Effect of Fertilizer Source and Variety on Growth and Yield of Potato (*Solanum tuberosum*) at South Omo Zone, Southern Ethiopia

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Abstract: - The main problem in Ethiopia is food insecurity. The potato has been recognized by the Ethiopian government as a strategic crop to increase food security and farmers' incomes. Potato yields are strongly influenced by agronomic practices such as crop management, fertilizer source and variety. The country's productivity is far below than of the world. Therefore, this study aimed to investigate the effect of fertilizer source and potato variety on growth and tuber yield. The field trial was carried out in a factorial design with the RCBD and repeated three times in each case. The experiment included four fertilizer sources (Control, DAP, NPS and NPSB) and four potato varieties (Local, Gudenie, Belete and Jalenie). During the experiment: data on growth and yield parameters were collected. Experimental results showed that the interaction between fertilizer source and variety was very significant in terms of physiological maturity, number of main shoots, average tuber weight, marketable tuber weight in t/ha and non-marketable tuber yield in t/ha. The interaction of NPBS mixed with the Jalenie cultivar was found to provide a maximum commercial tuber yield of 23.04 t/ha. Because of this, we were advised to use NPSB and urea fertilizer with variety Jalenie to get the maximum marketable tubers yield under condition of little rainfall and a prolonged dry period.

Keywords: Fertilizer Source; Variety of Potatoes; Growth; Tuber Yield

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1. Introduction

The potato (*Solanum tuberosum*) is the most important root and tuber crop in the world. It is grown in more than 125 countries and consumed almost every day by more than a billion people. Hundreds of millions of people in developing countries depend on potatoes for their livelihoods (FAO, 2014). Their ability to produce food in large quantities per unit area and time (Israel *et al*., 2012) and their ease of cultivation and nutritional content have made them a valuable crop for food security and for millions of farmers (FAO, 2014).

Global and African annual production in 2018 was about 368.2 and 26 million tons, respectively (FAOSTAT, 2020). Ethiopia has one of the largest producers in East Africa due the agroecology and domestic consumption of the product (Tekalign, 2006; Brasesco *et al*., 2019). According to 2015/16 census data a total area of about 496,148.99 ha and 7.21 million tons of land was occupied and produced by root and tuber crops, of which about 296,578 ha (60%) and over 3.67 million tons (51%) potato, national productivity exceeds 12 t/ha, with average yields of advanced farmers well above 30 t/ha (CSA, 2016), but this performance is considered low compared to other countries.

The use of fertilizers in Ethiopia for several years has mainly focused on the use and application of nitrogenous and phosphate fertilizers in the form of diammonium phosphate (DAP) and urea to almost all crops for commercial and food security purposes. Such imbalanced use of plant nutrients can exacerbate the depletion of other important soil nutrients such as K, Mg, Ca, S and micronutrients. In Ethiopia, nutrient deficiency is the most important yield-limiting factor in vegetable production (Alemu and Ermias, 2000). The use of sustainable fertilizers is the basis for achieving higher agricultural production from existing agricultural land (Amalfitano *et al*., 2017; Caruso *et al*., 2019). It improves sustainable production and provides nutrients to plants based on their physiological needs and expected yields (Ryan, 2008). Therefore, this study aims to evaluate the effect of fertilizer source and potato variety on growth and yield of potato at Debub Ari, Southern Ethiopia.

2. Materials and methods

Description of study area

The experiment was conducted in 2022 during the main rainy season ("*Belg*") in Debub Ari districts at the South Omo Zone of southern Ethiopia which is located 769 km from Addis Ababa 17 km from the city of Jinka at 5°52'N, 36°38'E and 1605m elevation (Shiferaw, 2014). The precipitation regime in the area is bimodal (*Belg*: from February to April and *Meher* from July to September). The average annual precipitation of the district ranges from 601 to 1600 mm. The mean annual temperature is between 10 and 20 °C (Dilamo *et al*., 2021).

Treatment and Experimental Design

The experiment was performed in a factorial design using a three-replicate fully randomized block (RCBD) design. The trial included four potato varieties (*Belete*, *Gudenie*, *Jalenie* and *a Landrace*) and four fertilizer sources (control, DAP 195 + Urea 165 kg ha^{-1}, NPS 236.05 + urea 151 kg ha^{-1} and NPSB 237.93 + Urea 150 .72 kg ha^{-1}). Derived according to general national recommendations DAP 195 kg ha-1 (contains 89.7 kg P2O5 and 35.1 kg N) and urea 165 kg ha-1 (contains 79.2 kg N). Urea is used as a source of nitrogen fertilizer. The experimental course consisted of 16 treatment combinations.

Experimental procedure

Before sowing, the experimental field was ploughed four times by hand at intervals of 14 days. After soil preparation, tubers were planted (March 16, 2022) on well-prepared experimental plots of 9 m^2 (3 x 3 m; distance between plots and blocks 1m and 1.5m, respectively) and 40 seedlings were planted at a distance of 75cm x 30cm placed between rows and plants. There were 16 story arcs per block and a total of 48 story arc numbers. The type of fertilizer is applied at planting, using urea in particulate form (50% applied at planting and the remaining 50% before flowering 45 days after planting) as the main application method. Cultural practices such as weed control, cultivation and crop protection were consistently applied to all treatments as recommended by EIAR (2007).

Soil Samples and Analysis

Prior to surface seeding, a mixed soil sample was collected from the site characterization test field and the soil sample was collected in a zigzag pattern to a depth 30cm using an auger was used to collect the mixed sample. The collected sample was appropriately tagged, bagged and shipped to Hawassa Soil Laboratory and prepared for analysis according to standard procedures. The following soil test results were observed.

Table 1: Physico-chemical properties of experimental field at Gazer (Philla FTC)

No.	Parameter	Analysis result	No.	Parameter	Analysis result
1	Soil class	Clay	7	TN (%)	0.23
2	pH (H_2O) 1:2.5	5.28	8	Available P (ppm)	17.65
3	EC (ds/m)	0.94	9	B (ppm)	1.24
4	CEC (meq/100g	25.17	10	S (ppm)	14.28
5	OC (%)	3.81	11	Available K (ppm)	134.23
6	OM (%)	5.49	12	Cu (ppm)	12.58

Data collection

The parameters related to growth, yield and net yield components of each plot were collected using standard methods to avoid edge effects. Growth parameters included plant height, number of shoots per hill, flowering and maturity dates. Yield parameters: fresh weight and dry matter content, marketable tuber yield and non-marketable tubers as well as the total tuber yield were recorded. The tubers were harvested once (July 22, 2022) when the plants had reached physiologically matured (75% of the leaves had withered).

Data Analysis

The data collected for all potato parameters were subjected to analysis of variance (ANOVA) using SAS statistical software and a separation of means was performed using Duncan's multi-test range - means based on the ANOVA results.

3. Result and Discussion

Effect of fertilizer source and variety on growth parameters

The interaction between fertilizer source and variety had a very significant effect ($p<0.001$) on the number of days to physiological maturity and number of shoots per cluster (Table 2). However, other growth parameters (50% flowering day, number of main shoots per hill and plant height) were not significantly affected by the interaction between fertilizer source and cultivar.

Table 2: Fertilizer Source and Variety Interaction Effect on Growth Parameters

Treatment Combination		D50% F	DPM	NSpH	NsSpH	HP
Fertilizer source	**Variety**					
Control	Local	64.48^{cd}	96.13^{bc}	2.17^{i}	32.83^{f}	52.13^{g}
	Gudenie	60.31^{cd}	87.42^{g}	3.13^{defg}	46.33^{def}	71.27^{bcd}
	Jalenie	71.58^{ab}	96.08^{b}	2.93^{efgh}	45.40^{def}	63.60^{fg}
	Belete	61.42^{cd}	91.83^{def}	3.80^{abcd}	47.20^{de}	76.40^{abcd}
DAP + Urea	Local	63.44^{cd}	92.42^{def}	1.82^{i}	37.12^{ef}	56.07^{g}
	Gudenie	58.83^{d}	90.82^{ef}	3.33^{cdefg}	44.40^{def}	83.13^{ab}
	Jalenie	71.58^{ab}	96.82^{b}	3.93^{bcdef}	55.07^{bcd}	68.73^{cdf}
	Belete	61.50^{cd}	93.84^{cd}	4.40^{bc}	66.73^{ab}	77.80^{abc}
NPS + Urea	Local	64.40^{cd}	95.37^{bc}	2.37^{ghi}	34.23^{ef}	58.17^{fg}
	Gudenie	63.23^{cd}	90.17^{f}	3.47^{bcdfg}	51.60^{cd}	76.13^{abcd}
	Jalenie	74.103^{a}	95.81^{bc}	3.33^{cdefg}	52.53^{cd}	64.00^{dfg}
	Belete	61.10^{cd}	93.96^{cd}	4.67^{b}	61.13^{abc}	74.60^{abcd}
NPSB + Urea	Local	65.64^{bc}	92.00^{def}	2.70^{fghi}	42.40^{def}	57.90^{fg}
	Gudenie	59.42^{cd}	93.50^{cde}	4.67^{bcd}	63.13^{abc}	85.73^{a}
	Jalenie	70.58^{ab}	99.62^{a}	6.33^{a}	52.27^{cd}	71.80^{bcd}
	Belete	61.90^{cd}	93.95^{cd}	4.07^{bcde}	69.00^{a}	74.47^{abcd}
CV		5.21	1.60	17.88	14.55	9.48
P-Value		0.9229	0.0002	0.0001	0.2317	0.6608

D50%F= Day to 50% flower; DPM=day to physiological maturity; NSpH= Number of shoot per hill; NsSpH= Number of sub shoot per hill; HP= Height of plant in cm; CV= coefficient of variation

Days to physiological maturity: The maximum number of days to physiological maturity (99.62) was recorded from the interaction of the NPSB fertilizer source with the *Jalenie*. Consecutive days (96.62 and 96.08) were scored based on the interaction of DAP and control fertilizer sources, respectively, with the *Jalenie* cultivar. Minimum number of days required to reach physiological maturity (87.42) recorded from interaction of the control fertilizer source with the *Gudenie* variety. This showed that the interaction of NPSB fertilizer with the *Jalenie* cultivar tended to increase the number of days required to reach physiological maturity. The result of the study agrees with the finding of Yohanne *et al*., (2021) who's reported that the number of days to physiological maturity influenced by the main effects of NPSB and NPS with delayed N fertilization and increased time required for potato harvest to reach physiological maturity became. The longer days before maturity may be due to the synergistic effect of phosphorus with nitrogen uptake, which enhanced the vegetative stage and thus delayed physiological maturity, since its uptake increased with increased intake of these nutrients.

Number of shoots per hill: The maximum number of shoots (6.33) was obtained from the interaction of the fertilizer source NPSB with the cultivar *Jalenie*. Based on the interaction of the NPS fertilizer source with *Belete*, the following result was obtained (4.67). The minimum number of shoots (2.17) was obtained from control treatment with landrace. This may be because the trait is strongly influenced by potato crop heritability, although stem density is one of the most important components of potato yield; was not significantly affected by N or P fertilization (Zellem *et al*., 2009; Birtukan, 2016). The result obtained does not agree with the conclusion of Getachew *et al*., (2020) that the interaction between variety and fertilizer source and the main effect does not statistically reveal the variability in the number of main stems on the mound.

Effect of fertilizer source and variety on yield and its components

According to statistical analysis of the results, the interaction between fertilizer source and variety had a significant impact ($p < 0.005$) on the average number of marketable tubers per hill yield and non-marketable yield (Table 3). Yet, other yields and yield components parameters (average number of tubers per hill, total tuber yield and dry matter content) were not significantly affected by the interaction between fertilizer source and variety.

Table 3: *Fertilizer Source and Variety Interaction Effect on Yield and Yield Component*

Treatment Combination		ATN	ATW	TTY	MrY	uMrY	DM
Fertilizer source	Variety						
Control	Local	4.90^{g}	28.31^{d}	9.49^{e}	8.57^{f}	1.08^{bcd}	25.23^{b}
	Gudenie	12.70^{cdef}	51.53^{bcd}	18.71^{bc}	17.75^{bc}	0.96^{bcd}	28.28^{a}
	Jalenie	10.10^{defg}	48.44^{bcd}	16.78^{bc}	15.99^{cd}	1.12^{bc}	28.59^{a}
	Belete	9.80^{defg}	41.01^{bcd}	15.68^{cd}	14.23^{de}	1.78^{a}	28.62^{a}
DAP + Urea	Local	6.77^{efg}	34.54^{cd}	12.54^{de}	11.30^{ef}	1.91^{a}	27.51^{ab}
	Gudenie	20.67^{ab}	41.54^{bcd}	19.49^{bc}	18.64^{bc}	0.85^{cde}	28.721^{a}
	Jalenie	15.60^{bcd}	58.92^{bc}	17.38^{bc}	17.23^{bcd}	0.15^{f}	28.83^{a}
	Belete	14.43^{bcd}	53.76^{bc}	19.26^{bc}	18.74^{bc}	0.52^{ef}	28.85^{a}
NPS + Urea	Local	8.58^{defg}	29.04^{d}	9.87^{e}	8.34^{f}	1.53^{ab}	27.23^{ab}
	Gudenie	14.97^{bcd}	46.87^{bcd}	19.84^{b}	18.59^{bc}	1.25^{bc}	28.88^{a}
	Jalenie	13.43^{bcde}	64.06^{b}	20.07^{b}	19.44^{bc}	0.63^{de}	28.3^{a}
	Belete	14.21^{bcde}	44.31^{bcd}	18.91^{bc}	18.28^{bc}	0.62^{de}	28.59^{a}
NPSB + Urea	Local	5.83^{gf}	34.84^{cd}	11.25^{e}	10.30^{f}	0.95^{cde}	26.98^{ab}
	Gudenie	18.50^{bc}	43.63^{bcd}	20.07^{b}	19.63^{b}	0.49^{ef}	28.94^{a}
	Jalenie	26.13^{a}	96.36^{a}	23.88^{a}	23.04^{a}	0.84^{cde}	27.86^{ab}
	Belete	19.21^{abc}	53.58^{bc}	18.05^{bc}	17.45^{bcd}	0.60^{ef}	28.60^{a}
CV		***29.57***	***25.62***	***11.96***	***11.61***	***26.08***	***5.27***
P-Value		**0.0648**	**0.0243**	**0.0670**	**0.0444**	**0.0001**	**0.9008**

ATN= Average tuber number per hill; ATW=Average tuber weight in g/tuber; TTY= total tuber yield ton per hectare; MrY=marketable tuber yield ton per hectare; uMrY=unmarketable tuber yield ton per hectare; FW= fresh weight in g; and DM= Dry matter in %; CV= coefficient of variation,

Average tuber weight (g): The interaction of fertilizer source with cultivar had a significant effect (p<0.05) on mean tuber weight (Table 5). The mean maximum tuber weight (96.36 g) was obtained from the interaction of the NPSB fertilizer source with the Jalenie cultivar. Further (64.06 g) obtained from the interaction of the NPS fertilizer source with Jalenie. The mean minimum tuber weights (28.31 g and 29.04 g) were obtained from the interaction of the control and the NPS fertilizer source with the native variety, respectively. It was found that the average weight obtained from jalenie tubers tended to decrease significantly by (47.62 g) with the interaction of the NPSB fertilizer versus the control fertilizer source. The correlation analysis showed that the mean tuber weight correlated significantly and positively (r2 = 0.69) with the number of undergrowth on the hill.

Marketable tuber yield (ton per hectare): The interaction of fertilizer source with cultivar had a significant (p<0.05) effect on marketable potato tuber yield (Table 3). The highest marketable tuber yield (23.04t/h) was obtained from NPSB fertilizer source with the *Jalenie* variety. Further (19.63 t/h and 19.44 t/h) were recorded from the interaction of NPSB and NPS fertilizer sources with *Gudenie* and *Jalenie* cultivars, respectively. The lowest marketable tuber yields (8.34t/h and 8.57t/h) were obtained from the interaction of NPS and control source fertilizer with landrace, respectively. It was shown that the marketable yield of *jalenie* tubers tended to increase significantly (11.79 t/h, respectively) when treated with NPSB fertilizer compared to treating landraces with NPSB and NPS source, respectively Sommerfeld and Knutson (1965) found that shoot growth was stimulated more than tuber growth with excessive N application, which agrees with those of Egata *et al*.(2019), in which the management of fertilizers significantly influences the chemical and nutritional composition of plants in addition to the anatomical and morphological structure. The correlation analysis revealed that high yields of marketable tubers significantly and positively (r^2 = 0.73 and 0.995) correlated with mean tuber weight and total tuber yield.

Unmarketable tubers yield (ton/hectare): The interaction between fertilizer source and variety was very significantly high (p<0.001) affected the non-commercial yield of potato tubers (Table 3 above). The maximum yields of non-marketable tubers (1.91 and 1.78 t/h) were recorded based on the interaction of the DAP fertilizer source and control with native cultivars and *belete*, respectively. The lowest yield of unmarketable tubers yield (0.15 t/h) was obtained from the interaction of the DAP fertilizer source with the *Jalenie* variety. The result agrees with the results of Yohannes *et al*., (2021). The interaction between fertilizer source and variety had effect on non-commercial tuber yield.

4. Effect of Variety on Growth and Yield

Based on statistical analysis of results, cultivar has a significant (p<0.005) effect on mean days to 50% flowering, number of sub-shoots per hill, plant height, average tuber weight and dry matter content. This is due to the different potato cultivars, most likely related to cultivar genetics (Amenu et al., 2022).

Day of 50% flowering: The potato variety had a very high significant (p ≤ 0.001) effect on day to 50% flowering (Table 4). The maximum number of days required for 50% flowering (71.86) was obtained from the *Jalenie* variety, the closest (64.49) was obtained from the landrace. Minimum day to 50% flowering (60.45 and 61.48) were recorded from the *Gudenie* and *Belete* varieties. The study results agree with the findings of Getachew *et al*. (2020) who found that the variety had a significant effect on days up to 50% of flowering days and beyond (59 vs.17) Days up to 50% flowering. It also agrees with the statement (Amenu *et al.*, 2022) that in different potato varieties var. *Menagesha* reached 50% flowering first, followed by var. *Belete*, then *Gudanie*. The *Menagesha* variety seemed to mature earlier than the other varieties.

Number of sub-shoots per hill: The variation had a very large and significant (p<0.001) on the number of sub-shoots per hill (Table 4). The largest number of sub-shoot in the hills (61.02) was obtained from the *Belete* variety. The following (51.32 and 51.37) were obtained from the cultivars *Jalenie* and *Gudenie*, respectively. The smallest number of sub-shoot in the hills (36.65) was obtained from local varieties. The study result agrees with Jemberie, (2017) who concluded that the *Belete* variety had the longest record, consistent with the results of his study.

Table 4: *Variety Effect on Growth, Yield and Yield Components*

Fertilizer Source	D50%F	NsSpH	HP	ATW	DM
Local	64.49[b]	36.65[c]	56.07[c]	31.68[c]	26.74[b]
Gudenie	60.45[c]	51.37[b]	79.07[a]	45.89[b]	28.58[a]
Jalenie	71.86[a]	51.32[b]	67.03[b]	67.94[a]	28.40[a]
Belete	61.48[c]	61.02[a]	75.82[a]	48.18[b]	28.50[a]
CV	4.71	18.48	10.13	30.91	5.20
P-Value	0.0001	0.0001	0.0001	0.0001	0.0087

D50%F= Day to 50% flower; NsSpH= Number of sub-shoot per hill; HP= Height of plant in cm; ATW=Average tuber weight in gram; DM= Dry matter in %; CV= coefficient of variation,

Plant height (cm): The variety had a very large and significant (p<0.001) effect on plant height (Table 4). Maximum plant heights (79.07 and 75.82 cm) were recorded for the *Gudenie* and *Belete* cultivars, respectively. The following (67.03 cm) was recorded from the *Jalenie* varieties. The minimum plant height (56.07 cm) was recorded from the landrace. The investigation result was consistent with the finding of Mekashaw, (2016); Melkamu and Minwyelete, (2018) who's reported that low plant heights observed in the landrace compared to other improved potato.

Average tuber weight (g): variety had a very large and significant effect (p<0.001) on average tuber weight (Table 4). The maximum average tuber weight (67.94 g) was obtained from the *Jalenie*. Further (48.18 and 45.89 g) were obtained from the varieties *Belete* and *Gudenie*, respectively. The minimum average tuber weight (31.68 g) was obtained from the local variety. The average tuber weight obtained was very low compared to other reports, which was evidenced by the occurrence of minimal rainfall and prolonged drought during the experiment.

Dry matter content (%): the variety is characterized by a very high and significant (p < 0.001) variations of the dry matter content of the tubers (Table 4). The highest dry matter content (28.58, 28.50 and 28.40%) were registered for the *Gudenie, Belete* and *Jalenie* varieties; appropriate. The minimum dry matter content (26.74%) has been obtained from the local variety. In addition, the dry matter content of the tubers depends on the potato variety, which is consistent with the conclusions of other researchers, Tsehai, (1988); Mekashaw, (2016); Melkamu and Minwyelete, (2018); Egata *et al*., (2019) where improved potato varieties generally had the highest dry matter content in tubers compared to the farmers' native varieties.

4. Conclusions and Recommendations

As with other experiments performed with different sources of fertilizers and varieties, in this experiment it can be concluded that the interaction between fertilizer source and variety has a very significant influence on the day to physiological maturity, the Number of main shootss average tuber weight, marketable and unmarketable tuber yield in t/ha. It was found that the interaction of NPBS with cv *Jalenie* provided a maximum marketable tuber yield of 23.04 t/ha, while EIAR recommended DAP and urea for a marketable tuber yield of 17.23 t/ha under certain cultivar conditions. On the Gazer trial field, NPS achieved the maximum yield of marketable tubers of 19.44 t/ha. Based on the results obtained, it can be concluded that NPSB blend fertilizer for the *Jalenie* variety, a variety that tolerates very little rainfall and a prolonged dry spell very well.

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