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Effects of fertilizer application on yield and yield related parameters of low yielding potato varieties in Uganda

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The study was carried out in the first and second seasons of 2015 and the first season of 2016 at Kachwekano and Kalengyere stations of Kachwekano Zonal Agricultural Research and Development Institute in Rubanda county, Kabale district. A Completely Randomised Block Design was adopted with three replications and 4 treatments. The treatments composed of T1: Control, T2: 100 kg/ha N:P:K, T: 150 kg/ha N:P:K, and T4: 200 kg/ha N:P:K. Data was analyzed using Genstat computer package 13th Edition and significant means were separated using Fisher's Least significant difference at 5%. Application of N:P:K fertilizer enhanced the growth, yield components and total tuber yield of Kachpot1 potato variety. The highest number of haulms (3.361), plant height (48.50 cm), percentage of big tubers (86.27), yield of big tubers (91.94) and returns on investments of 1.42 were registered at an application rate of N:P:K of 200 kg/ha. The research revealed that, application of N:P:K fertilizer improves the yield and profitability of Kachpot1 potato variety.

Key words: Productivity, fertilizer, potato yield, nitrogen, phosphorus, potassium.

INTRODUCTION

Potato (*Solanum tuberosum*) is the 4th important crop, grown for both food and household income worldwide (FAOSTAT, 2007; FAO 2008; Bouwman et al., 2017). The crop is very important in human nutrition, providing essential amino acids, vitamins and minerals (Deußer et al., 2012). In Africa, potato is produced on 1,767,964 ha with a total production of 24,501,902 tonnes translating to 13.8 tons per hectare (FAOSTAT, 2007). Potato production in sub Saharan Africa has more than doubled since 1994 with 70% of that growth concentrated in Eastern Africa (Sebatta et al., 2014). In East Africa, the crop is grown on area equivalent to 684,847 ha with total production of 6,463,819 tonnes and a corresponding yield of 9.4 tons/ha. Among the East African countries, Uganda is ranked the lowest in potato production with yields of 4.3 tons/ha compared to Rwanda and Kenya with 7.1 and 9.2 tons/ha, respectively (FAOSTAT, 2007).

In Uganda, potato is grown by small holder households that produce a total of 169,490 tonnes on 39,107 ha (FAOSTAT, 2007). The major producing areas are the highlands of South Western Uganda, comprising Kabale, Kanungu, Rubanda, Rukiga and Kisoro districts accounting for 60% of total national production (Aheisibwe et al., 2015). Other producing areas are Kapchorwa,

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Sironko and Mbale districts on the slopes of Mt. Elgon in the East and Nebbi district in the North West. Averagely, on farm potato yields has been reported at 4.3 tonnes/ha (FAOSTAT, 2007) which is very far below 20 tonnes reported for developing countries (Muthoni and Nyamongo, 2009). The low yield is attributed to use of poor quality seed, pests and diseases, low soil fertility among others.

It is worth noting that, different potato varieties have been bred and released with more focus on yield and adaptability than nutrient requirements. Among the varieties that have been bred by National Agricultural Research Organisation is Kachpot1 with very good processing qualities for crisps, tolerant to low soil moisture levels, attractive market potential but with low yield response. The low yields could be due to limited information on the nutrient requirements by the variety. Invariably, each cultivar has specific morphological and developmental characteristics that may cause differences in nutrient uptake and utilisation (Downs and Hellmers, 1975). Different nutrients perform different functions during crop growth cycle. For example, Westermann (2005) and Kavvadias et al. (2012) show that N is essential for protein synthesis and growth of tubers, although excess N may result in excessive vegetative growth at the expense of tuberisation (Ruza et al., 2013). Phosphorus promotes root growth, rapid formation of tubers and starch synthesis (Rosen et al., 2014), while Potassium is essential for translocation of sugars to the tubers and also starch synthesis a fundamental processes in tuber growth and filling (Reis and Monnerat, 2000). Muzira et al. (2005) assert that, potato yield and yield components increased with increase in NPK fertiliser rates. However, there is little information on the effect of different NPK combinations on growth and yield of Kachpot1. Therefore, the study investigated the effect of NPK fertilizer combinations on Kachpot1 yield and profitability using different NPK fertilizer rates.

MATERIALS AND METHODS

On station experiment was carried out in the first and second seasons of 2015 and first season of 2016.

The experiment was established at Kachwekano Agricultural Research and Development Institute (2250 masl) and Kalengyere (2450 masl). Four fertilizer levels: 0, 100, 150 and 200 kg/ha of N, P and K were used and the fertilizer source NPK 17:17:17 was applied as basal. Sprouted medium sized (45-60 mm) diameter tubers of Kachpot1 variety were planted at a spacing of 70 cm between rows, 30 cm between plants on a plot size of 2.8 m×3 m. A completely Randomized Block design was adopted. Late blight disease was controlled using Mancozeb and Ridomilat a rate of 2.5 kg/ha on a monitor and spray basis. All other recommended agronomic practices were considered. At physiological maturity (when leaves turned yellow) data on haulm numbers per plant and plant height was collected. Ten plants from two middle rows per plot were used to collect data on haulm numbers and plant height. At harvest, plants from two middle rows were counted and recorded per plot. Tubers from all plants were lifted using a hand hoe, bulked together and graded. Two tuber grade sizes were considered, that is, small (>30 mm diameter) and big (<30 mm diameter). Tubers from each grade size were counted, weighed, recorded for further analysis. Data was subjected to Analysis of variance using Genstat computer package 13th Edition. Means were compared and separated using Fisher's Least Significant Difference at 5%.

RESULTS

Effect of application of NPK fertilizer on haulms and plant height

Study results indicated that NPK application rates affected the plant height (cm) and number of haulms per plant significantly (P<0.001) (Table 1). Higher levels of nitrogen significantly increased the number of haulms per plant (Table 1) and similar trends were observed in plant height. The maximum number of haulms per plant (3.361) was realised at an application rate of 200 kg NPK ha^{-1} while the lowest was observed in the control plots. Maximum height of the plant (48.5 cm) was recorded under 200 kg of NPK ha^{-1} and the lowest under control treatment.

Effect of NPK fertiliser levels on Kachpot1 yield

Application of NPK fertilizer significantly enhanced potato yield attributes. Increasing the levels of NPK fertiliser resulted in a corresponding increase in potato tuber yield parameters in terms of numbers and weight. Study results (Table 2) showed that the highest number of tubers per plant 10.22 was recorded on application of 200 $kgha^{-1}$ of NPK, 8.39 in treatments that received 150 $kgha^{-1}$ NPK, while the yield of 7.4 was obtained on application of 100 $kgha^{-1}$ NPK and lowest yield of 5.14 t in the control plot (Table 2). Application of 200 $kgha^{-1}$ of NPK was significantly P = 0.05 different from application of 150 kg ha^{-1} of NPK.

However, there was no significant difference in tuber yield when 150 and 100 kg NPK ha^{-1} were applied. In addition, the percentage number of big tubers increased with increase in the application rate with 86.27% observed under NPK applied at 200 kg ha^{-1} and the lowest 73.9% obtained under the control treatment (Table 2).

Significant (P<0.001) difference were also observed across the three seasons (Figure 1). In the same study, correlations between number of haulms per plant, plant height and yields with fertilizer application rates in kg ha^{-1} revealed strong linear relationships of 91, 98 and 98%, respectively (Figures 2 and 3).

NPK fertilizer application rates for economically profitable production of Kachpot1 in SWHAEZ

In the current study, the highest returns on investment

Table 1. Effect of application of NPK fertilizer on haulms and plant height.

Treatment	No. of haulms/plant	Plant height (cm)
Control (T1)	1.667c	36.61c
100 kgha^{-1} (T2)	2.111bc	42.69b
150 kgha^{-1} (T3)	3.083b	44.22b
200 kgha^{-1} (T4)	3.361a	48.50a
l.s.d	0.2702	2.923
F-Prob	0.001	0.001

Table 2. Effect of NPK fertilizer application on yield attributes of Kachpot1 potato variety.

Treatment	Tuber numbers per plant				Tuber weights tons ha^{-1}			
	Small	Big	Overall yield	% number of big tubers	Small	Big	Overall yield	% weight of big tubers
Control	1.397^{b}	3.84^{c}	5.14^{c}	73.9^{b}	1.531^{b}	7.08d	8.61d	82.23^{c}.
100 kgha^{-1}	1.459^{b}	5.96^{b}	7.45^{b}	78.49^{ab}	1.921^{a}	15.82^{c}	17.74^{c}	88.92^{b}
150 kgha^{-1}	1.230^{a}	7.16^{ab}	8.39^{b}	84.00^{a}	2.229^{a}	18.54^{b}	20.76^{b}	89.76^{b}
200 kgha^{-1}	1.237^{a}	8.87^{a}	10.22^{a}	86.27^{a}	1.931^{a}	22.35^{a}	24.37^{a}	91.94^{a}
l.s.d	0.1084	0.982	1.696	6.542	0.5507	1.701	1.380	4.19
F Prob	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Figures with the same letter are statistically similar at the 95% level of probability.

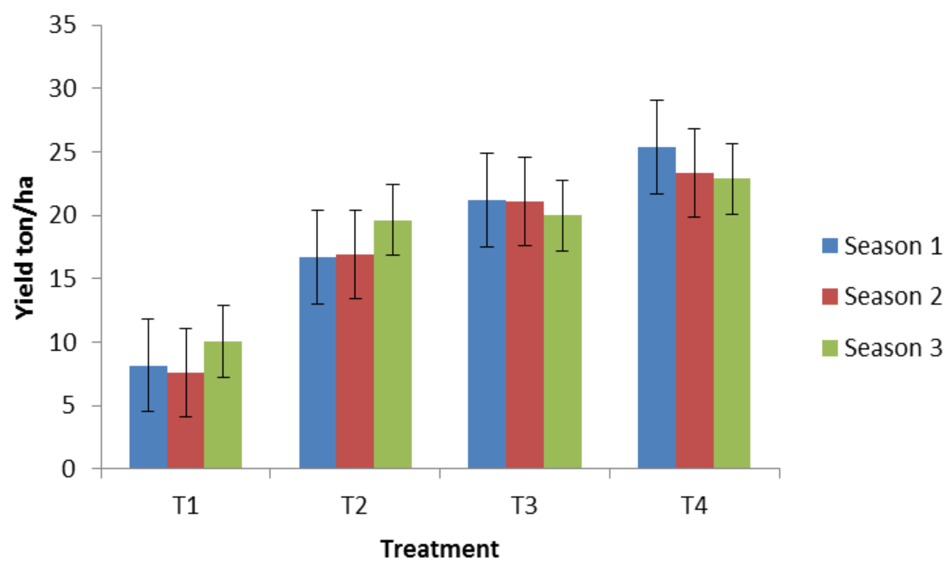

Figure 1. Yield of Kachpot1 in response to NPK fertiliser application across season (T1=Control, T2=100, T3=150 and T4=200).

were realised at the highest application rate of 200 kg ha^{-1} of NPK (1.42) and the lowest was recorded in treatment without fertilizer (0.45). However, application of fertiliser at the rates of 100 kg of NPK ha^{-1} and 150 kgha^{-1} also resulted in positive responses (1.18 and 1.28), respectively.

DISCUSSION

The study that was set out to improve productivity of Kachpot1 using fertilizer met its expectations. Indeed fertilizer application, irrespective of the level/rate significantly increased yield in terms of yield components

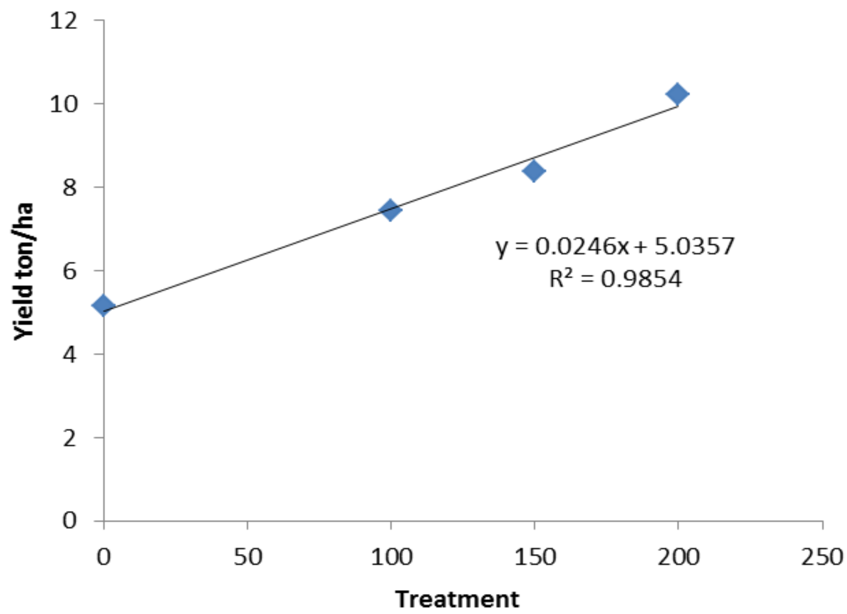

Figure 2. Correlation of fertilizer rates with yield ton/ha.

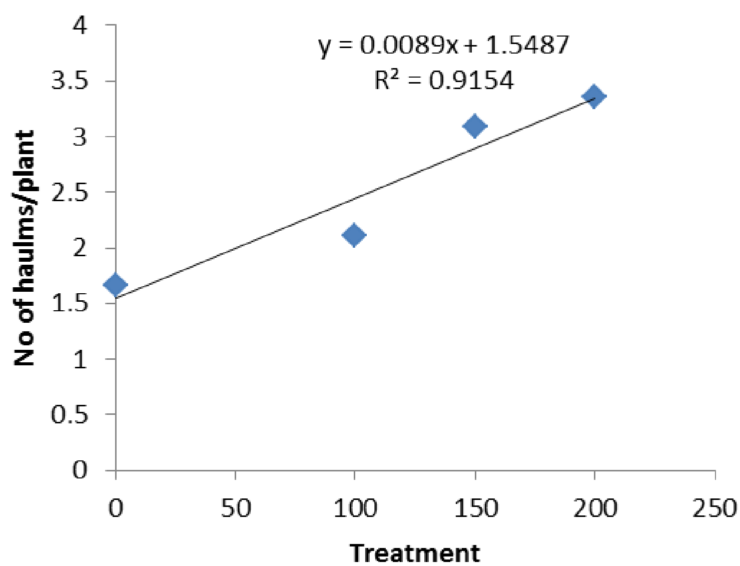

Figure 3. Correlation of fertilizer rates with haulms/plant.

(haulms per plant and plant height), tuber attributes (size) and overall yield (t ha^{-1}) with a corresponding monetary gain.

Number of haulms and plant height

Application of fertilizer to Kachpot 1 increases the number of haulms produced by a potato plant up to a rate of 150 kg ha^{-1}. Haulms produced when 200 $kgha^{-1}$ was applied were not different from those produced at 150 $kgha^{-1}$ application. Though, the number of haulms per hill depends on the number of buds present on seed tubers, their survival with plant growth will depend on the nutrition available in the soil. Availability of nitrogen with increasing rates therefore seems to be the main cause of increased number of haulms per hill. Similarly, positive significant effect of increased nitrogen doses on number of haulms per hill has also been reported by Gupta and Pal (1989), Singh et al., (1994) and Shiri-e-Janagrad et

Table 3. Cost benefits analysis of using NPK fertilizer on Kachpot1 potato variety.

Item	Fertilizer rate			
	C	**100**	**150**	**200**
(a) Revenue per ha	8,610,000	17,740,000	20,760,000	24,370,000
(b) Fixed Costs				
Hire of land	1,500,000	1,500,000	1,500,000	1,500,000
Cost of seed potato (bags)	1,120,000	1,120,000	1,120,000	1,120,000
Fertilizer cost	0	1,223,250	1,864,800	2,446,500
Cost of seed transportation	80,000	80,000	80,000	80,000
Fertilizer transportation	0	60,000	90,000	125,000
Cost of fungicide (Ridomil)	80,000	80,000	80,000	80,000
Poly bags	48,000	48,000	48,000	48,000
Total fixed costs	2,828,000	4,111,250	4,782,800	5,399,500
(c) Variable costs				
Labour costs (Land prep.)	3,111,000	4,024,000	4,326,000	4,687,000
Total variable costs	3,111,000	4,024,000	4,326,000	4,687,000
(d) Total costs (b+c)	**5,939,000**	**8,135,259**	**9,108,800**	**10,086,500**
(e) Gross margins/ha (a-d)	**2,671,000**	**9,604,741**	**11,651,200**	**14,283,500**
(f) Returns on investment (e/d)	0.45	1.18	1.28	1.42
Yield (t/ha)	8.61	17.74	20.76	24.37
Revenue/ha	8,610,000	17,740,000	20,760000	24,370000

al. (2009).

Superior results in plant height on fertilizer treatments may be due to higher N concentration which is an essential element for cell division, cell enlargement and it also increases the protoplasm activity.

The increase in plant nitrogen concentration could have stimulated the assimilation of carbohydrates and proteins, which in turn enhanced cell division and formation of more tissues that resulted in higher vegetative growth of plants. Similar results were revealed by Dangi et al. (2018) where the highest plant height (30, 60 and 90 DAS) was achieved at the highest application rate of 100% NPK. Increasing levels of nutrients increased plant height by 15 to 42% as compared to zero level. This is because relatively high dose of nitrogen application results in vigorous growth of the plant (Adhikari, 2009). Nitrogen being an essential constituent of protoplasm is vitally associated with the activity of every living cell. In the present investigation nitrogen application has a profound effect on different biomedical attributes of potato. The supply of nitrogen is related to carbohydrate utilization. When nitrogen supply is adequate and conditions are favorable for plant growth, proteins are formed from the manufactured carbohydrates. This extra protein allows the plants to grow faster. Thus, height of plant was significantly increased by increasing levels of nitrogen.

Tuber attributes and yield (number per plant, size and weight ton/ha)

The higher number of tubers may be due to increased absorption of nutrients in higher level of recommended dose of fertilizer which would have increased photosynthetic activity as well as translocation of photosynthasates for formation of new tubers. This is in conformity with a study conducted by Babaji et al. (2009) where application of NPK increased tuber numbers. Nizamuddin et al. (2003) reported an increase in yield of marketable tubers on application of NPK. Nitrogen affects tuber formation in potato by influencing the activity and phytohormone balance in the plants, especially on the levels of gibberellic acid, abscisic acids and cytokinins. Potassium application significantly ($P<0.001$) affected tuber yield compared with treatments without K fertilization (Table 3). Similar studies by Haile (2011), were observed whereby application of K increased tuber size and quality.

Tuber numbers increased with increased application of NPK. Phosphate availability at tuber initiation is important to ensure maximum tuber set, especially if tuber numbers need to be increased for certain varieties, or where the market demands a large number of smaller tubers.

Correct balanced nutrition is critical to influencing tuber numbers (Ekelöf, 2007). In a study by Jenkins and

Mahmood (2003) application of phosphorous and potassium also increased potato tuber numbers.

Further phosphate availability at tuber initiation is important to ensure maximum tuber set, especially if tuber numbers need to be increased for certain varieties, or where the market demands a large number of smaller tubers especially for seed production.

In this study, potato yield depicted a linear relationship with increase in the level of fertilizer rate. Also tuber weight increased with increase in NPK application rate. Similar results were reported by Dangi et al. (2018) whereby the maximum average weight of tubers per plant was obtained when a higher rate of 100% NPK was applied. Akinpelu et al. (2011) observed the highest yield of 3.81 t ha^{-1} on application of 200 kg ha^{-1} of NPK (15:15:15). The genotype and stems (haulms) per hill are some of the factors that influence the number of tubers per plant (Protocol, 2009). Similar results were reported by Etiang et al. (2018) in which an increase in potato yields and yield components were registered with a corresponding increase in NPK fertilizer.

Profitability of fertilizer application

Fertilizer application improved Kachpot1 productivity especially in terms of tuber numbers and sizes. The highest return on investment was obtained when 200 kg NPK ha^{-1} was applied and lowest when no fertilizer was applied. Growing Kachpot1 potato variety without fertiliser is not profitable as the return on investment was 0.45, which is far below 1. In a related study by Alemayehu et al. (2018), higher benefits were generally observed from nitrogen and phosphorus application than the control. Rware et al. (2016), Shaaban and Kisetu (2014) and Li et al. (2015) also appreciated NPK fertilizer optimization for better returns to investment.

Conclusion

Application of NPK at 200 $kgha^{-1}$ increases the yield of Kachpot1 to 24.37 ton/ha with a corresponding higher returns to investment. Application of 200 kg of NPK $kgha^{-1}$ gave the best results in terms of plant height, tuber numbers and tuber size. Further research should be done to explore other rates for the purpose of obtaining the optimum fertilizer rate needed to produce Kachpot1potato variety more economically.

RECOMMENDATIONS

Application of N:P:K fertiliser at a rate of 200 kg/ha should be more effective as it gave the highest yield and most economically feasible.

FUTURE RESEARCH AREAS

More studies focusing on the optimum NPK application rate on the variety should be conducted since the breakeven point had not be attained in the current study. Similarly, the study did not evaluate the environmental effects of the applied treatments.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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