The Effect of Fertilizer Combinations on Growth, Yield, and Economics of Potato Production

Elgon Region of Uganda

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Background

Potato is the third most important staple food crop after rice and wheat in terms of human consumption.(FAO, 2014). Uganda ranks the ninth potato producer in Africa and the third in East Africa behind Kenya and Rwanda (Kisakye et al, 2020;FAO, 2014). Potato is an important crop for Uganda as it contributes to national food security and source of income for smallholder farmers.

Nevertheless, potato yields in Uganda remain low. For instance, current average yields of 7.5 t/ha (FAO, 2018) are lower than yields in other sub-regions such as Kenya (20.3) and Rwanda (14.2) (Mbowa & Mwesigye, 2016) and also below the attainable 25 t/ha and achievable yields of 40-60 tons/ha (CIP, 2011). The on-farm yields of as low as 19.7t/ha (Tatwangire & Nabukeera, 2017) are not only below expectations but also result in negative marginal returns for most households in Uganda.

Some of the major factors contributing to lower potato output include poor soil fertility; low adoption of modern agricultural technologies such as chemical fertilizers, fungicides, and insecticides; lack of financial capability to purchase inputs and limited availability of clean and quality seed.

IFDC through REACH and PNSP programs aims at improving potato productivity in Uganda by addressing such technical challenges.

A field research was conducted in Elgon region during the first planting season in 2021, specifically, to address soil fertility concerns through application of various fertilizer combinations to boost yield and improve economic benefits for the smallholder farmers.

Objectives

1. To analyze growth and yield response to different NPK fertilizer combinations and micronutrients at varying rates and mode of application
2. To evaluate the economic performance of potato production through adoption of location- specific fertilizer recommendations.

Methods

Soil sampling and analysis

Composite surface soil samples (0-30cm) were collected from each site with an auger two weeks prior to ploughing. The soil samples were then prepared and analyzed for various soil chemical and physical properties according to standard soil analysis procedures by CropNuts Laboratories in Kenya and Makerere University in Uganda.

Treatment formulations

Seven treatment combinations including a control were tested during the experiment.The treatments were T1 (Control), T2 (120kg N/ha, 120kg P2O5/ha, 120kg K2O/ha -basal only), T3 (120kg N/ha, 80kg P2O5 /ha,160kg K2O/ha -All basal), T4 (120kg N/ha, 80kg P2O5 /ha,160kg K2O/ha -split application), T5 (120kg N/ha, 80kg P2O5/ha, 160kg K2O/ha -split application; Zn & B – soil applied), T6 (120kg N/ha, 80kg P2O5/ha, 160kg K2O /ha -split method; Zn & B – Foliarly applied), T7 (120kg N/ha, 60kg P2O5 /ha, 200kg K2O/ha -split method). The treatments were formulated based on high nutrient demand for N and K and lower P as well as the yield goal (40t/ha). The fertilizer treatments were applied with the available fertilizer sources at varying rates as summarized in Table 1.

Table 1. Fertilizer treatments

Treatment	N	P_2O_5	K_2O	Fertilizer combinations	Application Protocol	Micronutriments (1 kg B & 1 kg Zn)
	Kg/ha					
T1 (Control)	0	0	0	No fertilizer	None	None
T2	120	120	120	17:17:17 only	At planting	None
T3	120	80	160	17:17:17 + SOP + Urea	At planting	None
T4	120	80	160	17:17:17 + SOP + Urea	*5 WAP	None
T5	120	80	160	17:17:17 + SOP + Urea	*5 WAP	Zn & B – soil applied
T6	120	80	160	17:17:17 + SOP + Urea	*5 WAP	Zn & B – Foliarly applied
T7	120	60	200	17:17:17 + SOP + Urea	*5 WAP	None

*5 WAP means fertilization at planting and top dressing at 5 weeks after planting (WAP)

Experimental layout

The experiment was set up in three major potato producing districts in Eastern Region of Uganda (Mbale, Kween and Kapchorwa). The experiment was replicated four times (Done in four sub-counties) in each district. Sub-counties within each district were considered as replicates for the experiment. This is equivalent to having four blocks in each district (twelve blocks in total). Seven plots (spaced at 1m apart) were set up within each selected site/sub-county. Each plot measured 18 m2 (6m × 3m) and consisted of five rows spaced at 75cm apart (IFDC, 2017). Tubers were planted in a total area size of 0.58 acres (0.23 ha). The total harvested area was about 0.32 Acres (0.15 ha). All best agronomic practices recommended for potato production were followed as presented below.

Agronomic activities

All land preparation activities including conventional tillage were done using hoes. Whole potato (Rwangume/NARAPOT 4) tubers weighing about 30-50g were used for the study. A total of 700 tubers were planted per site making a sum total of 8,400 tubers for the whole region. Nitrogen, Phosphorus and Potassium were applied through NPK 17:17:17, Urea and Sulfate of potash (SOP) in both basal and split application to compare different practices adopted in the study area.

Weeding was done twice; two to three weeks after emergence and after soon after top dressing (KAZARDI, 2014). Stargem (Mancozeb) and Victory 72 WP fungicide (Mancozeb and Metalaxyl) were applied on a weekly basis at a rate of 2.5kg/ha to prevent and treat late blight disease while seed-borne diseases such as bacterial wilt disease were monitored, and infected crops were rogued. Insecticides M-D Thoate (Dimethoate) and Orizon (Abamectin and Acetamiprid) were applied at 75ml/100L per hectare and 1L/ha respectively, to protect the crop against a wide range of insects such aphids, leaf miners, grasshoppers, and caterpillars. Dehaulming was carried out two weeks prior to harvesting to enhance skin hardening and to prevent skin peel thereby enhancing quality and preventing entry of pathogens. Harvesting was done manually by using hoes.

Data collection and statistical analysis

Growth and yield parameters were recorded during the plant growth and development cycle. The measured growth attributes include germination period, plant height, leaf area index, number of stems, canopy cover and chlorophyll level. These attributes except leaf area index and stem number, were measured three times; at three, six and nine weeks after emergence. Five randomly chosen plants from the middle of each plot were sampled from which growth parameters were collected. This was done to eliminate border effects as described by Gomez & Gomez (1984).

Data were collected using growth and harvest data sheets and recorded in Microsoft Excel Software for management and later analyzed by GenStat Software (18th Version). R software was used to analyze regression and correlations between climatic factors and yield. Analysis of Variance (ANOVA) as used to generate means of the treatments which were compared using Fisher's protected Least Significant Differences (LSD) at 0.05 significance level. Partial Budget Analysis technique (through Microsoft Excel) was used to analyze the economics of potato production due to application of various fertilizer combinations.

Results

Yield performance by study location

Results of this study showed that Kween District had the highest yields which were also above the national productivity potential of 40-60 t/ha. For instance, Benet sub-county recorded maximum yields (75.62 t/ha) from T6 and lowest (53.65 t/ha) from the control treatment. Likewise, Kwosir recorded highest yields (57.55 t/ha) from T5 and lowest in T1 (43.92 t/ha). Kaptum also recorded higher yields with a range of 53.1-43.37 t/ha from T3 and T1. Contrastingly, Moyok recorded lower yields than expected. The highest tuber yields were 31.14 t/ha from T4 and lowest 8.62 t/ha from T1. Lower yields observed in Moyok could be due to drier soils resulting from insufficient moisture and high occurrences of bacterial wilt and late blight.

In Kapchorwa district the yields were also relatively higher. The highest total yields (55.6 t/ha) were recorded in Kapchesombe, followed by Munarya (53.1 t/ha) and Chema (49.48 t/ha) from T3 and lastly Tegeres (38.36 t/ha) from T2. The lowest corresponding yields of 41.42, 22.24, 33.92 and 24.07 t/ha were obtained from T1 (Figure 1). Higher yields observed in most of the study sites in Kween and Kapchorwa districts could be attributed to healthier soils and higher altitudes which provided favorable cold temperatures and more moisture for optimum potato growth. Lower incidences of late blight and bacterial wilt in these districts also resulted in increased yields.

Results also showed that overall lowest yields were recorded in Mbale district. The highest yields were recorded in Wanale-Naburwa (40.59 t/ha) in T2 followed by Wanale-Nkongola (38.36 t/ha) in T3, Budwale-Buwanangadi (33.58 t/ha) in T4 and Budwale-Kyesula (24.19 t/ha) in T6. The control treatments recorded the lowest yields in all the four study sites in the district. Mbale district experienced worst dry spells and heat waves during the first growing season which reduced soil moisture and possibly affected potato growth and tuber development. Additionally, high infestation by bacterial wilt and late blight resulted in death of plants, reduced tuber size, and consequently resulted in lower total yield. Diseases such as late blight and bacterial were particularly common in Mbale district due to overutilization of the soil due to smaller farm sizes which limits crop rotation in the district.

Photo by Hopkins Mwanza

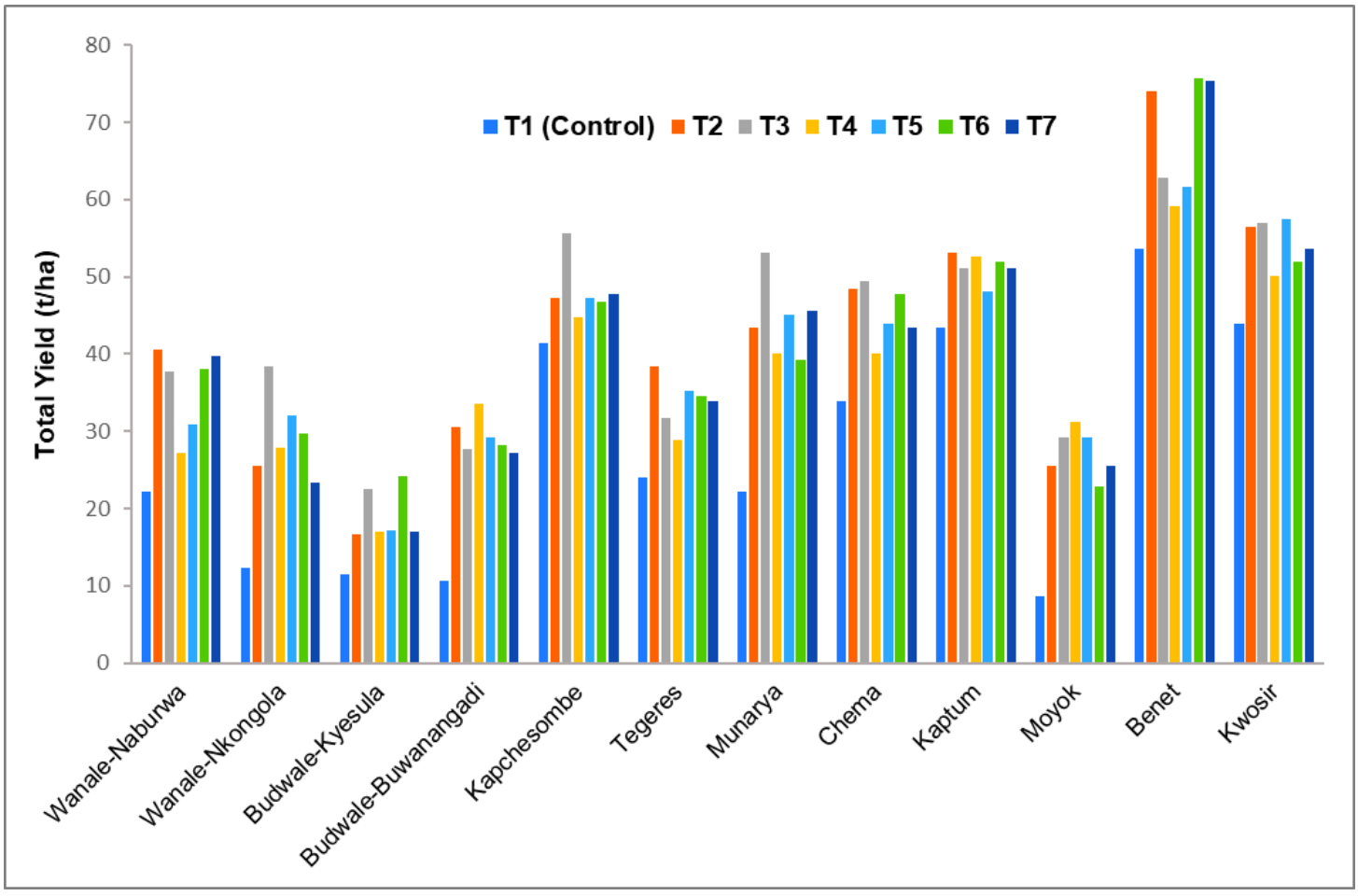

Figure 1: Total yields in response to various fertilizer combinations

Results

Yield performance by treatment

Results indicated that average total yields across the region ranged from the highest in T3 (43.03 t/ha) to the lowest in T1 (27.3 t/ha). Higher average total yields were also observed T2 (41.65 t/ha), T5 (39.78 t/ha), T6 (40.89 t/ha) and T7 (40.3 t/ha) (Figure 2). The percentage yield increase was 58%, 53%, 50%, and 48% for T2, T3, T6 and T7, respectively. This was an indication that the fertilizer had a significant effect on yield. The application of combined fertilizers resulted in increased stem number and leaf area which could be responsible for increased tuber number and enhanced synthesis of carbohydrates for tuber weight increment (Belachew, 2016;Misgina, 2016).

N, P and K nutrients have a greater effect on tuber size. N is involved in cell division resulting into accelerated growth of vegetative parts which enhance plant photosynthetic processes that produce carbohydrates (Sandhu et al, 2014).

On the other hand, K plays a vital role in potato nutrition as it activates several enzymes involved in photosynthesis, carbohydrate metabolism, protein synthesis, and translocation of water, sugars and other assimilates from the leaves to the tubers which results in tuber enlargement (Trehan, 2005).

In addition to plant nutrition, yield potential of genotypes also significantly affects total tuber yields. For instance, Rwangume is ranked among the highest yielding varieties such as Kinigi, Rutuku and Victoria with yield of over 7t/ha (Kaguongo et al, 2008). This could explain higher yields observed even in the control treatments in some plots.

Relatively higher yields observed in T5 and T6 as compared to T4 and T7 could be attributed to the effect of Zn and B. It is reported that application of Zn and B enhances the uptake of major nutrients like N,P,K and S and translocation of assimilates which result in yield increment (Singh et al., 2014). Similar results on positive effects Zn and B on yield have also been reported by Puzina (2004) and Mousavi et al (2012). However, the antagonistic interaction of Zn and P should be closely monitored to avoid nutrient imbalance (Sarker et al., 2019).

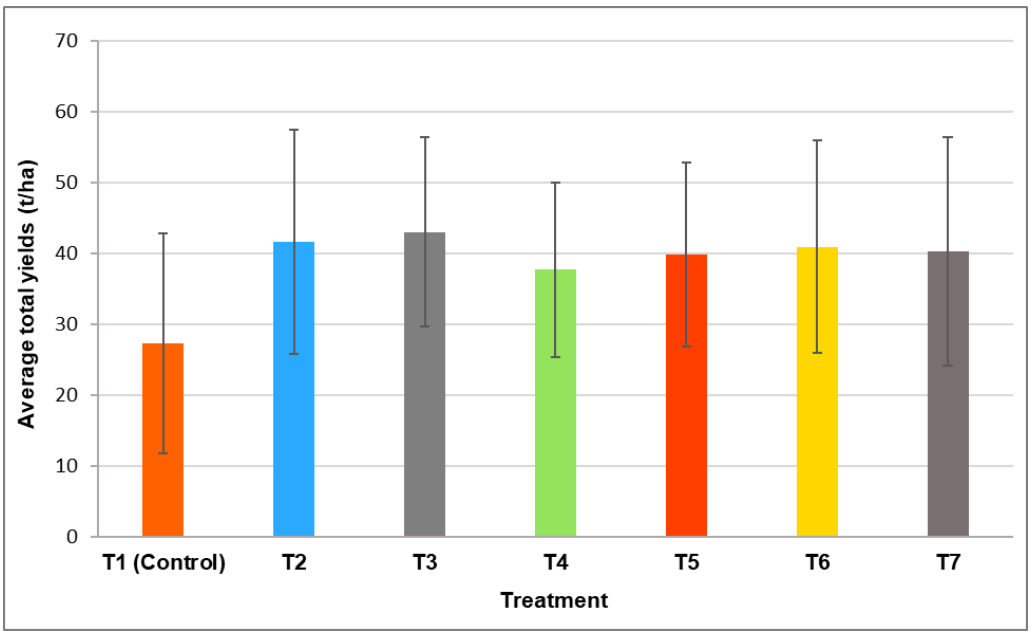

Figure 2: Average total yields due to application of different fertilizer combinations

Results

Economic Analysis of potato production

The partial budget analysis done indicated that in a typical farmers' practice, T2 (application of NPK:17:17:17 fertilizer only) would record the highest net benefits (UGX 11,293,200) from an investment of UGX 2,026,800 in fertilizer for the yield of about 33 t/ha (Figure 3). T3 which had the highest yield (34.46 t/ha) would produce marginal returns of UGX 11,033,600 from an expenditure of UGX 2,750,800. The control treatment would give off the lowest net income of UGX 8,582,400 from ~22 t/ha of potato yield. T7 with the highest investment in fertilizer (UGX 3,449,400) would record a lower profit of UGX 9,611,400 from yield of ~33t/ha.

Total Variable Costs (TVC) and Gross Benefits (GB) determine profit realization in production systems. Profit driven farmers strive to minimize production costs while sustaining the yield. Highest net benefits realized from T2 were due to higher yield with minimal variable costs. The costs were reduced due to the use of NPK (17:17:17) fertilizer only which was applied once during planting. In T3 the cost of fertilizer increased due to the additional application of Urea and potassium sulfate while the yield was statistically the same with T2.

This resulted in decreased overall net income. T5 and T6 also recorded lower net benefits although the yield was similar yield to T2. This was due to higher cost of fertilizer from combined application of Urea, potassium sulfate, Boron and Zinc and labor for top dressing. The cost of fertilizer was even higher in T7 due to higher rates of potassium sulfate in addition to Urea and NPK (17:17:17) and labor for the top dressing. Higher TVC observed in T4, T5, T6 and T7 resulted in lower net profits.

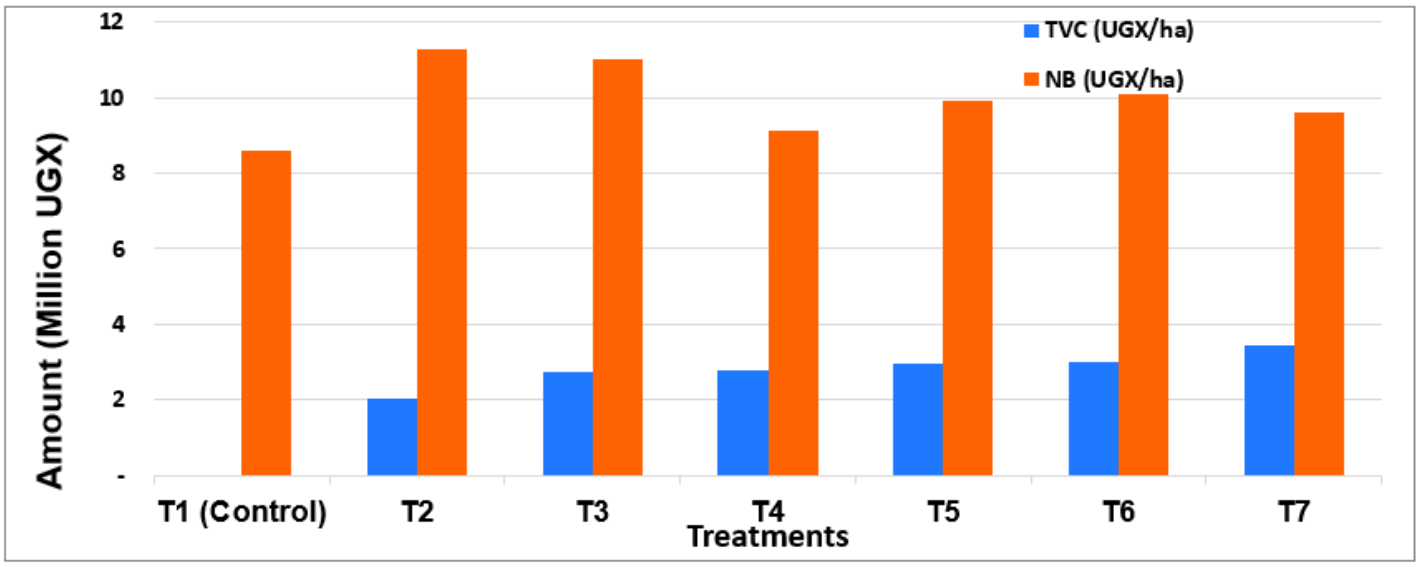

Figure 3: Net benefits for the treatments (TVC=Total Variable Costs; NB=Net Benefits)

Conclusions

Appropriate use of chemical fertilizers is the most effective means of increasing potato yields. This study showed that combined application of NPK (17:17:17), Urea and potassium sulphate at a rate of 120-180-160 (kg/ha) either at planting or by split method, resulted in faster growth rate, higher chlorophyll, canopy cover, leaf area index, tuber number/hill and marketable tuber yield. It was also observed that application of NPK (17:17:17) at a rate of 120kg/ha recorded higher growth and marketable yields and gave maximum economic returns. This treatment was thus, considered the most effective and economically viable option for potato production in Elgon region.

Kween District recorded the highest yield followed by Kapchorwa while lowest yields were observed in Mbale. These yield variations could be due to differences in altitude which highly influences local temperature and rainfall.

Future research should focus on developing specific fertilizer recommendations for the districts/sub-counties and analyze potato yield trends in response to climate variations over a longer period.

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