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Effect of inorganic fertilizer and cattle manure on growth and yield of two Kenyan potato varieties

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Abstract

Low soil fertility is a major constraint to irish potato (*Solanum tuberosum* L.) production in most parts of Kenya. An experiment was conducted at Kenya Agricultural Livestock Research Organization (KALRO) Tigoni to determine the effect of inorganic fertilizer and cattle manure on growth and yield of Desiree and Kenya Mavuno potato varieties. The experiment was a split plot design with two main plots each with four subplots and three replicates. Varieties formed the main plots while treatments (NPK (23:23:0) 100kg acre^{-1}, NPK (23:23:0) 50kg acre^{-1} plus cattle manure 1.6t acre^{-1}, cattle manure 3.2t acre^{-1} and control formed the subplots. Data collected included, stem height, canopy %, tuber size and yield. Data was analyzed by Analysis of variance (ANOVA).First season, stem height was significantly different among all treatments, NPK gave the highest. Second season, NPK and NPK plus cattle manure was not significantly different. NPK gave the highest height. Canopy %, during the first season, NPK had the highest although it was not significantly different from NPK plus cattle manure. Second season, NPK had the highest canopy % and was significantly different. The best tuber size distribution resulted from NPK treatment. On tuber yield, first season NPK and NPK plus cattle manure had no significant difference. Second season, NPK was significantly different. In all tested parameters NPK treatment had better performance from the rest of the treatments and can be recommended in irish potato production.

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Introduction

The potato (*Solanum tuberosum* L.) is an edible tuber. It is a member of the Solanaceae or nightshade family. Also called the "earth apple", the potato is the world's fourth largest food crop after wheat, rice and maize. World production reached a record of 320 million tonnes in 2007; and production in the developing countries has almost doubled since 1991 with corresponding increase in consumption (Hoffler and Ochieng, 2008; FAO, 2008). Potatoes are an important source of food, employment and income in developing countries (Kabira *et al*., 2006; FAO, 2008). In addition the crop is an important component of urban agriculture which provides jobs and food security to some 800 million people globally (Hoffler and Ochieng, 2008).In East and Central Africa potato is an important food and cash crop. It provides nutritional security, poverty alleviation and income generation as it offers employment in production to consumption continuum (Kabira *et al*., 2006).

Hundreds of millions of people in the developing countries including Kenya are facing food crisis, as the cost of their staple food such as rice, wheat and maize continues to rise. Rice prices almost doubled during the year 2008, as wheat prices climbed rapidly while maize prices were skyrocketing. On the contrary, the price of potato has remained stable (Hoffler and Ochieng, 2008). The potential of potato is yet to be fully realized and has never been more evident until the recent rising prices of rice, wheat and maize (FAO, 2008). Potatoes have the potential to relieve the pressure of increasing cereal prices on the poorest people and contribute significantly to food security. Potatoes are grown and eaten locally with little significant trade compared to cereals so they are particularly valuable as food in the developing countries. Potatoes mature in 3-4 months and can yield 40t ha^{-1} and hence ideally suited to places where land is limited and labour is abundant (FAO, 2008).Potato in Kenya is produced both as a subsistence and commercial crop, mainly by small scale farmers (MoA,2005). Yields on farmers' fields vary from 4.4 to 15 tha^{-1} with an average of 6-7 t ha^{-1}. However, yields of 40 t ha^{-1} have been attained from research fields (Lung'aho *et al*., 1997; MoA, 2008). The low yields have been attributed to, low soil fertility , low use of inputs especially fertilizers and good quality seeds, diseases (especially bacterial wilt, late blight and viruses) and insect pests (Maingi *et al*., 1992; Nganga *et al*., 2002; MoA, 2005).

Low soil fertility is occasioned by continuous cultivation without adequate replenishment of mined nutrients (Kaguongo *et al*., 2008). Potato being a heavy feeder of plant nutrients requires adequate supply of added mineral nutrients in the form of inorganic fertilizers or organic manure (Powon *et al*., 2004). In addition fertilizers used are usually not right depending on soil PH status and also not in the appropriate rates. Furthermore, application of organic matter is limited. This is because crop residues are used as fodder while cattle manure when used the quantity and quality are often below recommendations (Muthoni *et al*., 2010).

Guided by this background, an experiment was set up at KARLO Tigoni station in 2013 (short rains) and 2014(long rains).The specific objective of the study was to determine the effect of inorganic fertilizer and organic manure on growth and yield of two established varieties, namely: Desiree and Kenya Mavuno.

Materials and methods

Experimental Site Description

The KALRO Tigoni station is located 40 km Northwest of Nairobi City Centre at an altitude of 2131 m.a.s.l., latitude 1°15'S and longitude 23°46'E (Jaetzold *et al*., 2006). The average rainfall is 1096 mm with biomodal distribution, with long rains occurring between March and May, while short rain seasons are between October and December (Jaetzold *et al.,* 2006). The mean annual air temperature is 18°C with a minimum of 12°C and maximum of 24°C. The soil type is humic nitosols which is very deep and well drained with a PH of 4.3 to 5.82 (Muthoni *et al.,* 2010).

The Experiment

Before planting, a soil analysis was carried out on the trial plots. The soils were found to be strong acidic and low in magnesium (Table 9). As per the recommendations, the soil was treated with Dolomite (300kg/acre) three weeks before planting.

Then two varieties of potatoes namely Desiree and Kenya Mavuno were planted in an open field. The two varieties were subjected to NPK (23:23:0) fertilizer treatment at optimal level of 100kg acres^{-1}, NPK (23:23:0) plus Cattle manure both at half optimal rates (50kg acre^{-1} plus 4 tha^{-1}) Cattle manure 8 tha^{-1} and Control where no fertilizer or manure was applied. The experiment was a factorial split plot design with two main plots and four subplots with three replications. Factors were the two types of irish potato varieties (in main plots) and the different types and rates of fertilizer (in sub plots). Each subplot measured 3 m by 4.5m with 75 plants at spacing of 75 cm by 30 cm. Spacing between subplots was 75cm. The whole experimental plot measured 22.25m x 22m (489.5m^2). The land was dug, harrowed and rows marked out accordingly. The main plots and subplots were allocated randomly. All the fertilizer and cattle manure were measured as per the required rate, then applied during sowing to all subplots and mixed well with soil to avoid scotching the seeds. Other agronomic practices like weeding, earthing up, disease and pest control were carried out uniformly on all plots. The experiment was carried out in two seasons. The first season was from October to February (2013) and the second one from April to August (2014).

Sampling and Sampling Procedure

Subplots had each 75 plants in five rows (each with 15 plants). During sampling the inner plants were considered avoiding the boundary lines which could have an outside influence. A total of 6 plants per subplot were picked and marked for growth characteristics measurements.

Data Collection

Data collected was on, plant stem height which was measured by use of one meter rule, canopy % which was taken by use of line transect and yield in Kilogram (kg). Other parameters included; tuber size distribution (width and length) which were measured by use of a string and a ruler. These parameters were taken at two weekly intervals or any other time when need arose.

Harvesting was done by use of a sharpened wooden stick whereby the soil was scoped from the plant hill and by use of hands, the potato tubers were separated from the soil and the plant.

Statistical analysis

Data collected was analysed by analysis of variance (ANOVA) using Genstat 2009 12th Edition statistical package and means were separated by Fisher's (2009) protected LSD at P=0.05.

Results and discussion

Effects of inorganic fertilizer and cattle manure on plant height

During the first season (October, 2013 to February, 2014), the treatments were significantly different on plant height (Table 1). Among the treatments the NPK (23:23:0) gave the highest mean average height. On plant height trend during the first season (October, 2013 to February, 2014), the NPK (23:23:0) gave the best performance for both varieties (Fig. 1A and Fig. 1B). This is because inorganic fertilizer has an immediate effect, and its release of nutrients is often well synchronized with plant growth. During the second season (April, 2014 to August, 2014) the treatments were significantly different on plant height (Table 2). NPK (23:23:0) and NPK (23:23:0) + Cattle Manure had no significant difference on height but there was significant difference compared to Cattle Manure and Control treatments.

The performance of mean height had agreed with findings of (Powon *et al*., 2004), which showed that farm yard manure alone cannot significantly affect plant height compared to inorganic fertilizer. This is because inorganic fertilizer releases nutrients faster as compared to farm yard manure which releases nutrients slowly. On plant height trend during the second season (April, 2014 to August 2014), the NPK (23:23:0) gave the best performance for both varieties (Fig. 2A and Fig. 2B). On plant height performance the results agreed with findings of (Djilani Ghemam and Mourad (2013) where organic fertilizer had slow nutrient release capacity causing low plant height.

Table 1. Effect of inorganic fertilizer and cattle manure on plant height first season (October, 2013 to February, 2014) Tigoni.

Treatment	Height
NPK (23:23:0)	57.56 a
NPK (23:23:0) + Cattle Manure	48.03 b
Cattle Manure	45.11 c
Control	39.14 d
Desiree	42.78
Kenya Mavuno	52.14
Grand mean	47.46
S.E.	4.31
CV%	9.1
LSD	2.009
P value	<.001

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

Table 2. Effects of inorganic fertilizer and cattle manure on plant height (cm) second season (April, 2014) to August, 2014) Tigoni.

Treatment	Mean Height
NPK (23:23:0)	74.54 a
NPK (23:23:0) + Cattle Manure	73.22 a
Cattle Manure	67.08 b
Control	57.31 c
Grand mean	68.04
S.E of means	4.034
LSD	1.88
CV %	5.9
P value	<.001

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

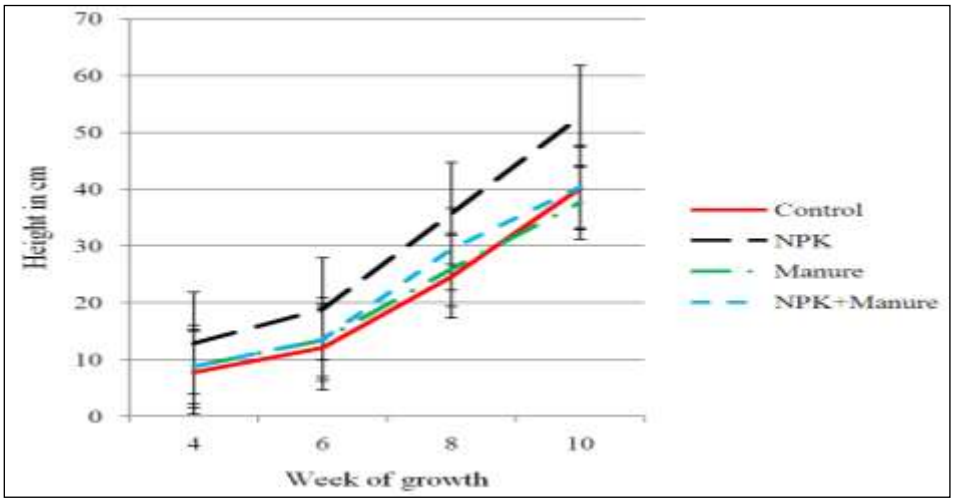

Fig. 1A. Height (cm) trend for Desiree Tigoni first season (October, 2013 to February, 2014). Error bars with standard error.

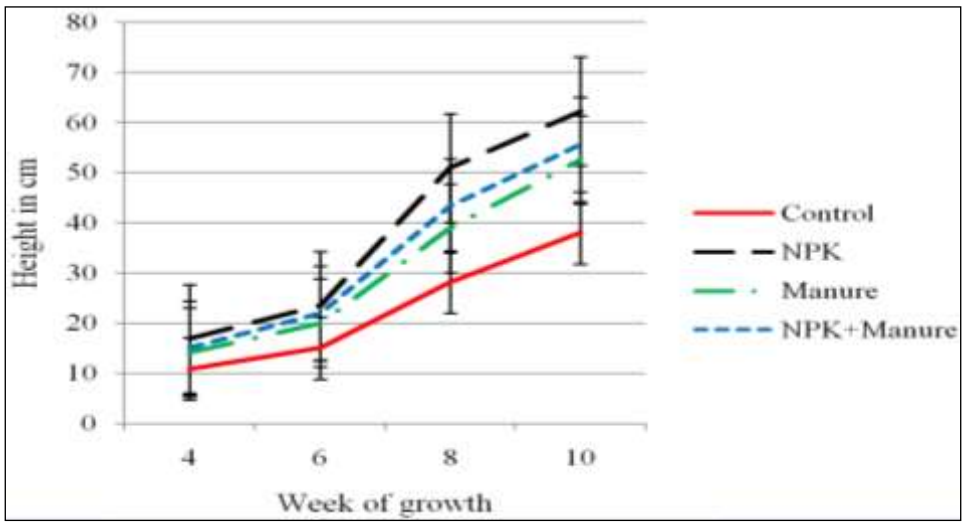

Fig. 1B. Height (cm) trend for Kenya Mavuno Tigoni first season (October, 2013 to February, 2014). Error bars with standard error.

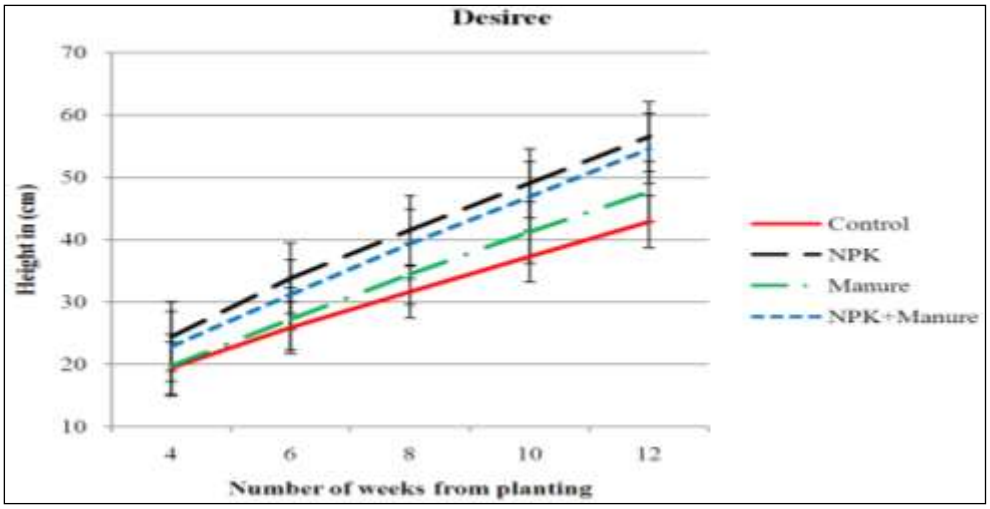

Fig. 2A. Height (cm) trend for Desiree Tigoni second season (April, 2014 to August, 2014). Error bars with standard error.

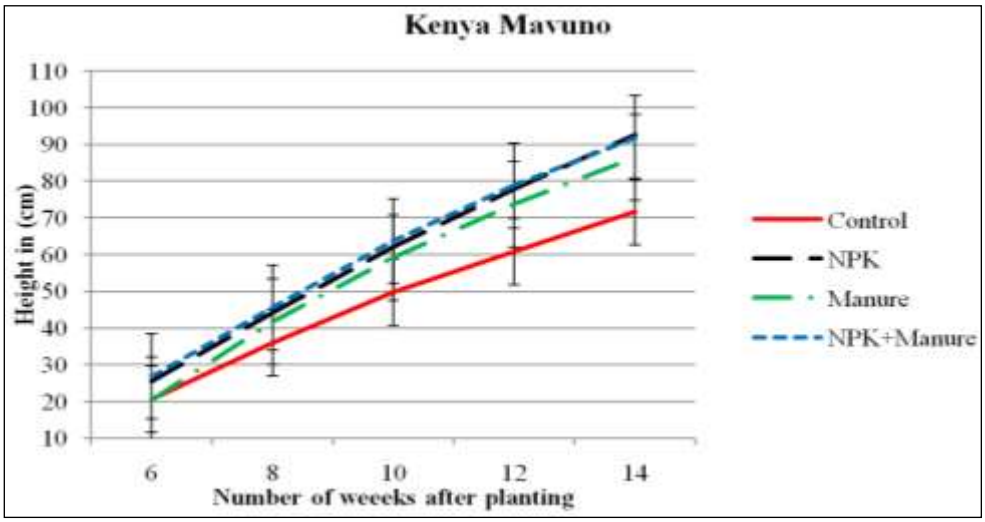

Fig. 2B. Height trend for Kenya Mavuno Tigoni second season (April, 2014 to August, 2014). Error bars with standard error.

Effects of inorganic fertilizer and cattle manure on canopy %

There was significant difference (P=0.05) among the treatments on canopy % during the first season (October, 2013 to February, 2014), NPK (23:23:0) treatment had the highest canopy % mean although it was not significantly different from the NPK (23:23:0) + Cattle Manure treatment (Table 3). During the second season (April, 2014 to August, 2014), the treatments had significance difference (P=0.05). NPK (23:23:0) treatment had the highest mean canopy % (Table 4). This is due to the fact that Nitrogen stimulates canopy growth and phosphorous influences vegetative vigour.

Table 3. Canopy % first season (October, 2013 to February, 2014) Tigoni.

Treatment	Canopy %
NPK (23:23:0)	96.32 a
NPK (23:23:0) + Cattle Manure	93.99 a
Cattle Manure	85.84 b
Control	81.52 c
Grand mean	89.4
S.E. of means	3.02
LSD	7.38
CV %	6.7
P Value	0.002

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

Table 4. Canopy % second season (April, 2014 to August, 2014), Tigoni.

Treatment	Canopy %
NPK (23:23:0)	98.66 a
NPK (23:23:0)+ Cattle Manure	94.33b
Cattle Manure	90.34c
Control	89.84c
Grand mean	93.29
S.E. of means	2.504
LSD	3.1
CV %	2.7
P Value	<.001

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

Effects of inorganic fertilizer and cattle manure on tuber yield.

The tuber yield in the first season was significantly different (P < 0.05) between varieties. Also the inorganic fertilizer and cattle manure treatments effects were significantly different but the interaction between variety and treatments were not significant. Although the NPK (23:23:0) + Cattle Manure and NPK (23:23:0) treatments were not significantly difference, NPK (23:23:0) gave the highest yields in the first season (Table 5). This is because inorganic fertilizer releases nutrients faster than cattle manure.

During the second season, the inorganic fertilizer and cattle manure treatments effects were significantly different (P<0.05) (Table 6). However the interaction between potato varieties and treatments was not significant. As per all treatments NPK (23:23:0) treatment was significantly different (LSD =0.05) from the rest of the treatments and yielded the highest (Table 6). This could be due to fast release of nutrients by NPK (23:23:0) and slow release of nutrients by cattle manure. The first released nutrients especially phosphorous had a health influence of sprouting, root development vegetative vigour and maturing of the potato thus highest yield.

The second season had higher yields than first season. This could be due to cool temperatures (Table 10) in the second season which are known to enhance tuberization in potatoes and to lengthen the growing period hence more yields (Acquaah, 2007). For both first and second seasons, the results confirmed the findings of Mugambi (1979) which showed that the presence of NPK increases tuber yield. The NPK (23:23:0) released adequate nutrients faster than the rest of the treatments thus highest yield. Results also confirmed the findings of (Powon *et al.*, 2004), that manure alone cannot result on higher yields, but when combined with inorganic fertilizer higher yields are achieved (Table 5 and 6).

Table 5. Effects of inorganic fertilizer and cattle manure on tuber yield in first season (October, 2013 to February, 2014) Tigoni.

Treatment	Mean Yield Ton/ha
NPK(23:23:0)	29.12 c
NPK(23:23:0)+Cattle Manure	24.22 bc
Cattle Manure	22.36 ab
Control	16.35 a
Grand mean	23.01
S.E. of means	1.511
LSD	4.585
% CV	16.1
P value	<.001

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

Table 6. Effects of inorganic fertilizer and cattle manure on tuber yield in second season (April, 2014 to August, 2014) Tigoni.

Treatment	Mean Yield Ton/ha
NPK(23:23:0)	31.85 a
NPK(23:23:0)+Cattle Manure	26.24 b
Cattle Manure	23.96 bc
Control	19.37 c
Grand mean	25.36
S.E. of means	1.237
LSD	3.753
CV%	12
P value	<0.001

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

Effects of inorganic fertilizer and cattle manure on tuber size

On tuber size for both short and long rains season, there was significant difference among the treatments. During the first season (October, 2013 to February, 2014),) NPK (23:23:0) treatment had the highest big average size of tubers which was significance compared to other treatments. On small tuber size there was no significance difference between NPK (23:23:0) treatment and NPK (23:23:0) + Cattle Manure treatment (Table 7). During the second season (April, 2014 to August, 2014) NPK

(23:23:0) treatment had the highest average big tuber size, although there was no significance difference with NPK (23:23:0) and NPK (23:23:0) + Cattle Manure treatments (Table 8).

On tuber small size there was no significance difference among the Manure, NPK (23:23:0) and NPK (23:23:0) + Cattle Manure treatments (Table 8).

Table 7. Tuber size in first season (October, 2013 to February, 2014) Tigoni.

Treatment	Tuber big size (cm)	Tuber small size (cm)
Control	18.17 a	10.83 a
Cattle Manure	18.83 a	11.67 a
NPK (23:23:0)	25 b	14 b
NPK (23:23:0) + Cattle Manure	21.08 a	12.5 ab
Grand mean	20.77	12.25
S.E. of means	0.824	0.475
LSD	2.499	1.439
CV%	9.7	9.5
P value	<.001	0.002

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

Table 8. Tuber size in second season (April, 2014 to August, 2014) Tigoni.

Treatment	Tuber big size (cm)	Tuber small size (cm)
Control	27.17 a	10.93 a
Cattle Manure	29.17 a	12.45 ab
NPK (23:23:0)	34.08 b	14.5 b
NPK (23:23:0)+ Cattle Manure	30.5 ab	12.78 ab
Grand mean	30.23	12.67
S.E. of means	1.138	0.698
LSD	3.383	2.075
CV%	9.2	13.5
P value	0.003	0.017

Within a column, values followed by the same letter are not significantly different from each other at LSD= 0.05.

Table 9. Experimental Site Soil Analysis Results Analysed Soil depth (0-30cm).

Soil Parameters	Value	Class
Soil pH	4.57	Strong acid
Total Nitrogen %	0.19	Low
Total org. Carbon %	1.92	Moderate
Phosphorus ppm	20	Low
Potassium me %	1.16	Adequate
Calcium me %	2.9	Adequate
Magnesium me%	0.90	Low
Manganese me%	0.75	Adequate
Copper ppm	4.00	Adequate
Iron ppm	81.4	Adequate
Zinc ppm	28.5	Adequate
Sodium me%	0.24	Adequate

Table 10. Weather conditions at Tigoni during the study period.

Year	Month	No. of rainy days	Monthly rainfall (mm)	Min	Temperature (O^c) Max
2013	October	3	9	14.61	18.08
2013	November	13	121.4	15.05	16.13
2013	December	8	137.2	14.79	15.69
2014	January	1	25.2	15.11	17.77
2014	February	8	189.4	15.39	15.39
2014	March	7	136.1	15.79	17.04
2014	April	8	136.7	14.81	15.88
2014	May	3	68	15.01	16.0
2014	June	9	103.4	13.88	14.28
2014	July	4	35.7	12.84	14.48
2014	August	6	81.5	13.01	13.82

Source: KALRO Tigoni Weather Annual Reports (2013-2014).

Conclusion

From the study it can be concluded that, the NPK (23:23:0) gave the best performance. This is because it had a positive effect on vegetative and reproductive growth of the potato hence good yields. The findings recommended that farmers can apply NPK (23:23:0) in soils with adequate potassium during sowing irish potatoes, for high yields, ultimate food security and increased income.

Acknowledgment

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