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Full Length Research Paper

Effects of different sources of nitrogen on potato at Tigoni, Kenya

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A field experiment was set up to investigate the effects of different sources of nitrogen on potato at Tigoni in Kenya. The treatments consisted of ten fertilizer materials and two potato *Solanum tuberosum* varieties, namely, 'Tigoni' and 'Asante'. The experiment was conducted for two consecutive seasons: October, 2008 to February, 2009 (first season) and April, 2009 to August, 2009, (second season). The experiment was a factorial laid in randomized complete block design with three replications. The potato yields were high with variety 'Tigoni' giving an average of 81.0 tons/ha in the first season and 86.8 tons/ ha in the second season. Variety 'Asante'yielded an average of 59.5 tons/ha in the first season and 62.1 tons/ha in the second season. The fertilizer materials, the varieties, and the interaction between fertilizers and varieties were all significant (P = 0.05) in both seasons. The experiment need to be repeated on farmers' fields where the masking effects of the residual fertilizers can be eliminated. In addition, the cost of different fertilizer combinations needs to be evaluated so as to make the most profitable recommendations to potato growers in Kenya.

Key words: Asante, Kenya, nitrogen sources.

INTRODUCTION

Potato is the second most important food crop after maize in Kenya (MoA/GTZ, 1998; CIP, 2006; MoA, 2008). It is grown by about 500,000 farmers, cultivating 120,000 hectares per season with an annual production of about 1 million tonnes in two growing seasons (MoA, 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 t ha^{-1} with an average of 6.7 t ha^{-1}. However, yields of 40 t ha^{-1} had been attained from research fields (Lung'aho et al., 1997; MoA, 2008). Potato yields in the country are generally low (Kaguongo et al., 2008); Muthoni et al., 2010). One of the contributing factors to low potato yields is low soil fertility, occasioned by continuous cultivation without adequate replenishment of mined nutrients (Kaguongo et al., 2008. In addition, fertilizers are usually applied below the recommended rate (90 kg N ha^{-1} + 230 kg P_2O_5 ha^{-1}) for potato production in Kenya (Kaguongo et al., 2008).

Furthermore, application of organic matter to the fields is limited. This is because crop residues are used as fodder, and cattle manure when used, the quantity and quality are often below the recommended rates (Muthoni et al., 2010). The most limiting soil nutrients to potato production in Kenya are nitrogen and phosphorus (Recke, 1997).

Against this background, an experiment was set up whose objective was to investigate the effects of different sources of nitrogen on potato.

MATERIALS AND METHODS

The experiment was conducted at Kenya Agricultural Research Institute (KARI), National Potato Research Centre, Tigoni. It was conducted for two consecutive seasons: October, 2008 to February, 2009 (first season) and April, 2009 to August, 2009 (second season). The KARI-Tigoni station is located 40 km North-west of Nairobi city centre, at an altitude of 2131 masl, latitude of 1°15' S and longitude 23° 46' E (Jaetzold et al., 2006). The average annual

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Table 1. Fertilizer treatments.

No.	Fertilizer materials	Application rate/ plot
1	Di ammonium phosphate (DAP) (18:46:0)	600 g
2	DAP + Manure	300 g + 3 kg
3	Nitrogen Phosphorus Potassium (NPK) (20:20:20)	540 g
4	NPK + Manure	270 + 3 kg
5	Manure (1.8% N)	6 kg
6	Manure + Calcium ammonium nitrate (CAN) (26:0:0)	3 kg + 173 g
7	Triple super phosphate (TSP) (0:46:0) + CAN (26:0:0)	600 g + 346 g
8	NPK + TSP	540 g + 3 65 g
9	DAP (1/2 Rate)	300 g
10	Control	Nil

rainfall is 1096 mm with a bimodal distribution. Long rains season occurs between March and May while short rains season is between October and December (Jaetzold et al., 2006). The mean annual air temperature is 18°C and ranges between 12 and 24°C. Rainfall, temperature, and relative humidity during the study period were recorded. The soil type is humic nitosol (alfisol) derived from quartz trachyte (Jaetzold et al., 2006). The soil is very deep and well drained with a pH range of 4.3 to 5.82 (Muthoni and Kabira, 2010). The soil is of medium inherent fertility with organic carbon content of about 1.65%. Exchangeable bases of potassium, calcium and magnesium are moderately high with available potassium being about 1.7 % milliequivalent (Muthoni and Kabira, 2010). The treatment combinations consisted of ten fertilizer materials and two potato varieties, 'Asante' and 'Tigoni'. The manure was collected from open paddocks and was found to contain 1.8% nitrogen. The experiment was laid out in a factorial arrangement with potato varieties and fertilizer materials as factors giving a total of twenty treatment combinations. These treatment combinations were laid in a Randomized complete block design replicated three times. Blocking was introduced due to gradient /slope of the experimental site.

Each plot measured 4 m long x 3 m wide and contained four rows. Potatoes were planted at a spacing of 75 x 30 cm giving a total of 53 plants per plot. Fertilizer materials application rates were calculated on the basis of % nitrogen content so as to give the recommended nitrogen rate for potato production in Kenya which is 90 kgN/ha (Table 1). The half rate of Di-ammonium Phosphate (DAP) used was to simulate farmers' field practice. All the fertilizer materials were mixed with soil in the furrow during planting except CAN which was top dressed 21 days after planting. Plants were weeded and irrigated regularly as need arose. The plants were also sprayed against late blight using Ridomil MZ 68^{R} WP (Metalaxyl-M 40 g/kg + Mancozeb 640 g/kg) (Syngenta Crop Protection, AG basele, Switzerland) at 30 gm/15 L of water and against insect pests using Actellic Super (Syngenta Crop Protection, AG basele, Switzerland) at 20 mls/15 L of water. This was done three times as was dictated by the prevailing weather conditions and insect pest infestation.

Data on the number of leaves and primary branches per stem were obtained from five plants in the middle two rows. This was done at 60 days after planting when the varieties had reached 50% flowering. At maturity, tubers were harvested from six hills from the two middle rows per plot and weighed out. The yields were converted into tons/ha. Data were subjected to analysis of variance (ANOVA) using Genstat statistical package (Genstat, 2009). The treatment effects were tested for significance using F-test at 5%. Where the F-test showed significance effects, treatment means were separated using least significant difference (LSD) test at 5% (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The mean air temperature was below 18°C for most of the experimental period (Table 2).

Tuber yields

There were significant differences (P = 0.05) in tuber yields between varieties in the first season (Table 3). The fertilizer effects were also significant. However, the interaction between the variety and the fertilizer was not significant (Table 3).

Variety 'Tigoni' gave an average yield of 81.0 tons/ha while 'Asante' yielded 59.5 tons/ha on average. Although DAP + Manure and DAP treatments were not significantly different (LSD = 0.05) from each other, DAP + Manure gave higher yields than all the other treatments in the first season (Table 4). During the second season, the fertilizer treatments had significantly different effects (P = 0.05) on tuber yields (Table 5). The same applied to potato varieties. However, the interaction between potato varieties and fertilizer treatments was not significant (Table 5).

Variety 'Tigoni' yielded 86.8 tons/ha on average while 'Asante' yielded 62.1 tons/ha on average. The overall mean yield was 74.4 tons/ha. The NPK (20:20:20) gave the highest yields (Table 6).

The yields recorded in this experiment were very high. This could have been due to the high fertility of the experimental site because the fields are normally fertilized each season, and there is a likelihood of residual fertilizer effects. The high yields could also have been due to other nutrients in the fertilizers in addition to nitrogen because the fertilizer materials were not straight fertilizers. In addition, the cool weather that prevailed

Table 2. Weather conditions at Tigoni during the study period.

Year	Month	No. of rainy days	Monthly rainfall (mm)	Temperature (°C)	RH
2008	January	11	80.3	16.11	67.81
2008	Feb	6	72.0	16.01	64.85
2008	March	15	304.1	16.10	69.53
2008	April	11	323.1	15.43	69.23
2008	May	7	51.3	15.47	67.23
2008	June	3	8.3	12.94	70.77
2008	July	12	60.5	12.56	77.10
2008	August	4	14.0	18.97	66.84
2008	September	6	79.8	15.50	68.87
2008	October	13	194.2	15.39	73.37
2008	November	8	69.9	15.88	69.93
2008	December	-	88.3	16.74	88.31
2009	January	3	21.7	16.80	64.80
2009	February	3	21.0	16.70	61.50
2009	March	3	61.9	18.10	65.20
2009	April	13	212.8	17.00	71.20
2009	May	17	180.1	15.40	72.90
2009	June	7	66.5	14.90	70.30
2009	July	11	46.2	14.00	74.70
2009	August	-	-	14.10	51.60
2009	September	3	37.8	16.20	67.97
2009	October	11	138.4	15.42	74.10
2009	November	11	111.1	15.90	72.30
2009	December	12	142.8	16.02	73.90

Table 3. Analysis of variance for total tuber yields (ton/ha) for the first season (October, 2008 to February, 2009).

Source of variation	df	ss	ms	vr	Fpr
Block stratum	2	4240.8	2120.4	4.13	
Block.*Units* stratum					
Variety	1	41456.4	41456.4	80.83	<.001
Fertilizer	9	24534.3	2726.0	5.32	<.001
Variety. Fertilizer	9	3282.4	364.7	0.71	0.699
Residual	338	173357.1	512.9		
Total	359	246871.0			

during the experimental period could have contributed to these high yields. Cool temperatures are known to enhance tuberization in potatoes and to lengthen the growing period hence more yields (Acquaah, 2007).

Number of leaves per stem

In the first season, the fertilizer materials, the varieties, and the interaction between fertilizers and varieties were all significant (P = 0.05) (Table 7). In NPK + TSP and DAP half rate, there were no significant (P = 0.05) differences in the number of leaves per stem between the two potato cultivars (Figure 1).

During the second season, the fertilizer materials, the varieties, and the interaction between fertilizers and varieties were all significant (P = 0.05) (Table 8).

The greatest differences in leaves per stem between the two potato cultivars were found in NPK + Manure, Manure + CAN, and TSP + CAN fertilizers (Figure 2). In both seasons, variety 'Tigoni' had significantly (P = 0.05) higher number of leaves per stem than 'Asante' (Table 9).

The differences between cultivars 'Tigoni' and 'Asante' in terms of leaves per stem could be due to genetic differences between them. Generally, cultivar 'Tigoni' is taller and has more foliage than cultivar 'Asante'.

Table 4. Effects of fertilizers on mean tuber yield for the first season (October, 2008 to February, 2009).

Fertilizer	Mean tuber yields (tons/ha)
DAP + Manure	83.7a
DAP(18:46:0)	78.0ab
NPK (20:20:20)	77.0ab
TSP(0:46:0) + CAN (26:0:0)	75.8ab
NPK + Manure	68.7bc
Manure	68.3bc
Manure + CAN (26:0:0)	66.4bc
NPK + TSP	70.0bc
DAP(1/2 Rate)	59.4cd
Control	55.2d
Mean yield	70.3
% CV	6.0
LSD	10.5

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

Table 5. Analysis of variance for tuber yields during the second season (April, 2009 to August, 2009).

Source of variation	df	ss	ms	vr	Fpr
Block stratum	2	6036.1	3018.0	8.28	
Block.*Units* stratum					
Variety	1	54935.5	54935.5	150.75	<.001
Fertilizer	9	117673.9	1963.8	5.39	<.001
Variety. Fertilizer	9	4602.1	511.3	1.40	0.185
Residual	338	123174.1	364.4		
Total	359	206421.7			

Table 6. Effects of fertilizer on mean tuber yield for the second season (April, 2009 to August, 2009).

Fertilizer	Mean tuber yields (tons/ha)
NPK (20:20:20)	85.9 a
TSP (0:46:0) + CAN (26:0:0)	83.0 a
DAP + Manure	81.2 ab
DAP (18:46:0)	79.8 abc
NPK (20:20:20) + TSP (0:46:0)	72.5 bcd
NPK + Manure	70.8 cd
Manure	67.4 d
Manure + CAN (26:0:0)	68.9 d
DAP (1/2 rate)	69.4 d
Control	65.2 d
Mean yield	74.4
% CV	6.7
LSD	8.85

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

Table 7. Analysis of variance. Leaves per stem for the first season (October, 2008 to February, 2009).

Source	df	ss	ms	vr	Fpr
Block	2	927.05	463.52	38.78	
Fertilizer	9	317.85	35.32	2.96	0.002
Variety	1	1795.85	1795.85	150.27	<0.001
Fertilizer x variety	9	406.41	45.16	3.78	<0.001
Residual	278	3322.42	11.95		
Total	299	6769.59			

LSD for interaction 2.485.

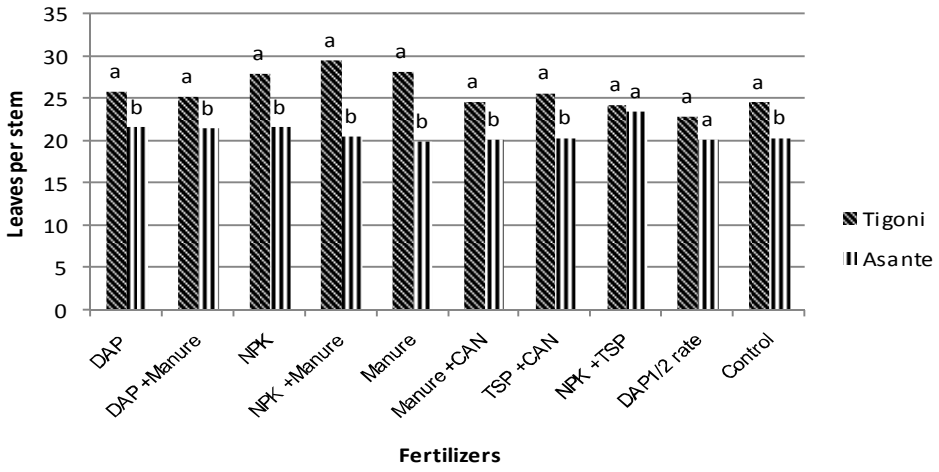

Figure 1. Leaves per stem during the first season.

Table 8. Analysis of variance: Leaves per stem during the second season (April, 2009 to August, 2009).

Source	df	ss	ms	vr	Fpr
Block	2	981.087	490.543	60.99	
Fertilizer	9	1726.350	191.817	23.85	<.001
Variety	1	2964.163	2964.163	368.56	<.001
Fertilizer x variety	9	457.470	50.830	6.32	<.001
Residual	278	2235.847	8.043		
Total	299	8364.917			

LSD for interaction 2.039.

Differences in the effects of the fertilizer materials could have been due to other nutrients in the fertilizers in addition to nitrogen because the fertilizer materials were not straight fertilizers. Nitrogen in the presence of adequate phosphorus and potassium stimulates canopy growth, leaves and branches. This is through production of extra leaves and branches, extension of leaf area duration and expansion of leaf area. Nitrogen needs to be present from emergence to flowering to promote rapid canopy growth (White et al., 2007).

Number of primary branches per stem

There were no significant differences among the fertilizer treatments on the number of primary branches per stem during the first season (Table 10). However, varieties showed significant differences (P = 0.05) while the interaction between fertilizer and varieties was not significant.

Generally, variety 'Tigoni' had significantly higher number of primary branches than 'Asante' (Table 11).

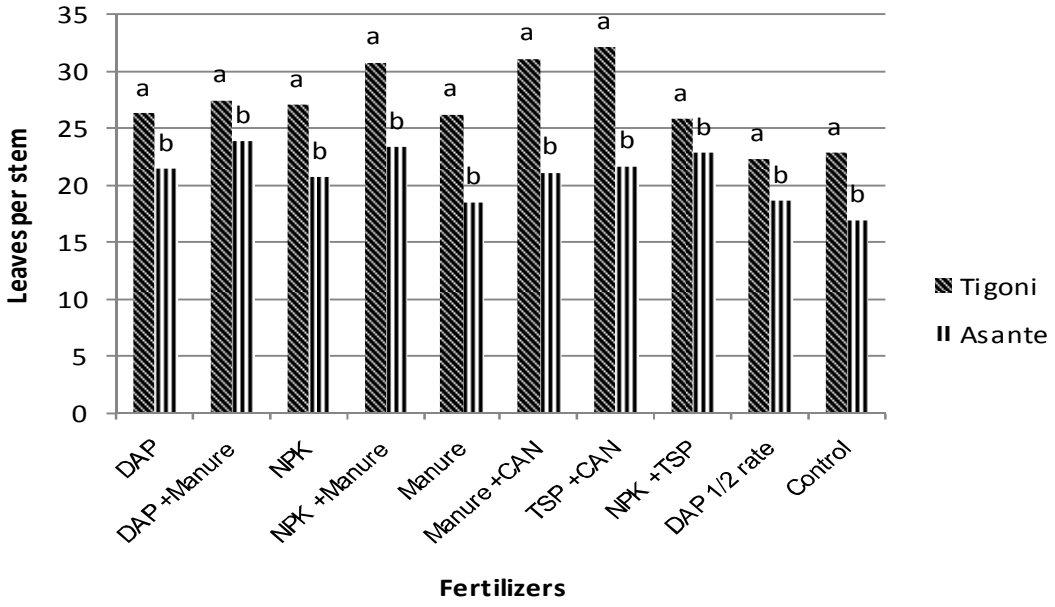

Figure 2. Leaves per stem during the second season.

Table 9. Mean leaves per stem for the two potato cultivars in both seasons.

Cultivar	Season 1	Season 2
Tigoni	25.72	27.23
Asante	20.83	20.94
LSD (0.05)	0.786	0.645

Table 10. Analysis of variance: Primary branches per stem during the first season (October, 2008 to February, 2009).

Source	df	ss	ss	vr	Fpr
Blocks	2	30.780	15.390	2.34	
Fertilizer	9	66.733	7.415	1.13	0.342
Variety	1	225.333	225.333	34.32	<.001
Fertilizer x variety	9	32.933	3.659	0.56	0.831
Residual	278	1825.220	6.566		
Total	299	2181.000			

Table 11. Varietal differences in primary branches per stem (first season).

Variety	Tigoni	Asante	LSD (0.05)
Branches/stem	14.37	12.63	0.582

There were significant differences among the fertilizer treatments on the number of primary branches per stem during the second season (Table 12). Varieties were also significantly different (P = 0.05). However, the interaction between fertilizer and varieties was not significant.

Generally, variety 'Tigoni' had significantly higher number of branches than 'Asante' (Table 13).

The NPK + Manure treatment gave the highest number of branches per stem, although there were no significant differences between this treatment and DAP + Manure

Table 12. Analysis of variance: Branches per stem during the second season (April, 2009 to August, 2009).

Source	df	ss	ms	vr	Fpr
Block	2	63.447	31.723	8.88	
Fertilizer	9	242.187	26.910	7.53	<.001
variety	1	507.000	507.000	141.89	<.001
Fertilizer x variety	9	50.600	5.622	1.57	0.123
Residual	278	993.353	3.573		
Total	299	1856.587			

Table 13. Varietal differences in branches per stem during the second season (April, 2009 to August, 2009).

Variety	Tigoni	Asante	LSD (0.05)
Branches/stem	15.41	12.81	0.43

Table 14. Effects of fertilizer materials of branches per stem during the second season (April, 2009 to August, 2009).

Fertilizer materials	Mean branches per stem
NPK + Manure	15.17 a
DAP + Manure	15.13 ab
DAP	15.13 ab
NKP + TSP	14.60 abc
TSP + CAN	14.17 abcd
NPK	14.07 bcd
Manure + CAN	13.67 cd
Manure	13.57 cd
DAP(1/2 Rate)	13.33 d
Control	12.23 e
Grand mean	14.11
%CV	13.4
LSD (0.05)	0.961

and DAP alone (Table 14).

The differences between cultivars ‘Tigoni’ and ‘Asante’ in terms of number of primary branches per stem could be due to genetic differences between them. Generally, cultivar ‘Tigoni’ is taller and has more foliage than cultivar ‘Asante’. Differences in the effects of the fertilizer materials could have been due to other nutrients in the fertilizers in addition to nitrogen because the fertilizer materials were not straight fertilizers.

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RECOMMENDATIONS

The experiment need to be repeated on farmers’ fields where the masking effects of the residual fertilizers can be eliminated. In addition, the cost of different fertilizer combinations needs to be evaluated so as to make the most profitable recommendations to potato growers in Kenya.

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