

Research Article

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Determination of Optimum Nitrogen and Potassium Levels for potato Production in Central high lands of Ethiopia

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Abstract: To determine the required levels of nitrogen and potassium, an experiment was conducted at Holetta Agricultural Research Center and Jeldu sub Center from 2014-2015 using three factors (Jalenie, Gudenie and Belete potato varieties; 87, 110, 133kg/ha nitrogen rates and 0, 34.5, 69, 103.5kg/ha potassium in the form of K_2O levels) and as a completely randomized block design arrangement with three replications. In each location every year the 36 treatments (4 potassium oxide levels x 3 nitrogen levels x 3 varieties) were assigned in random combinations to 36 plots of one block in a random case which was replicated in to two additional blocks of different randomizations in order to make total of three replications/blocks. Data were analyzed by SAS software Version 9.2. Potassium rates significantly affected the total yield and marketable yield as compared to the control treatment. Application of potassium at 103.5 kg/ha produced significantly a higher marketable yield than all rates. As compared to Jeldu, the Holetta location produced the maximum highly significant yield and yield component. Interaction of potassium and nitrogen fertilizers affected marketable tuber numbers and plant height significantly. In 2014, Belete produced the highest (27.31 ton/ha) marketable yield at an application of 34.5 kg/ha potassium and 110 kg/ha nitrogen while Gudenie produced the highest (30.53 ton/ha) marketable yield at an application of 69 kg/ha potassium and 110 kg/ha nitrogen rates in 2015. It is better to apply 69 kg/ha potassium and 110 kg/ha nitrogen

to potato production for reasonable yield at sites similar to experimental locations. It can be concluded that, interaction of nitrogen and potassium rates significantly affected plant height and marketable tuber numbers.

Keywords: Potassium, Nitrogen, Potato, marketable and unmarketable yield

1 Introduction

Potato (*Solanum tuberosum* L.) is very important for food and income generation as it produces a high yield per unit land and time. About 70% of cultivated agricultural land of Ethiopia is suitable for potato production (Yilma 1991). The annual potato production in Ethiopia was 1.62 million ton from an area coverage of 0.18 million hectares (CSA 2014). The national average yield is 9 tons/ha (CSA 2014) which is very low compared to the world mean of 16.4 tons/ha (Husna and Eliakira 2014). One of the contributing factors was poor use of optimum plant nutrition. This way of application can lead to excessiveness or shortage. When excessive nitrogen is applied, crop yield is reduced; cost of production increased and the environment is polluted, especially soil and ground water is acidified (Honisch et al. 2002). Cultivation with low or no fertilizer usage (Gezu 2015) is common practice in Ethiopian farmers. Lower levels of fertilizer use and/or inappropriate type of fertilizers application is one of the productivity problems in Ethiopia (Chillot and Hassan 2010). It was mentioned that there was soil nutrient depletion due to human interventions (Chillot and Hassan 2010) which can significantly influence food security in Ethiopia (MOARD 2101). Inappropriate soil fertility management is a cause of food shortage and malnutrition of tremendous numbers of people which also have associated health impact (Gete et al. 2010). Furthermore, information about potassium fertilizer and its levels on potato product is also scarce in Ethiopia. Even though the crop requirement of potassium

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is higher than N and P rates (Bansal and Trehan 2011), the cultivation is done without its application in most areas. Achieving optimum applications for plant nutrient is a pre-requisite substitute strategy as it determines yield and varies with soil, crop and water available to the crop for optimum return and farm profit.

Potatoes respond to inorganic and organic fertilizers. Potato yield and yield components were affected by application of Nitrogen and phosphorus fertilizers (Zelalem *et al.* 2009). Yield and yield components are complex traits, which exhibit polygenic or quantitative inheritance patterns (Dia *et al.* 2016a). Quantitative traits are governed by multiple genes whose expression is greatly influenced by the external environment; and, thus, results into scale or rank shift of their performance (Dia *et al.* 2016a, Dia *et al.* 2016d). According to (Yibekal 1998; Zelalem *et al.* 2009) potato plant height was reported as significantly affected by fertilizer application and positively yield correlated parameters which showed that higher potato plant height contributed to higher potato yield. Therefore, this research was conducted to determine the interaction effect of rates of nitrogen and potassium fertilizer on yield and plant height of potato varieties.

2 Materials and Methods

This experiment was conducted in 2014 and 2015 at Holetta Research and Jeldu sub-center using three factors (Jalene, Gudenie and Belete potato varieties; 87, 110, 133 kg/ha nitrogen rates and 0, 34.5, 69, 103.5 kg/ha potassium in the form of K_2O rates) and completely randomized block design with three replications. In each location every year the 36 treatments (4 potassium oxide levels x 3 nitrogen levels x 3 varieties) random combinations were assigned to 36 plots of one block in a random case which was replicated in to additional two blocks of different randomizations in order to make a total of three replications (Geremew *et al.* 2015; Iqbal *et al.* 2011). The fertilizers sources used were urea ($CO ([NH_2]_2)$) (46% N) and potassium nitrate ($KNO_3=13\% N$ and 46 % K_2O). The average pH H_2O (1:2.5), exchangeable acidity (cmol(+)/kg, bulk density (g/cm^3), total available nitrogen and % organic matter, available P (PPm) were 4.26, 0.38, 1.18, 0.15, 1.50 and 6.92 respectively for the Holetta growing location. The land was prepared until fine tilth development in a similar way to the land preparation rule for potato fields in the Holetta research center (ploughing to 25- 30cm depth, 3 to 4 times until fine tilth was developed). Planting was carried out using sprouted tubers at 10 cm depth and 75cmx30cm spacing on 3mx3m plot size. The nitrogen fertilizer was applied in

two splits; half before planting and half at 45 days after planting at 5cm around the root zones. The recommended phosphorus 195 kg DAP/ha and potassium fertilizer was applied during planting. Other practices were done following the same practice as the Holetta research center recommended for potato production. Tuber harvesting was done once at proper physiological maturity (75% leaves withering). Marketable tubers were tubers which were greater than 30mm in diameter and free of cracking, diseases, insect and mechanical damage. The plant height from the soil surface to the top most growth point of ten (10) randomly selected plants from the middle rows of each treatment was measured using a ruler at 75% of flowering which was averaged in to one representative treatment plant height. The data collected were tuber fresh weight ton/ha, marketable tuber number/plot, marketable tuber yields in ton/ha, total tuber number/plot, plant height in cm at maturity. Data were subjected to analysis of variance using proc GLM (general linear model) procedure of SAS 9.2 software (SAS 2009). The means were compared with Duncan's Multiple Range Test at 5% significance level.

3 Results

Plant height: Growing year and location was highly significant (<1%) in influencing plant height. Higher plant height (63.34cm) was produced in the 2015 growing season while a lower plant height (56.19cm) was produced in 2014 (Table 1). The Holetta growing location produced higher plant height (77.02cm) while Jeldu growing location provided the lower plant height (42.50cm). The interaction of Potassium and nitrogen was also highly significant (<1%) in affecting plant height (Table 2). The maximum plant height was attained at application of 34.5 kg/ha potassium and 133 kg/ha nitrogen rates while the minimum value of plant height was produced at application of 0 kg/ha potassium and 133 kg/ha nitrogen.

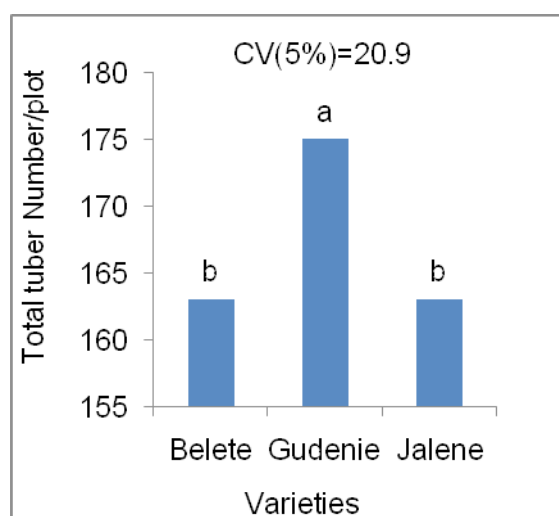
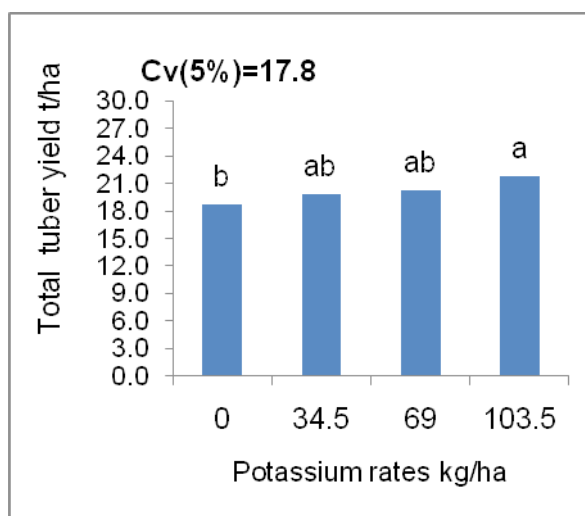
Total tuber number and weight: Growing location was highly significant (<1%) in affecting total tuber number and weight ton/ha (Table 1). Higher tuber number (175) and weight (37.55 t/ha) were produced from Holetta while lower tuber number (159) and weight (23.62 t/ha) were recorded from the Jeldu location. Potassium rates significantly affected total tuber yield in terms of ton/ha while the variety was highly significant (<1%) in affecting the total tuber number/plot (Figure 1 & 2). The maximum tuber number was produced by Gudenie variety while minimum value of tuber number was produced by Belete even though it was not statistically significantly different from that at Jalene. The maximum tuber yield ton/ha was

Table 1: Effect of growing Year and location on potato yield and plant height

Location	Total Tuber Number/plot	Marketable Tuber Weight (ton/ha)	Total Tuber Yield (ton/ha)	Unmarketable Tuber Number/plot	Unmarketable Tuber Weight (ton/ha)	Plant Height (cm)
Holetta	175a**	27.9a**	37.55a**	68a**	4.31a**	77.02a**
Jeldu	159b**	18.15b**	23.62b**	42b**	1.1b**	42.50b**
Cv (5%)	20.9	24.14	20.5	30.49	23.21	14.95
Year						
2014	167ns	22.7ns	25.93b**	46.79b**	1.81b**	56.19b**
2015	166.5ns	23.36ns	35.24a**	63.16a**	3.61a**	63.34a**
Cv (5%)	20.9	24.14	20.5	30.49	23.21	14.95

Table 2: Interaction of nitrogen with potassium and variety effect on tuber number and plant height

K ₂ O kg/ha	N kg/ha	Marketable Tuber Number/plot	Plant Height (cm)	N kg/ha	Variety	Total Tuber Number	Marketable Tuber number/plot
0	87	100bc*	59.27bc**	87	Belete	154c**	93c**
	110	99bc*	59.3bc**		Gudenie	172b**	110ab**
	133	110ab*	57.23c**		Jalenie	175b**	109ab**
34.5	87	115a*	57.45bc**	110	Belete	168ab**	107ab**
	110	105abc*	57.57bc**		Gudenie	179a**	109ab**
	133	101bc*	63.89a**		Jalenie	150c**	92c**
69	87	107ab*	59.93abc**	133	Belete	166ab**	105ab**
	110	99bc*	62.29ab**		Gudenie	174ab**	111a**
	133	106abc*	58.77bc**		Jalenie	163bc**	104ab**
103.5	87	94c*	60.11abc**	CV% (0.05)		20.9	26.04
	110	108ab*	62.66ab**				
	133	109ab*	58.69bc**				
CV% (0.05)		26.04	14.95				

**Figure 1:** Total tuber numbers for Belete, Gudenie and Jalenie varieties. First and second columns of this figure indicate total tuber number of Belete and Gudenie varieties while the 3rd shows the Jalenie variety total tuber number**Figure 2:** Total tuber weight results for 0, 34.5, 69 and 103.5kg/ha potassium rates. The 1st, 2nd, 3rd and 4th columns indicated the 0, 34.5, 69 and 103.5kg/ha potassium rates results for total tuber weight ton/ha, respectively

attained at application of 103.5 kg/ha potassium while the minimum was obtained from controls. Interaction of nitrogen and variety was also highly significant (Table 2). The maximum total tuber number was produced by the Gudenie variety at application of 110kg/ha nitrogen while the minimum was obtained from the Belete variety at application of 87 kg/ha nitrogen.

Marketable tuber number and weight: Growing location was highly significant (<1%) in affecting marketable tuber weight (Table 1). A higher marketable yield (27.9 t/ha) was recorded from the Holetta location while lower marketable yield (18.15 t/ha) was produced from the Jeldu growing location. Potassium rates significantly affected (5%) the marketable tuber weight ton/ha (Figure 3). The maximum marketable tuber yield ton/ha was attained at application of 103.5 kg/ha potassium. Marketable tuber number was affected by interaction of potassium and nitrogen rates significantly (5%) (Table 2). The variety and nitrogen rate interactions were also highly significant in affecting marketable tuber number (<1%) (Table 1). The interaction of variety, nitrogen, potassium and year was significant in affecting marketable yields ton/ha. The Gudenie variety provided a maximum marketable yield (30.53 ton/ha) at an application of 69 kg/ha potassium and 110 kg/ha nitrogen while Jalenie produced minimum marketable yield (16.16 ton/ha) at an application of 110 kg/ha nitrogen and control potassium rate in 2015 production season.

Unmarketable tuber number and weight: Variety was highly significant (<1%) in affecting unmarketable tuber weight ton/ha (Figure 4). The maximum unmarketable tuber yield ton/ha was produced by the Belete variety while the minimum value of unmarketable

tuber yield was recorded from the Gudenie variety even though it was on par with the Jalene variety unmarketable tuber yield ton/ha (Figure 4). Growing year and location was also highly significant (<1%) in affecting both unmarketable tuber and weight ton/ha (Table 1). The Holetta location and 2015 production season provided higher unmarketable tuber numbers and weight ton/ha while the Jeldu location and 2014 growing year produced both lower unmarketable tuber number and weight ton/ha (Table 1).

4 Discussion

The potassium rates affected the total tuber yield and marketable tuber yield ton/ha significantly. A higher tuber yield (21.72 kg/ha) and marketable yield (18.58 kg/ha) was obtained at 103.5 kg/ha potassium than other rates. Consistent with this result (Shahid and Moinuddin 2001) indicated similar findings. It also agrees with the finding of (Bansal and Trehan 2011) which mentioned yield increment due to applied potassium through increasing tuber number and size. According to Bansal and Trehan (2011) there is a significant yield variability in relation to variety and growing location which makes it consistent with the present experiment as variety, growing year and location were highly significant in affecting yield and yield component of the potato. Potato yield and yield component varied with variety, soil characteristics and geographical escarpment (Naz et al. 2011). These results again correlated with the investigation results of (Lamberti et al. 2004; Vreugdenhil et al. 2007; Trehan 2007; Gumul et al. 2011). The interaction of potassium and nitrogen also produced significantly

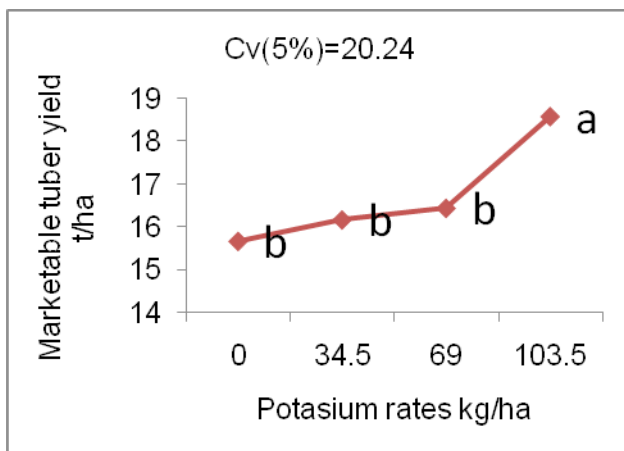


Figure 3: Marketable yield results of 0 to 103.5kg/ha potassium rates. The 1st, 2nd, 3rd and 4th stars indicated the 0, 34.5, 69 and 103.5kg/ha potassium rate results of marketable yield ton/ha, respectively

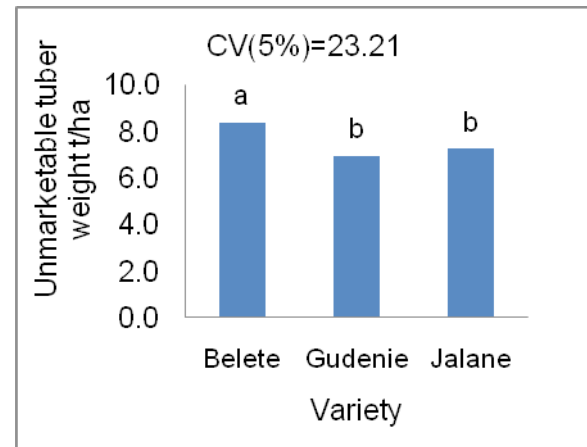


Figure 4: Unmarketable tuber weight of Belete, Gudenie and Jalenie varieties. The First and second columns indicated unmarketable tuber weight ton/ha of Belete and Gudenie varieties while the 3rd indicated the Jalenie variety unmarketable tuber weight ton/ha

different marketable tuber numbers and plant height while potassium and variety interaction provided significantly different total and marketable tuber numbers which were similar with the experimental results of (Talley 1983; Berug et al. 1979). The interaction of nitrogen and variety was also highly significant. The report of (Gause 2014) indicated an increment of yield of potato with applied K and N. A similar concept was also noticed by (Allison et al. 2001). Supporting investigation results were found in (Anabousi et al. 1997; Tawfik 2001; Al-Moshileh et al. 2005; Sharmila et al. 2006). On other hand, Lcascio et al. (1992) did not find any effect on the crop yield with K rate increasing, which may be due to the variety's response to potassium fertilizer and growing location soil and climatic condition variation with present experiment. According to Ismail and Abu-Zinada (2009) interaction of potassium and nitrogen significantly increased tuber number and yield. Response variability to applied K by variety was mentioned by some authors (Moinuddin et al. 2003; Trehan 2007). According to Singh and Lal (2012) interaction of N & K has significantly affected the plant height, tuber number and size. In addition, potato produced by potassium application has less weight loss and higher resistance to diseases. An increase in potato tuber yields due to potassium application up to 120 kg K₂O/ha was observed in (Moinuddin et al. 2005; Umar and Moinuddin 2001). The report of (Eleiwa et al. 2012) indicated increase yield with increasing NPK, the highest yield was attained at (120:80:100) rates. A significant response of the Gudenie potato variety to potassium fertilizer is identified (Geremew et al. 2015).

5 Conclusion and Recommendation

According to these results, the nitrogen without interaction effect did not affect any measured parameters of the varieties under experiment, but the interaction of potassium and nitrogen was highly significant in affecting the marketable tuber number and plant height. The interaction of potassium and variety showed a significant influence on total and marketable tuber number. The interaction of growing year, potassium rates, nitrogen rates and variety also brought a significant effect on marketable tuber yield ton/ha. The maximum marketable tuber yield was attained in 2015 at 69 kg/ha potassium and 110 kg/ha nitrogen from the Gudenie variety. It is better to apply 69 kg/ha potassium and 110 kg/ha nitrogen to potato production for reasonable yield at sites similar to the experimental locations. However, further research on time of application will be required in relation to locations and the rates of potassium and nitrogen.

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