CEC (Cmol kg^{-1})
Sand (%)	Silt (%)	Clay (%)	Textural Class						
52	21	27	SCL	6.5	0.50	0.86	0.12	7.56	39.84

Where: - OC- organic carbon, OM- organic matter, TN- total Nitrogen, Available P. - available phosphorus, CEC- Cation exchange capacity and SCL- Sandy Clay Loam.

The Cation exchange capacity of the soil is a crucial factor to take into account in order to identify the type of clay mineral present in the soil and its capacity to prevent nutrients from leaching. As a result, it is reasonable to deduce from the soil analysis results that nitrogen and phosphorus may be factors that limit the output of potatoes grown in the area.

Method of Data Collection and Analysis

Plants in the plot area were used to collect all the growth and yield parameters such as lant height, main stem numbers, marketable tuber numbers per plant, unmarketable tuber numbers per plant, total tuber number plant, marketable tuber yield per hectare, total tuber yield per hectare.

RESULTS AND DISCUSSION

Plant height

On plant height, the major impacts of the NPS mixed fertilizer and compost rates as well as their interactions were very significant ($P<0.01$). The 150 kg NPS ha^{-1} + 20 t compost ha^{-1} treatment combination produced the tallest plant height (111 cm). The mean plant height grew as the different rates of NPS mixed fertilizers were raised from zero to 150kg ha^{-1}. Similar to this, raising the various compost rates from zero to 20 t ha^{-1} also increased plant height (Table 2).

The current finding is consistent with Ababiya, (2018), who showed that plots fertilized with cattle manure at a rate of 20 t ha^{-1} and NPK 150 kg ha^{-1} had higher values of plant height than plots fertilized with just cattle manure or NPK mineral fertilizer. The results are also consistent with those of Zewide *et al*., (2018), who reported that the integrated application of organic and inorganic fertilizers may be attributed to the provision of adequate micro and macronutrients. This improvement in micronutrient availability is likely what helped to increase metabolic activity during the early growth phase, which in turn likely helped to promote overall growth. The majority of the necessary nutrients were provided by the organic manure and inorganic fertilizer during the growth stage, which led to a rise in growth variables, including plant height (Itelima *et al*., 2018). Lombardo *et al*., (2020) found that plants grown with N and P fertilizer and CM were noticeably taller than those in the control plots, which is consistent with our findings.

Table 2. Interaction effect of NPS blended fertilizer and compost on plant height (cm) at Efrata Gidim District in 2022

	NPS rate (kg ha^{-1})				
Compost (t ha^{-1})	0	50	100	150	Mean
0	87.87^{h}	93.7^{ef}	93.23^{fg}	98.27^{cd}	93.27
10	89.27^{gh}	98.2^{cd}	100.57^{c}	105.0^{b}	98.26
20	95.8^{def}	97.43^{cde}	107.83^{ab}	111.0^{a}	103.02
Mean	90.98	96.44	100.54	104.76	
LSD (0.05)			4.14		
CV (%)			2.49		

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

Marketable tuber numbers per plant

The highest marketable tuber numbers per plant (14.1) was recorded from treatment combination of 150 kg NPS ha^{-1} + 20 t compost ha^{-1} followed by (13.17) from treatment combination of 150 kg NPS ha^{-1} + 10 t compost ha^{-1} (Table 3). The marketable tuber numbers per plant increased with increasing compost application rate because the compost applied to soil might have resulted in an increase in carbon mineralization in the soil due to available carbon for microbial respiration and provision of nitrogen. However, the lowest marketable tubers numbers per plant (7.13) was obtained from treatment combination of zero NPS and zero compost of the control plots (Table 3).

The synergistic effect of mineral NP and cattle manure could be responsible for the high marketable tuber yields attained by the combined application of mineral and organic fertilizers (Zewide *et al*., 2021). The presence of an acceptable amount of nitrogen may have improved vegetative growth and increased photoassimilation, both of which contributed to the highest observed marketable number of tubers per hill from the highest combined application of NPS mixed fertilizer and cattle dung (Getacher, 2021). Similarly, Wilkinson *et al*., (2020) demonstrated that the number of marketable tubers increased significantly as the sulfur rate increased. This is likely because sulfur plays a role in the synthesis of sulfur-containing amino acids, proteins, energy conversion, and enzyme activation, all of which improve carbohydrate metabolism and the photosynthetic activity of plants with increased chlorophyll synthesis. This was crucial for the processes of photosynthesis and net assimilation, and it appears that no re-absorption from the tubers occurred, resulting in an increase in tuber size and weight so the tuber could be marketed.

Table 3. Interaction effects of NPS blended fertilizer and compost on marketable tuber numbers per plant of potato at Efrata Gidim District in 2022.

	NPS rate (kg ha^{-1})				
Compost (t ha^{-1})	0	50	100	150	Mean
0	7.13^{e}	10.57^{c}	10.63^{c}	10.67^{c}	9.75
10	8.7^{d}	10.97^{bc}	11.8^{b}	13.17^{a}	11.16
20	10.5^{c}	11.27^{bc}	11.93^{b}	14.1^{a}	11.95
Mean	8.78	10.94	11.45	12.65	
LSD (0.05)			0.98		
CV (%)			5.26		

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

Total tubers numbers per plant

The main effect of NPS fertilizer and compost rates highly significantly ($P<0.01$) influenced total tuber numbers per plant while, the interaction effect of NPS fertilizers with compost rates was significant ($P<0.05$) influenced total tuber numbers per plant. The highest total tuber numbers per plant (17.6) was recorded from treatment combination of 150 kg NPS ha^{-1} + 20 t compost ha^{-1} (Table 4). The total tuber numbers per plant was increased with combined application of organic and inorganic fertilizers compared to sole application of NPS blended fertilizers and compost. This might be due to its higher nutrient composition and capacity to increase availability of native soil nutrient through higher biological activity. The lowest total tuber numbers per plant (9.57) was recorded from treatment combination of zero NPS and zero compost of the control plots (Table 4).

The result of this study is in agreement with Bhujel *et al*., (2021) who reported that the increase in total tuber numbers per plant is in response to the increased application of the combined NPS fertilizers and CM might be due to the increased photosynthetic activity and translocation of synthesized

Table 4. Interaction effects of NPS blended fertilizer and compost on total tuber numbers per plant of potato at Efrata Gidim District in 2022.

	NPS rate (kg ha^{-1})				
Compost (t ha^{-1})	0	50	100	150	Mean
0	9.57^{g}	13.57^{e}	13.87^{e}	13.97^{de}	12.75
10	11.23^{f}	14.4^{cde}	15.23^{bcd}	16.57^{ab}	14.36
20	13.53^{e}	14.7^{cde}	15.43^{bc}	17.6^{a}	15.32
Mean	11.44	14.22	14.84	16.05	
LSD (0.05)			1.35		
CV (%)			5.67		

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

Table 5. Interaction effects of NPS blended fertilizer and compost on marketable tuber yield (quintal ha^{-1}) of potato at Efrata Gidim District in 2022

	NPS rate (kg ha^{-1})				
Compost (t ha^{-1})	0	50	100	150	Mean
0	6.23^{f}	7.69^{de}	7.8^{de}	8.87^{d}	7.58
10	6.73^{ef}	10.83^{c}	11.59^{bc}	12.26^{ab}	10.35
20	7.22^{e}	10.87^{c}	12.26^{ab}	13.0^{a}	10.84
Mean	6.64	9.79	10.55	11.37	
LSD (0.05)			1.21		
CV (%)			7.47		

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

product/photo assimilate to the root, which is probably helped in the initiation of more stolon in potato. Taheri *et al*., (2011) also found the highest ratio (13.07%) of number of large tubers as a result of application of 20 t compost ha^{-1} of combined with 225 kg P ha^{-1} and 50 kg zinc ha^{-1}. Other researchers also reported significant tuber numbers per plant increment in response to increasing N rates and increase in cattle manure application (Masrie *et al*., 2015).

Marketable tuber yield

The analysis of variance showed that main effect of NPS blended fertilizer and compost rates and their interaction showed significant (P<0.01) effect on marketable tuber yield of potato. The highest marketable tuber yield (265.6 q ha^{-1}) was recorded from treatment combination of 150 kg NPS blended fertilizer ha^{-1} + 20 t compost ha^{-1} followed by 150 kg NPS blended fertilizer ha^{-1} + 10 t compost ha^{-1} and 100 kg NPS blended fertilizer ha^{-1} + 20 t compost ha^{-1} with marketable tuber yield of 12.258 and 12.257 tha^{-1} respectively (Table 5). However, the lowest marketable tuber yield (6.23 tha^{-1}) was recorded from treatment combination of zero NPS and zero compost of control treatment (Table 5). The control plot produced the lowest values for marketable tuber yield of potato, due to the absence of adequate nutrient level needed for proper growth, development and yield.

The result of this study is in agreement with Amin, (2018) who showed that combining mineral fertilizers with cattle manure prolonged the release and added more macro and micro nutrient thereby promoting better crop growth and marketable tuber yield of potato. The possible reasons for the maximum marketable tuber yield ha^{-1} observed with the higher combined application of NPS blended fertilizer and CM could be due to a function of total biomass production, the percentage of biomass that is partitioned to the tubers, the moisture content of the tubers and the proportion of tubers that are acceptable to the market, in terms of size and lack of defects; and great opportunities exist to increase potato yield and quality by improving nutrient management (Mekashaw *et al*., 2020).

Total tuber yield

The main effects of NPS blended fertilizer and compost rates had highly significant (P<0.01) effect on total tuber yield, while, the interaction effect of NPS blended fertilizers

and compost had significant ($P<0.05$) influence on total tuber yield of potato. The highest total tuber yield (316.33 q ha^{-1}) was obtained from combined application of 150 kg NPS blended fertilizer ha^{-1} + 20 t compost ha^{-1} followed by 150 kg NPS blended fertilizer ha^{-1} + 10 t compost ha^{-1} and 100 kg NPS blended fertilizer ha^{-1} + 20 t compost ha^{-1} with total tuber yield of 14.55 and 14.48 tha^{-1} respectively (Table 6). On the other hand the lowest total tuber yield (7.83 tha^{-1}) was obtained from the treatment combination of zero NPS and zero compost of control treatment (Table 6).

The result of this study is in agreement with Balemi, (2012) who reported that application of 20 or 30 t ha^{-1} FYM + 66.6% of the recommended inorganic NP fertilizers significantly increased total tubers yield. The presence of nutrients in manure and balanced supplement of nitrogen and phosphorus through mineral fertilizers might have contributed to increased cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters (Mohammadi *et al.,* 2013).

This result is consistent with that of Ababiya, (2018), who reported that the variation in the rate of application of organic manure and inorganic fertilizers could influence the yield of potato. Atanaw, (2021) also observed that tuber yield was increased by the combined use of cow dung and NPK (20: 10: 10) compared to sole application of cow dung or NPK. Maximum tuber yield (36.8 t ha^{-1}) was obtained by using 150 kg N ha^{-1} + 20 t CM ha^{-1} (Darzi et al., 2012).

Table 6. Interaction effects of NPS blended fertilizer and compost on total tuber yield (tha^{-1}) of potato at Efrata Gidim District in 2022.

	NPS rate (kg ha^{-1})				
Compost (t ha^{-1})	0	50	100	150	Mean
0	7.83^{g}	9.74^{ef}	9.86^{ef}	10.99^{e}	9.60
10	8.74^{fg}	12.98^{d}	13.78^{bcd}	14.55^{ab}	12.51
20	9.05^{fg}	13.1^{cd}	14.48^{abc}	15.48^{a}	13.03
Mean	8.54	11.94	12.71	13.67	
LSD (0.05)			1.42		
CV (%)			7.18		

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

CONCLUSIONS

Potato is a tuber vegetable which is considered as heavy feeder. It growth and yield response to the application nutrients is significant. In the present study the combined application of blended NPS fertilizer and compost improved growth, yield and yield components of potato. Accordingly, the highest marketable tuber number per plant (14.1), total tuber number per plant (17.6), marketable tuber yield (13.0 t ha-1) and total tuber yield (15.48 ha^{-1}) were obtained from combined application of 150 kg ha^{-1} NPS blended fertilizer and 20 t ha^{-1} compost. When the rate of NPS and compost increased, all the growth and yield parameters of potato also increased. The integrated application of nutrients might have benefited the crop to access the essential elements for growth and development. The soil of the experimental site is also low in nutrient such as N and P. Hence, the application of compost could benefit the crop through supply nutrients and modification of the soil structure. The experiment clearly indicated the benefits of integrated nutrient management (organic and inorganic fertilizers). The result can be temporarily recommended for potato producers around the area and similar agroecologies. However, to validate the findings of the current experiment, it has to be repeated across seasons and locations with different types of organic fertilizers.

CONFLICT OF INTEREST

The authors confirm that this manuscript has no conflict of interest.

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