The Effects of Manure, Lime and P Fertilizer on N Uptake and Yields of Soybean (Glycine max (L.) Merrill) in the Central Highlands of Kenya

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Abstract: Soybean (Glycine max (L.)) is one of the most important legume crops being introduced in the CHK (Central Highlands of Kenya) expected to increase yields. However, low levels of soil N (nitrogen) and other plant nutrients and soil acidity are seen as the major causes impairing goal achievement. To evaluate the influence of manure, lime, P (phosphorus) fertilizer and their combination on N uptake and soybean performance, an experiment was conducted in Embu ATC (Agricultural Training College) comprising 9 treatments, arranged in a Randomized Complete Block Design with 4 replicates in plots of 4 m × 4.5 m. The study included manure (0, 5 and 10 t·ha⁻¹), lime (0 and 2 t·ha⁻¹) and P fertilizer (0, 30 and 60 kg·P·ha⁻¹). The treatments significantly influenced N uptake and soybean yields. Both parameters responded well to application of manure both alone or combined to lime and TSP (triple super phosphate). From these it was concluded that organic and inorganic resources have potential to enhance N uptake and soybean and other crops yields in CHK.

Key words: Manure, lime, P fertilizer, N uptake, soybean.

1. Introduction

Soybean is much widely spread as it is found in nearly every country in sub-Saharan Africa where Nigeria is the largest producer. However, Kenya is the second producer in Eastern Africa (only after Uganda), in small scale [1]. The crop has a high commercial value and concentration of protein, about 40%, calcium, phosphorus, fiber, and in addition it is cholesterol free [2]. In addition it provides food, cash, animal feed, increased other crop yield and contributes for soil improvement through biological nitrogen fixation [1]. In Kenya, this crop is relatively new and expected to increase production due to its importance on supply of food, income and fodder [3, 4]. The crop is recently introduced in central highlands of Kenya. However, its yields are still below the potential (3.0-3.6 t·ha⁻¹), with average of 0.8 t·ha⁻¹ [4, 5]. Many factor influence the low productivity which include inherent poor soil fertility of the African soils [6], continuous declining of the soil fertility [7, 8], poor management practices, low agricultural input use [9], worsened by the predominance of humic nitisol soil class with moderate to high acidity [10]. The prevalence of acidity is associated to N and P deficiency in the soil [11]. Diagnosis study carried out in the central highlands of Kenya have reported soil fertility constraints, particularly N and P deficiencies, low carbon content and low soil pH [12].

In this region increasing population with respective increased demand for food and land [13], causes less availability of land for agriculture. This associated to the previous underlined factors are found as the major reasons for food insecurity and poverty amongst smallholder farmers [4, 10]. To increase soybean and other crop yield is important to identify suitable
technologies which include use of high yielding varieties, application of inorganic and organic resources providing therefore nutrients and improve soil physical and chemical properties. Interventions leading to improvement on soil pH to enable crop development and microorganism’s activity are critical, since this impairs not only mineralization process but also the uptake of water and nutrients by the plant [11]. Thus, combination of organic resources with small amounts of inorganic resources will give better effects since inorganic sources are readily available and of rapid action. Liming will improve soil pH creating then conditions for microorganism’s activity, root development [11] and N$_2$ fixation [14] which in addition will increase nutrient availability and uptake. There is scarce information regarding effects of organic and inorganic or their combination on soybean N uptake and yields in the central highlands of Kenya.

2. Material and Methods

2.1 Site Description

The experiment is undergoing and was started in 2012 SR (short season) at Embu-ATC (Embu Agricultural Training College), in Embu West district (0°35’25.58” S and 37°25’31.84” E), located in Central Highlands of Kenya at an elevation of 1,494 m above sea level. The soils are mainly humic nitisols. The average rainfall varies from 1,230 mm to 909 mm with long rainy season (March to June) and short season (October to December).

2.2 Experiment Design

The experiment was designed as a RCBD (Randomized Complete Block Design), in plots measuring 4.0 m × 4.5 m and replicated four times. The study included: manure (M) (0, 5 and 10 t·ha$^{-1}$ as goat manure), lime (0 and 2 t·ha$^{-1}$ as CaO) and P fertilizer (0, 30 and 60 kg·P·ha$^{-1}$, as TSP (triple super phosphate)). The treatments were as shown in Table 1:

<table>
<thead>
<tr>
<th>Table 1  Treatments and description</th>
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</thead>
<tbody>
<tr>
<td>1. Manure</td>
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<tr>
<td>2. Lime</td>
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<td>3. TSP</td>
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<tr>
<td>4. Manure + Lime</td>
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<tr>
<td>5. Manure + TSP</td>
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<tr>
<td>6. Manure + Lime + TSP</td>
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<tr>
<td>7. Lime + TSP</td>
</tr>
<tr>
<td>8. Control No inputs</td>
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</tbody>
</table>

2.3 Agronomic Practices

Land was ploughed manually using a hand hoe followed by leveling two weeks before planting. Manure and lime, with regard to required rate, were broadcasted and then incorporated in the soil within 15 cm depth, using hand hoe also two weeks before planting. Triple super phosphate was applied per furrow and well mixed with the soil at planting. Soybean var. Gazelle, was sown by placing 3 seeds per hole at 50 cm × 10 cm spacing. Two weeks after emergence the seedlings were thinned to 2 plants per hill. All agronomic practices were undertaken during the growing season.

2.4 Soil and Plant Sampling and Analysis

Prior to experiment set up soil samples were collected for initial determination of soil fertility parameters. The soil samples were analyzed for pH, available P, exchangeable cations (Ca, Mg, and K) and exchangeable acidity. Soil pH was measured in a 1:2.5 ratio soil to water (pH$_{H_2O}$) [15] using a pH meter model AD 1000. Soil exchangeable acidity was determined by titration (0.1 M NaOH) method using 1 M KCl for extraction [15]. Exchangeable cations and available P were determined by Mehlich 1 method. To determine N concentration in the plant tissues, 10 plants per plot were sampled and taken to the laboratory for oven dry (65°C for 48 h) and ground. Thereafter the samples were analyzed for N concentration in an automatic CN (carbon and nitrogen) analyzer. N uptake was determined as the
product of the nutrient content and dry matter yield.

2.5 Harvest of Soybean and Yield Determination

At physiologic maturity stage four central lines were harvested by leaving 50 cm from the both edges of the rows, harvesting therefore a net area of 6 m². Plants were cut at ground level and fallen leaves were collected and weighed together in the field. Subsequently the plants were threshed and recorded fresh weight of the grain. Thereafter the grain samples were sun dried and yields determined and adjusted to 12% of moisture content.

2.6 Data Analysis

Data generated was subjected to ANOVA (analysis of variance) using SAS (Statistical Analysis System) version 8. The means were subjected to t-test at 95% of confidence to test means difference. LSD (Least Significance Difference) at 95% of significance level was used to separate means.

3. Results and Discussion

3.1 Soybean Growth and Yields

Plant height was significantly \((P = 0.0044)\) affected by the treatments (Table 2). The highest plant height was obtained in the plots receiving the combination of manure and P fertilizer (50.43 cm), while application of sole P fertilizer recorded the lowest plant height (40.15 cm) over the control. The number of pods per plant was affected statistically \((P = 0.0006)\) by application of soil amendments. The application of manure alone recorded the highest number of pods per plant (34.95) and the lowest was recorded for sole P fertilizer (22.63 cm). Treatments also affected significantly \((P = 0.0238)\) weight of 100 seed. Application of manure combined with P fertilizer mostly increased by 1.08 times 100 seed weight than the control followed by application of manure plus lime and P fertilizer, 1.06 times. Stover yield did not show significant \((P = 0.0937)\) difference as result of the treatment. However, grain yield and harvest index showed significant differences. Application of manure (10 t·ha⁻¹) significantly \((P = 0.0011)\) increased 2.5 times than control, and application of manure plus P fertilizer by 2.3 times. The lowest grain yield was recorded in the plots receiving P fertilizer alone (1.20) followed by combination of lime and P fertilizer (1.70) related to the control. HI (harvest index) which relates the grain yield to the total dry matter yield showed significant \((P = 0.0037)\) differences. The highest HI was recorded with application of manure combined with P fertilizer, and both lime plus P fertilizer (0.35), while the lowest was recorded in plots receiving sole application of P fertilizer (0.24).

These results show that application of manure whether alone or combined with lime and P fertilizer influenced in crop growth, yield components and yield of soybean. These results are similar with the results reported by Chiezey and Odunze [16] and Umoetok et al. [17]. Manure is a reservoir of nutrients which are released through mineralization, thus supplying the necessary elements for plant growth [16], and when

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Stover yield (t·ha⁻¹)</th>
<th>Grain yield (t·ha⁻¹)</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>49.90</td>
<td>5.52</td>
<td>2.80</td>
<td>0.34</td>
</tr>
<tr>
<td>Lime</td>
<td>42.35</td>
<td>4.42</td>
<td>1.66</td>
<td>0.27</td>
</tr>
<tr>
<td>TSP</td>
<td>40.15</td>
<td>3.78</td>
<td>1.20</td>
<td>0.24</td>
</tr>
<tr>
<td>Manure + Lime</td>
<td>45.00</td>
<td>4.70</td>
<td>2.45</td>
<td>0.34</td>
</tr>
<tr>
<td>Manure + TSP</td>
<td>50.43</td>
<td>4.81</td>
<td>2.66</td>
<td>0.35</td>
</tr>
<tr>
<td>Manure + Lime + TSP</td>
<td>48.60</td>
<td>4.84</td>
<td>2.62</td>
<td>0.35</td>
</tr>
<tr>
<td>Lime + TSP</td>
<td>41.98</td>
<td>4.86</td>
<td>1.70</td>
<td>0.26</td>
</tr>
<tr>
<td>Control</td>
<td>39.85</td>
<td>3.76</td>
<td>1.14</td>
<td>0.23</td>
</tr>
<tr>
<td>(P)-value</td>
<td>0.0044*</td>
<td>0.0937ns</td>
<td>0.0011**</td>
<td>0.0037*</td>
</tr>
<tr>
<td>LSD₀.₀₅</td>
<td>6.17</td>
<td>1.21</td>
<td>0.86</td>
<td>0.07</td>
</tr>
</tbody>
</table>
combined with P fertilizers increase nutrient supply which enhanced vegetative growth, affecting therefore and indirectly plant height and yields [17].

3.2 Nitrogen Uptake

Effects of treatments on crop nitrogen uptake are presented in Table 3. Nitrogen concentration in the plant were not affected by application of the treatments at 4 WAP (weeks after planting) ($P = 0.5081$), 8 WAP ($P = 0.4171$) and 12 WAP ($P = 0.9313$). Numerically application of lime alone recorded the highest value at 4 WAP (3.96%), while application of 10 t·ha$^{-1}$ of manure recorded the highest at 8 WAP (5.38%) and at 12 WAP the highest value was recorded in plots receiving the combination of 5 t·ha$^{-1}$ of manure with lime and 30 kg·P·ha$^{-1}$ (2.96%). There was not observed significant differences in stover N uptake ($P = 0.1415$). However, there were significant differences in grain N uptake ($P = 0.0011$) and total N uptake ($P = 0.0012$) as result of treatment application. Relative to the control, the highest N uptake in the grain was observed under 5 t·ha$^{-1}$ of manure plus 30 kg·P·ha$^{-1}$ application (16.33 kg·ha$^{-1}$), followed by the combination of 5 t·ha$^{-1}$ of manure with lime (15.77 kg·ha$^{-1}$) which was closely followed by manure alone (15.74 kg·ha$^{-1}$), but not significantly different. The total crop N uptake was high in 10 t·ha$^{-1}$ of manure (20.05 kg·ha$^{-1}$) followed by combined 5 t·ha$^{-1}$ of manure with 30 kg·P·ha$^{-1}$ (19.72 kg·ha$^{-1}$) and 5 t·ha$^{-1}$ of manure combined with lime (19.10 kg·ha$^{-1}$) against the control. Application of P alone (60 kg·P·ha$^{-1}$) did not affect significantly N uptake in the grain and in the crop (total plant N) over the control, therefore recorded the lowest values of 7.66 kg·ha$^{-1}$ and 10.64 kg·ha$^{-1}$ in grain and in the plant, respectively.

In the beginning (vegetative stage) the N concentration in the plant increased toward flowering as result of increased uptake of this nutrient as increased need for growth. Although the nutrient concentration reduced toward the pod fill which meant that this nutrient was redirected from vegetative parts to the grain and pods when vegetative stage stopped and took place the reproductive one. This was evidenced by high N uptake observed in the grain. Similarly [18] also reported high soybean N removal by grain. Similarly the grain yields N uptake was high in treatments receiving manure either alone or combined. These results indicate that manure applied was high in N which was released to the soil. High N uptake by soybean under manure application has also been reported [19, 20].

The fact that when manure was combined with lime increased uptake might be associated to the fact that both manure and lime have improved soil pH which led to increase of availability of this nutrient through
mineralization. However, when manure was combined with P fertilizer had also lead positive effects on N uptake. Furthermore addition of manure may have improved soil water storage capacity [21, 22], enhancing then N uptake. In addition P fertilizer might have supplied P which enhanced N uptake [23] and microorganism’s development, therefore mineralization. Lime alone or combined with P fertilizer did not have significant effect on N uptake, but when combined with manure increased significantly N uptake.

4. Conclusion

In conclusion, results showed manure applied at the rate of 10 t·ha$^{-1}$ or 5 t·ha$^{-1}$ combined with lime or mineral P fertilizer mostly improved soil conditions and the higher N uptake and consequently high soybean grain yields. Use of manure alone or combined with mineral amendments proved to be a solution for increased soybean N uptake and yields. The results showed that triple super phosphate alone cannot be a better solution for increased soybean yields in this region.

Acknowledgments

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