Influence of Phosphorous Fertilizer and Lime on Seed Yield of Soybean Cultivars in Western Kenya

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ABSTRACT

Soybean is an important crop in the economy of Kenya both as human food and livestock feed as well as industrial purposes. However, low availability of phosphorous (P) has perpetuated low soybean production in Western Kenya. Therefore, field trial was conducted at University of Eldoret in Uasin Gishu and Agricultural Training Centre (ATC) in Busia County during the period June-November 2015 to assess the influence of phosphorous and liming on seed yield and thousand seed weight of soybean cultivars. The experimental design was a factorial, laid out in RCBD with three replicates involving: two varieties of soybean; SB 19 (proteinous) and SB 133 (oily), three P fertilizer rates at 0, 30 and 60 kg P ha^{-1} and two levels of lime at 0 and 2 ton ha^{-1}. The result showed significant influence of cultivar and phosphorous fertilizer on soybean seed yield. The oily cultivar (SB 133) recorded the highest seed yield and thousand seed weight compared to the protenous cultivar (SB 19). Phosphorous fertilizer at 30 kg P ha^{-1} recorded the highest seed yield where further increased was counterproductive. Thousand seed weight declined with increased application of phosphorous. Lime application did not affect soybean seed yield and thousand seed weight. In conclusion, this study suggests use of P fertilizer to not exceeding 30 kg P ha^{-1} for optimal seed yield in Western Kenya.

Key words: Soybean cultivars, phosphorous fertilizer, lime, seed yield, thousand seed weight

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a leguminous crop grown for its edible beans which are valued for the superior nutritional attributes, that includes; 38-45% protein, 18-20% edible oil, 24-26% carbohydrate and vitamins on dry matter basis (Morshed *et al.*, 2008; Wilcox and Shibles, 2001). Accordingly, soybean exhibits multiple uses as a source of feed for livestock and fish, protein and oil for human diet, and bio-energy for industrial purposes among other uses (Morshed *et al.*, 2008; Myaka *et al.*, 2005). Soybean is value added to several consumable products that offers a longer shelve-life in storage (Chianu *et al.*, 2009). This products also supplies high levels of essential minerals and vitamins (BIDCO, 2005), and amino acids required for optimum body growth (Burstin, *et al.*, 2011). Moreover, the presence of bioactive isoflavones have been reported to help in preventing or treating the different cancer, diabetes, hypertension, heart diseases and easing symptoms of menopause condition in women (Chianu *et al.*, 2008; Mahasi *et al.*, 2010; Venter, 1999).

Despite, the huge benefits provided by soybean, its production in Kenya is very low averaging 715 kg ha^{-1} (FAO, 2009) and 450 kg ha^{-1} in Western Kenya compared to yield potential of 3000–3600 kg ha^{-1} (Chianu, 2009). The low yield is attributed to low agricultural input usage and poor agronomic management (Njeru, 2009), inherent poor soil fertility (Bationo *et al.*, 2006) and declining soil fertility (Kimani *et al.*, 2004) among others factors. According to Jaetzold and Schmidt (1983), the predominance of nitisols, acrisols and ferralsols soils in Western Kenya and the humid tropics is responsible for the unavailability and immobility of P due to high soil acidity.

Phosphorous is an important growth-limiting nutrient for plants in the world in spite of its abundance in organic and inorganic forms (Tairo and Ndakidemi, 2013), its unavailability for plant uptake makes it a serious fertility problem in tropical soils (Haru and Ethiopia, 2012; Nekesa *et al.*, 2007). For example, Hao et al. (2002) demonstrated that P availability is affected by extremes of pH levels because under acidic condition, the highly reactive Aluminium (Al^{+}) and Iron (Fe^{3+}) fixes P, whereas under basic and normal soils, P is precipitated by Calcium (Ca^{2+}) into immobile pools. Therefore, the limited supply of P in the plant interferes with its pertinent role of enhancing plant's physiological performance such as improved nodulation and symbiotic relationship, hastening maturity and enhanced tolerance to environmental stresses (Gangasuresh *et al.*, 2010; Shahid *et al.*, 2009).

The demand of phosphorous in legumes is relatively high to satisfy the need of forming the root system and the root nodules which increases the number and density of rhizobia bacteria, leading to increased quantities of nitrogen fixed (Bashir *et al.*, 2011). It had earlier been reported that nitrogen fixed by soybean range between 44 to 103 kg N ha^{-1} annually (Sanginga *et al.*, 2003), improving the production of intercrop and the following rotated crops (Giller, 2001; Vanlauwe *et al.*, 2006). This has contributed to reducing the cost of production on resource-poor farmers who cannot afford sufficient mineral fertilizers for sustainable agricultural intensification (Chianu et al., 2009; Rao and Reddy, 2017).

Successful production of any agricultural crop depends on the availability of plant nutrition in the soil. However, the essential plant nutrients are not available for plant uptake due to unfavourable soil reactions affected by extremes of the soil *p*H. To ameliorate the soil condition at low soil pH, liming is widely used to neutralize soil acidity, which acts by displacing H^{+}, Fe^{2+}, Al^{3+}, Mn^{4+} and Cu^{2+} ions from soil adsorption site to supply significant amounts of Ca and Mg (Onwonga *et al.*, 2010). This increases the availability of P, Mo and B, as well as improving the soil conditions, making it more favourable for microbial mediated reactions such as nitrogen fixation and nitrification. It is therefore against the background that this experiment was carried out to assess the influence of phosphorous fertilizer and lime on yield of soybean cultivars in Busia and Eldoret in Western Kenya.

MATERIALS AND METHODS

Description of field experimental sites

The experiment was conducted at both Uasin Gishu and Busia County between the months of June to November 2015. In Uasin Gishu, it was carried out at the University of Eldoret farm which is located at 0°34'26.53''N and 35°17'59.68''E, at an elevation of 2120 m above sea level. Eldoret receives rainfall of between 900-1300 mm and an annual mean temperature of 16.6° C. On the other hand, in Busia, the experiment was conducted at Agricultural Training Centre (ATC) farm located at 0°27'26.91''N and 34° 7'0.94''E at an elevation of 1130 m above sea level. Busia receives an annual rainfall that ranged of between 1270 mm to 1790 mm and a mean temperature range of 22° C. The soils at both site are generally well drained and predominantly Orthic ferralsols with a *p*H range of between 4.5 – 5.0 (Jaetzold and Schmidt, 1983).

Cultivars

Two soybean cultivars were selected; SB 133 (Saga) which is large seed, has a high oil content of 24.37% and relatively lower protein content of 37.59% and SB 19 which is small seeded and has a high protein content of 42.29% and relatively lower oil content of 19.71% (TSBF-CIAT, unpublished)

Fertilizer and lime

Triple supper phosphate (TSP) fertilizer (0.46.0) sourced from MEA limited was applied at the rate of 0, 30 and 60 P Kg ha^{-1}. Whereas Physiolith® lime ($CaCo_3$) sourced from Timak-agro chemical company was applied at 0 and 2 ton ha^{-1} (Okalebo *et al.*, 1993).

Experimental design and treatments

The experiment was a 2×3×2 factorial arrangement consisting of three main factors; cultivar, phosphorous and lime, laid out in a randomized complete block design (RCBD) and replicated thrice.

Field preparation and management

The field cropping history was obtained from the relevant authorities and established to have been used annually for production of vegetables, legumes and cereals in rotation. The plots were demarcated measuring 4 m by 3 m with 0.5 m walking paths between plots and 1 m separating the blocks. Land was conventionally ploughed to a fine tilth a month before planting. The granulated lime and TSP fertilizer were applied at different rates to the experimental units during planting. The seeds were planted on an inter row spacing of 50 cm and intra row spacing of 5 cm. Watering was done thoroughly to field capacity in all experimental sites in the first month after planting and later intermittently when necessary since the rain was unpredictable and unreliable. Weeding, pests and diseases control was done early in advance before they establish to ensure the development of a competitive crop stand.

Data collection and analysis

Each plot was harvested individually at about 15% seed moisture content at a time when the crop had attained uniform harvest maturity. The crop from each treatment was separately sun dried, gently hand threshed, cleaned, weighed and further dried to a uniform moisture content of 13% for storage. The seed weight (kg ha^{-1}) and 1000 seed weight (g) were determined and subjected to analysis of variance using R® statistical software version 3.4.3 (Kite-Eating Tree) and mean separation using Turkey's (HSD) test at (α 0.05).

RESULTS AND DISCUSSIONS

Seed yield (kg/ha)

The effect of cultivar and phosphorous fertilizer on seed yield was significant ($p < 0.05$) at both sites whereas no significant differences ($p < 0.05$) were observed for lime and the interactions. At both sites, application of phosphorous occasioned an increase in cultivar seed yield to a maximum at 30 kg P ha^{-1} where further increase resulted to a decline. In this respect, SB 133 yielded 1563.48 kg ha^{-1} when produced in Busia and 1627.56 kg ha^{-1} in Eldoret accounting for a yield increase of 39 % and 12 % over the control plots, respectively. Similarly, high seed yield for SB 19 of 1305.80 kg ha^{-1} in Busia and 1557.6 kg ha^{-1} in Eldoret was recorded, resulting to an increase of 26 % and 37 % respectively from the control value. Conversely, low seed yield in SB 133 was recorded when 0 kg P ha^{-1} was used in Busia and Eldoret (Figure 1). From the curves, it is apparent that SB 133 is high yielding compared to SB 19, suggesting a significant site influence.

The significant influence of phosphorous at both sites could be attributed to soybean response to P since the soils in the sites have low available P and low *p*H of less than 4.5. The application of TSP fertilizer could have increased the pool of available P necessary for crop uptake and early root growth translating to improved crop growth and yield as suggested by (Gangasuresh *et al.*, 2010). However, it was noted that the control experiment in Eldoret produced comparable yields. Similar response was observed by (Haq and Mallarino, 2005) thus suggesting the importance of residual P in the soil on crop yield. Other studies that have agreed to the residual P hypotheses had estimated 12 ppm P-Bray-1 (Ferguson *et al.*, 2006) and 6-7 mg P/kg P-Olsen (Ryan *et al.*, 2008) respectively as threshold levels above which application of P fertilizer would not be significant.

From this experiment, phosphorous fertilizer increased the seed yield to maximum point after which a further increase led to yield decline. This response had been reported before by Borges and Mallarino, (2000, 2003). Similar results had been observed by (Mahamood *et al.*, 2009) while working in acidic soils in Nigeria and Sharma and Namdeo, (1999) in Indonesia. Equally, the influence of P on seed yield had been demonstrated before in the study of Ryan *et al.*, (2008) that reported increased yields of legume when 15-60 kg of P_2O_5 fertilizer ha^{-1} year^{-1} was applied. Additionally, other studies have reported positive influence on application of P fertilizers on soils with low P test (Kamara *et al.*, 2008; Tahir *et al.*, 2009). The trend of decline in yield when the P application exceeded certain threshold as seen from this work had been reported elsewhere. For instance, (Verde *et al.*, 2013) in a study of humic nitisol in the Central Highlands of Kenya, reported significant reduction of yield when 60 kg P ha^{-1} was applied.

The cultivar differences were significant with SB 133 outperforming SB 19 in seed yield at both sites. These differences can be attributed to the genetic variation where SB 133 produces large seeds that are plumpy and heavier than SB 19 (TSBF-CIAT soybean data, unpublished). It can also be suggested that SB 133 is adaptive, with better root system that are efficient in P acquisition and utilization as ascribed by other scholars while studying the performance (yields) of different soybean cultivars under low P levels (Mahamood *et al.*, 2009).
Lime application at both sites resulted in an increase in seed yield. This positive effect of liming on seed yield had been reported in a recent study by Bekere, (2013) in Ethiopia while studying liming, nitrogen and bradyrhizobia bacteria in soybean. Similarly, Verde *et al.* (2013) in an experiment investigating the use of lime in Central Kenya also found significant effect on grain yield. In other studies elsewhere, positive response of other legumes had been reported following lime application either as alone or in combination with P fertilizer (Andric *et al.*, 2006). These findings were also consistent with the work of Nekesa et al. (2011) in Western Kenya that found significant soybean grain yield when TSP fertilizer or Di-ammonium phosphate (DAP) was combined with lime. The increased in seed yield following lime application might be as a result of lime reacting with water in the soil to produce OH^- ions and Ca^{2+} ions which displaced H^+ and Al^{3+} ions from soil adsorption sites causing an increase in soil pH and availing P for plant uptake (Chimdi *et al.*, 2012).

In both sites, the seed yield was below the average that was earlier suggested by Chianu *et al*. (2009) of 3000 kg ha^{-1}. The low yield could be attributed to a number of factors including late planting and poor rainfall pattern in the year. It was suspected that the prolonged dry spell experience in the area affected the soil moisture and subsequently dissolution of fertilizer and lime. It can also be alluded that decline in soil moisture negatively affected microbial activity, nutrients availability and its uptake which on severe cases might have suppressed normal growth and thus poor yields.

Generally, it can be deduced from this study that besides phosphorous fertilizer being an essential input for improving growth, development and yield of soybean (Kakar *et al.*, 2002; Mahamood *et al.*, 2009), rational decision over P fertilizer application should be guided by the results of soil P test. Additionally, in other studies, phosphorous efficient genotypes have been reported to exist (Sanginga *et al.*, 2000) which can provide an opportunity to maximize production without increasing cost of production in purchasing P fertilizers. It will therefore be meaningful for further studies to pursue and identify the P efficient genotypes to help maximize their potentials.

Thousand Seed Weight (TSW) (g)
Thousand seed weight was significantly influenced by the cultivar differences ($p < 0.05$) when produced in Busia and Eldoret. There was no significant differences on TSW when phosphorous fertilizer and lime were applied (Table 1). It was observed that TSW declined with phosphorus fertilizer application. In this respect, P application at control (0 kg P ha^{-1}) recorded the highest value of 94.19 g in SB 19 and 133.31 g in SB 133 when produced in Busia, while 184.00 g was recorded as the highest for SB 133 when produced in 0 kg P ha^{-1} and 111.21 g as the highest value for SB 19 at 30 kg P ha^{-1} respectively in Eldoret. However, lower TSW for SB 133 and SB 19 were recorded when the soybean were produced in 60 kg P ha^{-1} at both sites. Thousand seed weight (g) is an important yield contributory attribute that reflects the ultimate yield of the crop. The significant differences between the TSW of the oily seeds (SB 133) and the proteinous seeds (SB 19) indicated the absolute

cultivar differences in seed sizes and weight where the oily seeds were big, plumpy and heavier than the proteinous seeds.

Phosphorous fertilizer did not cause any significant differences on the TSW of the soybean cultivars. Similar observations had been made in previous findings by Ojo *et al.*, (2016) and Seguin & Zheng, (2006). The decline of TSW with P application has also been reported before in the works of (Suryantini and Kuntyastuti, 2015), which confirmed assertions that P levels above the soil critical threshold does not result in significant increase in TSW. However, other scholars have reported a significant increase in seed weight with increasing level of applied phosphate fertilizer (Devi *et al.*, 2012; Mohsen *et al.*, 2014). Similarly, a recent study conducted in Mozambique revealed significant effect of P fertilizer on 100 seed weight where high seed weight was recorded from 60 kg P_2O_5 ha^{-1} application (Mateus *et al.*, 2015).

On the other hand, lime application was not effective and did not produce any significant effects on thousand seed weight. Similar results were reported by Bekere, (2013) in Ethiopia on a study involving lime, nitrogen application and bradyrhizobia bacteria in soybean.

CONCLUSION

In conclusion, this study revealed that beside the pertinent role phosphorous plays in improving crop performance, high application levels negatively affect both the thousand seed weight and the seed yields of the two soybean cultivars. Therefore, this study recommended that application of phosphorous fertilizer should not exceed 30 kg P ha^{-1}. However, lime application at both sites contributed to an increase in thousand seed weight and seed yield of soybean though the increase was not statistically significant.

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Appendix

Appendix I: Effect of phosphorous fertilizer on seed yield of soybean cultivars.

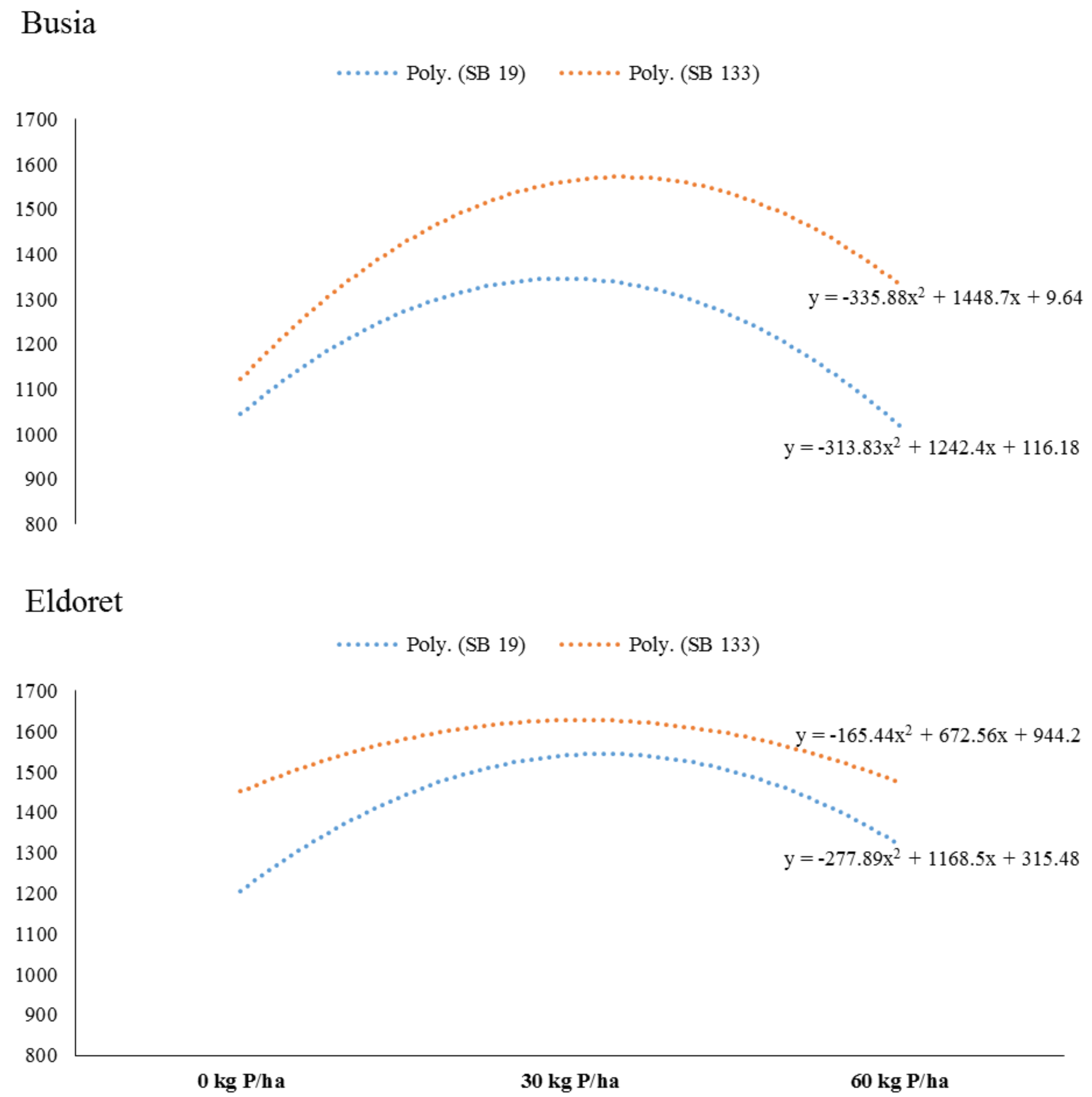

Figure 1: The polynomial curves of seed yield (kg/ha) for soybean cultivars (SB 19 and SB 133) produced in Busia and Eldoret when different rates of field applied P fertilizer at P0 = 0 kg P ha^{-1}, P1 = 30 kg P ha^{-1} and P2 = 60 kg P ha^{-1} were used.

Appendix II: Effect of lime on seed yield of soybean cultivars

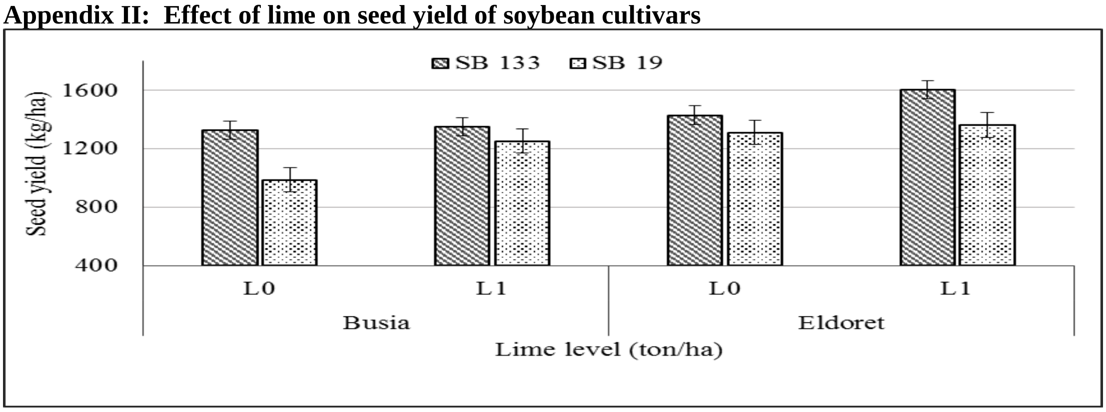

Figure 2: The seed yield (kg/ha) of soybean cultivars (SB 19 and SB 133) as affected by lime (L0 = 0 ton ha^{-1} and L1 = 2 ton ha^{-1}) in Busia and Eldoret. Error bars represent standard errors, n = 9.

Appendix III: Effect of phosphorous fertilizer and lime on thousand seed weight of soybean cultivars

Table 1. Thousand seed weight of soybean cultivars (SB 19 and SB 133) produced in Busia and Eldoret as influenced by field applied P fertilizer at 0 kg P ha^{-1}, 30 kg P ha^{-1} and 60 kg P ha^{-1} and lime at 0 tons ha^{-1} and 2 tons ha^{-1}.

		Site			
		Busia		Eldoret	
	Fertilizer	**SB 19**	**SB 133**	**SB 19**	**SB 133**
Phosphorous	0 kg P/Ha	94.19	133.31	107.14	184.00
	30 kg P/Ha	93.94	130.80	111.21	172.19
	60 kg P/Ha	89.94	126.73	109.89	169.02
	Tukey's ($p \leq 0.05$)	ns	ns	ns	ns
Lime	0 tons/ha	92.18	129.47	111.92	174.69
	2 tons/ha	93.20	131.09	106.91	175.45
	Tukey's ($p \leq 0.05$)	ns	ns	ns	ns
	Mean (Cultivar)	92.69 ^{a}	130.28 ^{b}	109.41 ^{a}	175.07 ^{b}
	CV(%)	5.18	5.18	6.91	6.91
Tukey's ($p \leq 0.05$) (Cultivar)		3.993	3.993	6.794	6.794