EFFECTS OF PHOSPHORUS SOURCES ON SOYBEAN YIELD IN CENTRAL HIGHLANDS OF KENYA

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Abstract
Farmers in Central highland Kenya continue to experience depressed land productivity and incomes mainly due to their farms' low soil fertility status. Fertilizer costs have remained high beyond the reach of many farmers. Integrated soil fertility management (ISFM) is espoused as appropriate in intervention. Integration of legumes into smallholder farming system is one of the ISFM options. Using legumes can minimize nitrogen fertilizer requirement while improving farmers' incomes and food security. Soybean is a versatile legume fixing more nitrogen (N) than most grain legumes but its production has not received adequate attention in spite of its huge demand and short supply in the country. The most limiting nutrient in soybean production is phosphorus (P), critical in soybean growth but is limited in the central highlands, needing replenishment. The study done at Kigogo in Meru South District and Kamujine in Tigania East District assessed selected sources of P. The sources of P were Triple Super Phosphate (TSP), Minjingu rock phosphate, Mavuno fertilizer, di-ammonium phosphate (DAP), manure and fortified manure (Manure with Minjingu fertilizer at 1:1 ratio) all providing 30 kg P ha^{-1}. The trial was carried out in randomized complete block design (RCBD) having four replications with a plot size of 4.0 m by 4.5 m, being done in two seasons. Data was analyzed using analysis of variance (ANOVA) and means separated using Least Significant Difference (LSD) ($p=0.05$). Results showed DAP and Mavuno were among the best sources of Phosphorus. Farmers have an opportunity to enhance soybean production through use of either DAP or Mavuno fertilizer. The study recommends consistent use of manure in central highland farms alongside DAP and Mavuno use.

Key words: Soybean yield, P sources, ISFM

1 Introduction

Africa is unable to feed her increasing population (Dyson, 1999; Muchena *et al.,* 2005), a situation attributed to poor technology adoption (Chianu *et al.,* 2011), poor infrastructure (Sanchez *at al.,* 1997), declining nutrients status of her soils (Omotayo and Chukwuka, 2009) and poor agricultural and marketing policies (Chianu *et al,* 2011). The major nutrient depletion causes are nutrient mining through crop harvests, residue removal (Mugendi *et al*., 2003) and soil erosion (Zobisch *et al.,* 1995; Muchena *et al.,* 2005), which are worsened by lack of or inadequate replenishment (Wallace and Knauzenberger, 1997; Mugendi et al., 2010). For increased food production, nutrient replenishment is necessary (Tilman *et al.,* 2002).

Farmers in Central highland Kenya continue to experience depressed land productivity and incomes mainly due to their farms' low soil fertility status. With a high economic and nutritional value of soybean, its suitability in growing in this region and a ready market, farmers in this region stand to gain by growing the crop. Soybean has the highest amount of proteins among the legumes (Venter, 1999). Its dietary composition is reported to be the best in the legume family containing vitamins (Venter, 1999) good for diabetics (Venter, 1999; Agwu *et al.,* 2009), for the dieting (Fabiyi, 2006) and protects against some types of cancer including breast cancer, lung cancer, prostate cancer and liver carcinoma (Venter, 1999). Soybean also delays onset of menopause and alleviating symptoms of osteoporosis in women (Venter, 1999; Agwu et al., 2009). Kenya's demand for soybean exceeds 100,000 MT (Wasike *et al.,* 2009), the highest in the East African region. Kenya imports most of its soybean (Chianu *et al.,* 2008; Tinsley, 2009). In 2008, Kenya spent a total of US $2.754 million to import soybean and its products (FAO, 2008) an amount that is a significant drain on her scarce foreign exchange.

Having considered this opportunity, farmers in the region have enthusiastically delved into growing soybean. Yields from the region are however lower than the national average of 0.93 Mg ha^{-1}. Given the vital role soybean can play in improving livelihoods, promoting nutritional wellbeing its production in the region needs to be promoted and up scaled. However, low P in soils of the region is a key constraint. There are several P sources in the market at different prices and degrees of accessibility and limitation giving farmers options depending on their availability, bulkiness, ease of use, labor costs, familiarity with the farmer and other factors. These P sources have not been evaluated regarding their efficacy on soybean yield. Assessment of these sources will inform on the most appropriate P sources for enhancing soybean yield and so guide policy makers in making appropriate policies regarding soybean and fertilizers in region and similar areas.

2 Materials and Methods

2.1 Study Site

The study was conducted at Kigogo Primary School (00^0 23' 08.6''S, 37 38' 0.3" E) in Magumoni Division, Meru South district and at Kamujine site (00^0 06'19.4"N, 037^0 54' 49.7''E) in Mikinduri Division, Tigania East district, in the Central Highlands of Kenya, respectively. Magumoni Division is in Upper Midland 2 and 3 (UM 2 -UM 3) agro ecological zones having an altitude of about 1432 m a.s.l with annual temperature of about 20^0 C and annual rainfall of between 1200-1500 mm (Jaetzold *et al*., 2006). The rainfall is bimodal with two seasons; long rains (LR) in March through to June and Short Rains (SR) from October through to January. Over 65% of the rains occur in the LR season (Jaetzold *et al.,* 2006).The soils of Kigogo site are humic Nitisols (Jaetzold *et al.,* 2006). Small-scale mixed farming is practiced with main cash crops being coffee, tea and horticultural crops. Food crops grown include maize (*Zea mays*), banana (*Musa spp.* L. e.g. *paradisiaca*.) and Irish potatoes (*Solanum tuberosum*).

Mikinduri Division is in Lower Midlands 3 (LM 3) and Upper Midland 3 (UM 3) agro ecological zone with average rainfall of 1175 mm yr^{-1} (Jaetzold *et al.,* 2006) having an altitude 1231 m a.s.l.

Agricultural practice is mixed farming with main cash crops being *Catha edulis* (Khat) and horticultural crops. Food crops grown include maize, banana and Irish potato. Farmer also practice livestock production with goat and cattle rearing being key. Soils in Mikinduri have been described as being eutric Nitisols with humic Cambisols (Jaetzold *et al.,* 2006).

2.2 Study Design

The experiment consisted of several P sources arranged in randomized complete block design replicated four times in plots measuring 4.0 x 4.5 m in size, having a net plot area of 10.5 m^2. The DAP applied treatment was a reference, being the most popular fertilizer among farmers. The sources of P were Minjingu phosphate rock, Mavuno basal fertilizer, triple superphosphate (TSP), di-ammonium phosphate (DAP) fertilizer, manure only and fortified manure (manure + Minjingu phosphate fertilizer).

The trial ran for two seasons with season one, long rains season (LR 2011), running from March 2011 to September 2011 and season two, short rains season (SR 2011), running from October 2011 to February 2012. All the P sources were measured as to contain 30 kg P ha^{-1}. The manure used was a mixture of goat and cattle manure whose total amount was to provide the required P amount of 30 kg ha^{-1}. Peat-based culture of *Bradyhizobium japonicum* USDA 110C, licensed by University of Nairobi and produced by MEA Ltd branded BIOFIX®, was inoculated in soybean seeds for all the treatments. Gazelle variety of soybean was used. It is the variety that farmer in the area were growing at the time of the study. It is also easily accessible and available, being a better variety for growing a sole crop (Wandahwa *et al.,* 2006). The soybean were planted in an inter row spacing of 50 cm and intra row spacing of 5 cm. This gave total plant population of 400,000 plants ha^{-1}. The plots were replanted two weeks after planting to maintain the required plant population. Weeding was done as per need basis. Spraying of pesticide was done as per occurrence of pest while maintain economic threshold for pesticide application.

The data was subjected to Analysis of variance (ANOVA) using PROC ANOVA in SAS Version 9.1 statistical Software for Windows (SAS Institute, 2009). Analysis was on soybean grain yield and biomass. Significantly different means were separated using Least Significant difference test (L.S.D) at P= 0.05.

3 Results

3.1 Soybean Grain Yield

Results show that in LR 2011 at Kamujine (Table 1), there were no significant changes on soybean yield among phosphorus source although manure and DAP had nominally higher yields than the yields from other P sources. Soybean treated with Manure and DAP had yields higher than control yields by 78% and 70% respectively. All the P sources had a nominally higher soybean yield than control within this period. In SR 2011, all soybean yields except those from TSP-treated soybean were significantly higher than control-treated ones. The yield from DAP was highest, being higher than control yield by 148% followed by that under manure treatment at 125% higher than control.

Table 1: Phosphorus sources and overall grain yield (Mg/ha) at Kamujine and Kigogo sites in both LR 2011 and SR 2011 seasons

Nutrient Sources	**Average grain Yield (Mg/Ha)**			
	LR 2011		SR 2011	
	Kamujine	Kigogo	Kamujine	Kigogo
TSP	1.10bc	0.96ab	0.86cd	0.61de
Manure	1.27abc	1.16ab	1.22abc	0.56e
Minjingu	1.05bc	0.92ab	1.16abc	0.80bcd
Fortified	1.20bc	0.99ab	1.18abc	0.78bcd
Control_P0	0.71c	0.70b	0.54d	0.69cde
DAP	1.21bc	0.71b	1.34ab	0.69cde
Mavuno	1.11bc	1.20a	1.04abc	0.90ab
LSD(α=0.05)	**0.704**	**0.473**	**0.447**	**0.1987**

Table 2: Phosphorus sources and overall grain yield (Mg/ha) at Kamujine and Kigogo sites in both LR 2011 and SR2011 seasons

Nutrient Sources	**Average biomass Yield (Mg/Ha)**			
	LR 2011		SR 2011	
	Kamujine	Kigogo	Kamujine	Kigogo
TSP	2.36c	2.17abc	2.90ab	2.74ab
Manure	4.12ab	1.68bcd	1.74b	0.56c
Minjingu	3.23abc	1.21cd	2.18ab	1.18bc
Fortified	3.60abc	1.80abcd	2.53ab	1.79abc
Control_N0_P0	2.56c	1.15d	2.28ab	1.83abc
DAP	4.15ab	2.72a	2.94a	2.75ab
Mavuno	3.81abc	2.59ab	1.98ab	0.83bc
LSD(α=0.05)	**1.47**	**0.98**	**1.18**	**1.96**

Performance of soybean yield at Kigogo in LR 2011 (Table 1) showed that Mavuno treated soybean had significantly higher yields than those under DAP treatment and control respectively being yielding better than control soybean by 71%. In SR 2011 season, Mavuno treated soybean yield was not only significantly higher than that under DAP and control but also than those treated with TSP and Manure. Mavuno treated soybean had higher yield than that of control by 30%.

3.2 Soybean Biomass Yield

Table 2 shows soybean yield performance among treatments. Soybean biomass yields from DAP and Manure treated soybeans in LR 2011 season at Kamujine were 62% and 60% higher than those under control treatment. Yields from TSP treated crop were 7% lower than yields under control treatment. In SR season, biomass yield from DAP-treated crop was significantly higher than that from manure (by 84%) but not significantly different from control treated crop.

At Kigogo site, results on biomass yield in LR 2011 season (Table 2) showed DAP treated soybean had significantly higher yield than the control treated soybean by 136%. The yields were however not significantly different from TSP, Manure, fortified manure and Mavuno treated soybean. In SR 2011 season, biomass yield from DAP-treated soybean was significantly higher than manure treated crop by 391%. This performance was however not significantly different from that of control nor that of the rest of the P sources.

4 Discussion and Conclusions

The results above indicate that the P sources effect on soybean gain and biomass yield is attributable to their ability to deliver the necessary soil nutrients the critical growth stage of the crop while providing the soil physical and chemical amendments like water retention and soil pH amelioration. The vital importance of P sources in soybean growth and development was demonstrated in LR 2011 at Kamujine by higher yields on all P-treated soybeans than the control. The good performance of DAP treated soybean can be attributed to the nitrogen available in the fertilizer at a rate of 18 kg ha^{-1} which may have been vital in vegetative growth and grain filling at a later stage of crop growth. Manure treated crops may have performed better than other crops due to its water retention capacity and availability of other micronutrients in it other than just P. Soybean under TSP may have had poor assimilation of P because of the soil fixation of P from the fertilizer.

At Kigogo site, soybean yield under Mavuno fertilizer performed better than even that of DAP because Mavuno fertilizer has a composition of at least 10 other micronutrients other than P, N, Ca, Mg and S, important for soybean production. Initial tests (not shown) had indicated Kigogo to have high amounts of N and so DAP had no competitive advantage to Mavuno, which, other than providing P also delivered other nutrients necessary for a good yield.

Results for biomass yield indicate a vital role of N in biomass accumulation. Soybean under DAP treatment had higher biomass yield than the others. The negative effect of P fixation to the soil colloids to the crop was seen in TSP, which also had less biomass. The amount of N in the manure may not have been enough to promote biomass accumulation considering microbes have to break down manure and so may have assimilated the N rendering it not to be immediately available for crop's vegetative growth and development.

In conclusion, results showed DAP fertilizer gave higher soybean grain and biomass yield in Kamujine while mavuno fertilizer gave the highest grain yield in Kigogo with DAP providing higher biomass yield. Consistent use of manure together with any of the two fertilizers, in line with Integrated Soil Fertility Management (ISFM) concept, will provide a sustainable soybean production. Use of TSP as a fertilizer for soybean production in the region was found be unnecessary. Farmers therefore, may use DAP or Mavuno fertilizer together with manure for soybean production.

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