Response of Three Legumes to Inorganic Fertilizer Application in Different Agro-Ecological Zones in Makueni County Kenya

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Abstract

Legume productivity in Makueni County is low mainly due to declining soil fertility. Improving soil fertility through use of inorganic fertilizers can greatly increase grain legume productivity in the area. The objective of the study was to evaluate the effect of DAP fertilizer application on the productivity of three legume species in different agro-ecological zones in Makueni County. This study was conducted in Makueni County during the 2014 long rain season in three locations namely Machinery (IL6), Utafiti (LM5) and Mwanzo (LM4) with five farmers from each location. The three legume species were Beans (KAT/B-9), Cowpea (M66), Lablab (KAT/DL-1) and Lablab accession CP1 81364. The two DAP fertilizer treatments were 0 kg/ha (farmer practise) and 50 kg/ha (recommended practise). The experiment was laid out as a Randomised Complete Block Design (RCBD) with five replications. Data was collected on biomass yield at flowering and harvest and the grain yield. Data was subjected to ANOVA using SAS. Soil analysis results showed that the soils were deficient in nitrogen, phosphorous and organic carbon across the three sites. DAP fertilizer application significantly increased the biomass yield of KAT Bean-9. Harvest biomass yields increased by 49% and 100% in the three agroecological zones. Grain yield increased by 171 to 204% in the AEZs. DAP fertilizer application significantly increased cowpea M66 grain and biomass yields. Biomass yields increased between 63% and 96% in the three AEZs. Cowpea M66 grain yield increased by 60 to 127% in the three AEZs. DAP fertilizer application increased biomass accumulation of the two lablab varieties between 70% and 120%. Grain yields increased between 70% and 116%. The results from the study showed that farmers across three agro-ecological zones will greatly increase their legume yields if they adopted the use of inorganic fertilizer to improve soil fertility.

Key Words: Beans, Cowpea, Lablab, Inorganic Fertilizer, Makueni County

Introduction

Grain legume production in Makueni County is low because of drought, low soil fertility, inadequate farm inputs, weeds, pests and diseases and lack of certified seed. However, low soil fertility is the major limiting factor in grain legume production in the county (Wambua, 2014). On average, fertile soils cover less than 10 % of the area under grain legume production (Kimiti *et al.,* 2009). Soils in the county are commonly nutrient deficient, especially of nitrogen (N) and phosphorus (P). This is largely due to continuous cropping without external inputs (Wambua, 2013). As a result, grain legume yields are low ranging from 30 kg/ha to 416 kg/ha (Kimiti *et al.*, 2009). Use of external inputs especially inorganic fertilizers can help replenish soil nutrients. However, inorganic fertilizer use in Makueni County is low and it's estimated that only 2 % of the farmers in Makueni County use inorganic fertilizers. Farmers in Makueni County believe that use of inorganic fertilizers will harden their farms resulting to a decrease in crop production (Kimiti, 2014).

Materials and Methods

Description of Research Area

The research was conducted in Makueni County. It stretches from latitude 1º35´S to 3º01´S from north to south and from longitudes 37º10´E and 38º30´E from East to West. It has an area of 8,009 km^2, about 70% being arid and semi arid lands (Makueni County report, 2013).
Majority of Makueni County lies within agro-ecological zone 5 (AEZ 5) in the semi-arid region of Eastern Kenya (Jaetzold *et al.,* 2010). Highly weathered soils (Ferralsols, Acrisols and Luvisols) dominate the area. The area receives mean annual rainfall of 231 mm and 361 mm during long and short rain seasons respectively (Recha et al., 2012). The mean maximum temperature of the area is 25°C and the mean minimum temperature is 13°C (Jaetzold et al., 2010).

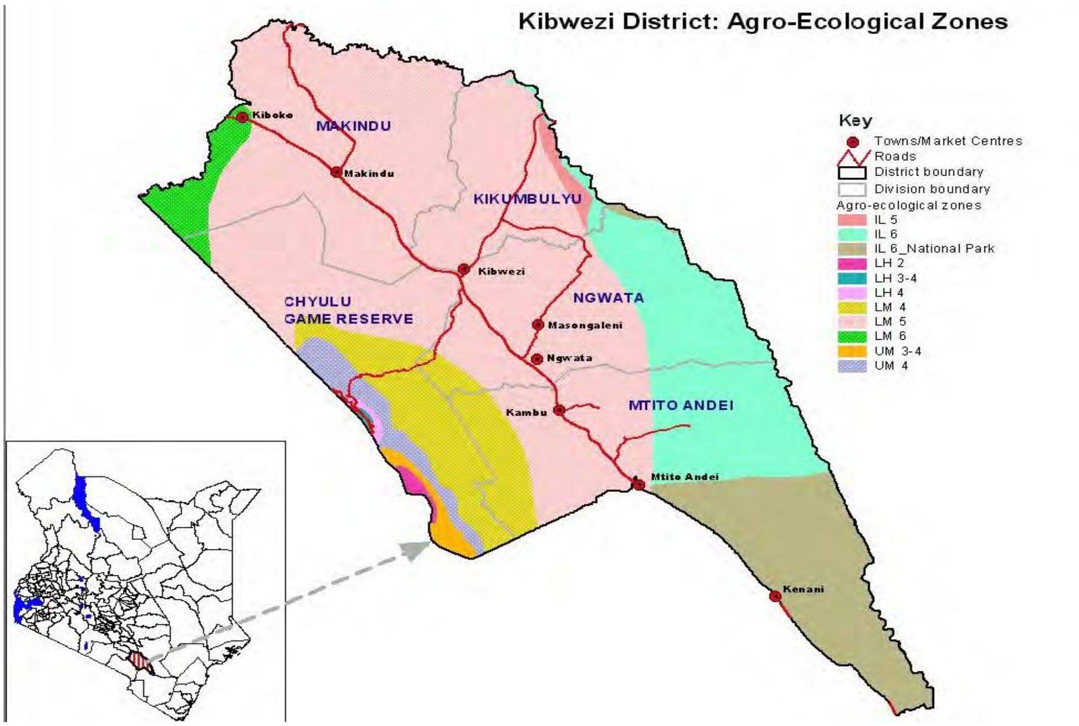

Figure 1: Map of Makueni County, Kenya showing different Agro-Ecological Zones (Map adapted from Bishaw et al., 2013)

Site and Farmer Selection

The study was conducted in three locations selected across Makueni County based on the different agro-ecological zones. The first location was at Machinery which is in the inner lowland ranching zone (IL 6). The other location was at Utafiti which is in the lower midland livestock-millet zone (LM 5). The third location was at Mwanzo which is in the Lower Midland marginal cotton zone (LM 4). From each location, five smallholder farmers that rely on farming activities as their first income source were selected.

Experimental Design, Treatments and Crop Husbandry

The experiment was carried out from March to July, 2014 during the long rainy season. The field experiments were laid out in a Randomized Complete Block Design and in a factorial arrangement with five replications per location. Each location had five farmers with one block per farm. The experimental units measured 5 metres by 3 metres separated by 1 metre paths. The three legume species were Beans (KAT/B-9), Cowpea (M66), Lablab (KAT/DL-1) and Lablab accession CP1 81364. The two DAP fertilizer levels were 0 kg of DAP per hectare and 50 kg of DAP per hectare. The legumes varieties selected were well adapted to the climatic conditions of the study area. The choice of DAP fertilizer treatments was determined by farmer practice and the recommended practise (Karanja et al., 2006; Karugia et al., 2012).

The experimental sites were cleared and all the ground vegetation and crop debris removed. The fields were ploughed and harrowed. They were then prepared to a fine tilth and levelled. Planting was done during the second week of March after the onset of long rains. The spacing was 0.45 m by 0.2 m for KAT Bean-9, 0.5 m by 0.3 m for cowpea M66 and 0.7 m by 0.3 m for lablab (Karanja *et al.,* 2006). Three seeds were placed in each planting hole and planted at a depth of three to five centimetres. Gapping was done eight days after sowing so as to establish a uniform plant population. First weeding was done at fourteen days after emergence. Thinning was done simultaneously with first weeding so as to achieve the required plant population. Second weeding was done five weeks after emergence (Karanja *et al.,* 2006). Duduthrin Super (Lambdacyhalothrin 50g/l) was sprayed to control caterpillars and aphids at rates of 1 litre per hectare. Soil samples were also taken from the various experimental units and taken for laboratory analysis.

Data Collection and Analysis

Data was collected on biomass yield at physiological maturity and grain yield at harvest. Biomass samples were taken from all plots by cutting the plants at first node from the soil surface using secateurs and packed in a well labelled paper bag. Plant samples from each experimental unit were oven dried at 65°C for 48 hours and weighed. The three legumes were harvested from the net plot at physiological maturity. The pods were harvested, dried, threshed, winnowed and weighed. The dry weight of seeds harvested in the net plot was recorded and extrapolated to kilogram per hectare. Data was subjected to ANOVA using SAS. Data were analysed using SAS Statistical software version 9.3 (SAS Institute Inc, 2012). Data collected were statistically evaluated by analysis of variance (ANOVA) using the general linear model; PROC GLM procedure (SAS, 2012). Least Significant Difference (LSD) test was used to separate treatment means significant at 95 % confidence level (Steel & Torrie, 1981).

Results and Discussion

Initial Soil Chemical and Physical Characterization

The results of the physical and chemical properties of the soil sampled from experimental sites at the beginning of the experiment are presented in Table 1 below.

Table 1. Physical and chemical characteristics of top soil (0-20 cm) across the three locations in Makueni County

	Location means			Critical levels
Soil characteristic	**Utafiti**	**Machinery**	**Mwanzo**	**(Thomas** et al**., 1997)**
Chemical composition				
pH	6.53	6.45	6.58	near neutral
N (%)	0.10*	0.07*	0.06*	< 0.2
P (mg/kg)	14.00*	7.00*	13.00*	< 20
C (%)	0.92*	0.69*	0.52*	< 1.0
K (cmolc/kg)	0.52	0.33	0.59	< 0.2
Ca (cmolc/kg)	1.90	1.60	2.00	< 0.2
Mg (cmolc/kg)	1.58	1.74	1.63	< 1.0
Physical composition (%)				
% clay	27.60	22.40	26.60	
% sand	67.60	70.80	66.20	
% silt	4.80	6.80	7.20	
Textural class	sandy clay loam	sandy loam	sandy clay loam	

* Below critical levels

Soil analysis results from Table 1 above show that the average values for total nitrogen, available phosphorus and organic carbon were below critical levels across the three locations (Thomas *et al.*, 1997). They are less than half of what is considered to be adequate for grain legume production. These soil test results are in conformity with those of Onduru *et al.*, (2001) and Mora-Vallejo *et al.*, (2008) whose study revealed that soils in Makueni County had low fertility and were generally deficient in nitrogen, phosphorus and soil organic carbon. The low nitrogen and phosphorus levels can be attributed to failure to apply farmyard manure and fertilizer, nutrient loss through crop harvest, soil erosion and continuous cultivation in the same piece of land. The same have been identified as the main causes of declining soil fertility in Makueni County (Kimiti *et al.*, 2009; Kimiti, 2014).

Response of Beans to DAP Fertilizer Application

DAP fertilizer application significantly ($P \leq 0.05$) increased the KAT Bean-9 biomass yield at harvest (Table 2). DAP fertilizer application increased biomass accumulation at harvest by 100 % in Mwanzo, 86 % in Utafiti and 49 % in Machinery.

Table 2. Plant biomass yield of KAT Bean-9 at different fertilizer levels

Location	**Fertilizer level**	**Biomass yield at harvest kg**/ha
Utafiti	0 kg DAP/ha	816a
Utafiti	50 kg DAP/ha	1525b
Machinery	0 kg DAP/ha	927a
Machinery	50 kg DAP/ha	1388b
Mwanzo	0 kg DAP/ha	1000a
Mwanzo	50 kg DAP/ha	2022b
LSD		171
CV%		14

Means with different letters in the column are significantly different at $P \leq 0.05$.

The increase in biomass yield was attributed to addition of Nitrogen and Phosphorus; two macronutrients that are most limiting in the three locations (Kimiti *et al.*, 2009). Nitrogen has been found to promote shoot and leaf growth and is very important for biomass accumulation (Lunze *et al.*, 2012).

DAP fertilizer application significantly ($P \leq 0.05$) increased the grain yield of bean KAT/B-9 across the three locations (Figure 2). DAP fertilizer application increased the grain yield by 204 % in Mwanzo. The grain yield increased by 195 % and 171 % in Utafiti and Machinery respectively.

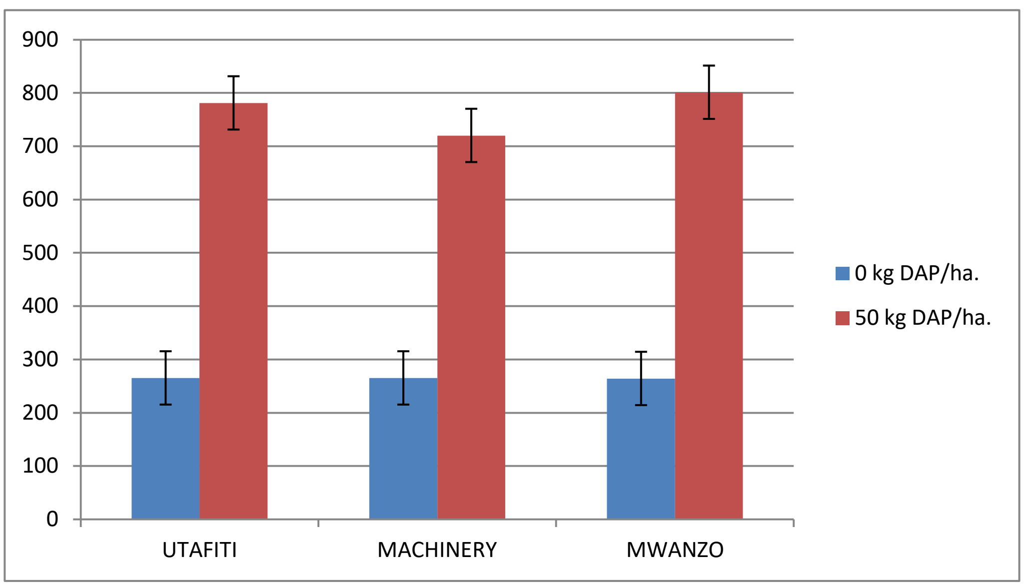

Figure 2. Grain yield of KAT Bean-9 (kg/ha) under two levels of fertilizer across three locations in Makueni County

The consistently higher grain yields recorded in treatments where DAP fertilizer was applied was attributed to higher amounts N and P nutrients. The two macro elements were found to be below the critical level across the three locations (Table 1). Other studies have found both nitrogen and phosphorus to have a significant effect on yield and yield components of beans. Farm trials carried out by Mugwe *et al.,* (2009) showed that application of 60 kg N/ha increased yields by more than 100 % above the control. A study carried out by Zafar *et al.,* (2011) showed significant improvements on the grain yield and yield components of common bean such as number of pods per plant following phosphorus supplementation over the control treatment.

Response of Cowpea to DAP Fertilizer Application

DAP fertilizer application significantly (P≤ 0.05) increased the biomass yield of cowpea M66 at harvest as shown in Table 3. DAP fertilizer increased biomass accumulation at harvest in Mwanzo by 96 %. Harvest biomass yields also increased in Utafiti and Machinery by 90% and 63 % respectively.

Table 3. Plant biomass yield of cowpea M66 at different fertilizer levels

Location	**Fertilizer level**	**Biomass yield at harvest kg**/ha
Utafiti	0 kg DAP/ha	1958a
Utafiti	50 kg DAP/ha	3721b
Machinery	0 kg DAP/ha	1144a
Machinery	50 kg DAP/ha	1866b
Mwanzo	0 kg DAP/ha	1866a
Mwanzo	50 kg DAP/ha	3674b
LSD		240
CV%		13

Means with different letters in the column are significantly different at *P≤ 0.05.*

The increase in biomass yield was attributed to addition of nitrogen and phosphorus nutrients which were deficient in the area. These results were similar to those of Odundo et al., (2010) who found out that application of 30 kg P/ha increased the dry matter yield of cowpea up to 74 % compared to the control. Research done by Gweyi-Onyango et al., (2011) also found that application of 50 kg/ha of TSP fertilizer increased the dry matter production of two cowpea genotypes. This is partly because P enhances plant physiology functions of such processes as photosynthesis, nitrogen fixation, flowering, fruiting and maturation (Pang et al., 2010). DAP fertilizer has been found to improve the biomass yield of soybean due to the supply of N which is important in biomass accumulation (Abuli et al., 2012). Research done by Ndor et al., (2012) showed that biomass and grain yield of cowpea was significantly higher in plots supplied with different levels of phosphorus as compared to the control.

DAP fertilizer application significantly (P≤ 0.05) increased the grain yield of cowpea M66 across the three locations. The grain yield increased by 127 % in Mwanzo, 101 % in Utafiti and 60 % at Machinery.

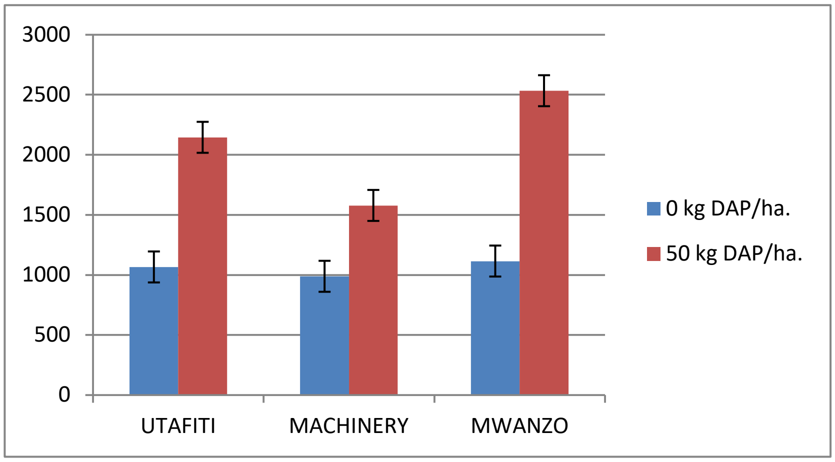

Figure 3. Grain yield of cowpea M66 (kg/ha) under two levels of fertilizer across three locations in Makueni County

The higher grain yields recorded in treatments where DAP fertilizer was applied was attributed to higher amounts N and P of nutrients. These results concur with those of Abuli et al., (2012) where grain yields of Soybean increased with application of DAP fertilizer. He attributed the increased grain yield of soybean under DAP fertilizer application to the nitrogen available in the fertilizer at a rate of 18 kg/ha which may have been vital in vegetative growth and grain filling at a later stage of crop growth. Phosphorus has been found to improve the grain yield of cowpea. Similar research done by Nyoki et al., (2013) and Ayodele et al., (2014) also found out that phosphorus supplementation increased the grain yield of cowpea and other yield parameters such as the number of branches per plant, number of nodules, number of pods, number of seeds per pod, mean pod weight and 100 seed weight. Onduru et al., (2008) also found out that application of TSP fertilizer improved the grain yields of cowpea to 1.7 tonnes per hectare.

Response of Lablab to DAP Fertilizer Application

DAP fertilizer application significantly (P≤ 0.05) increased the biomass yield of the two lablab varieties as shown in Table 4 below. DAP fertilizer application increased biomass accumulation of KAT/DL-1 by 101 % in Utafiti, 70 % in Machinery and 120 % in Mwanzo. Biomass yields of CP1 81364 also increased by 98 % in Utafiti, 74 % in Machinery and 102 % in Mwanzo.

Table 4. Plant biomass yield of lablab (kg/ha) at three locations in Makueni County

Lablab Variety	Fertilizer level	Biomass yield at Utafiti kg/ha	Biomass yield at Machinery kg/ha	Biomass yield at Mwanzo kg/ha
KAT/DL-1	0 kg DAP/ha	2526a	2046a	2506a
CP1 81364	0 kg DAP/ha	2101b	1325b	2070b
KAT/DL-1	50 kg DAP/ha	5186c	3488c	5518c
CP1 81364	50 kg DAP/ha	4256d	2300d	4114d
LSD			207	
CV%			11	

Means with different letters in the column are significantly different at $P \leq 0.05$.

The increase in biomass yield was attributed to addition of nitrogen and phosphorus nutrients to the soil which are deficient in the three locations. These results are consistent with those of Abuli *et al.,* (2012) whose research concluded that DAP fertilizer improved the biomass yield of soybean due to the supply of N which is important in biomass accumulation. Nitrogen and phosphorus application have been found to increase biomass yields of legumes (Odundo *et al.,* 2010; Gweyi-Onyango *et al.*, 2011).

DAP fertilizer application significantly increased the grain yield of the two lablab varieties in the three locations as shown in Table 5 below. DAP fertilizer application increased the grain yield of KAT/DL-1 by 114 % in Utafiti, 116 % in Machinery and 103 % in Mwanzo. The grain yields of CP1 81364 also increased by 78 % in Utafiti, 101 % in Machinery and 70 % in Mwanzo.

Table 5. Plant biomass yield of lablab (kg/ha) of the three locations in Makueni County

Lablab Variety	Fertilizer level	Grain yield at Utafiti kg/ha	Grain yield at Machinery kg/ha	Grain yield at Mwanzo kg/ha
KAT/DL-1	0 kg DAP/ha	686a	556a	786a
CP1 81364	0 kg DAP/ha	481b	340b	589b
KAT/DL-1	50 kg DAP/ha	1468c	1206c	1600c
CP1 81364	50 kg DAP/ha	858d	686d	1001d
LSD			172	
CV%			20	

Means with different letters in the column are significantly different at $P \leq 0.05$.

DAP fertilizer application significantly increased the grain yields of KAT/DL-1 and CP81364 in all the three locations. The consistently higher grain yields recorded in treatments where DAP fertilizer was applied was attributed to higher amounts N and P of nutrients which are deficient across the three locations. These results are in line with research carried out by Mugwe *et al.,* (2009) who found out that on farm trials showed that application of 60 kg N/ha increased yields by more than 100 % above the control. Phosphorus found in the fertilizer has been found to enhance nodulation in legumes which results in high nitrogen fixation and hence high grain and biomass yield (Singh *et al.*, 2011; Nyoki, *et al.*, 2013).

Conclusion

From the results, it is concluded that DAP fertilizer application at rates of 50 kg/ha significantly increased the biomass and grain yields of the three legumes in all locations when compared to the recommended practise. Farmers could greatly improve yields if they could apply DAP fertilizer at rates of 50 kg/ha in beans, cowpea and lablab production in Makueni Coumty.

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