Utilising soil fertility replenishment measures for nutrient use efficiency in maize production in western Kenya

S.K. Alwang’a, J.R. Okalebo, M. Osundwa¹ and K.N. Wairimu²

Eldoret University, Department of Soil Science, P.O. Box 1125-30100 Eldoret, Kenya
¹Ministry of Agriculture, Eldoret, Kenya
²Kenya Agricultural Research Institute, Kitale, P.O. Box 450-30200 Kitale, Kenya
alwangas@yahoo.com

Abstract

Soil acidity and fertility depletion, particularly nitrogen (N) and phosphorous (P) are major limitations to food production in sub-Sahara Africa. This on-farm experiment was done to determine the nutrient use efficiencies in maize production. Ten farmers were involved from each of Trans-Nzoia, Uasin-Gishu and Siaya Counties in Kenya. Fertiliser application rates were 75 kg N ha⁻¹ plus 26 kg P ha⁻¹. The plots were arranged in an incomplete randomised block design and all the yield data subjected to one-way analysis of variance. The initial soils characterisation indicated that the soils were low in soil pH, available P (<10 mg P kg⁻¹), total N (<0.2%) and organic carbon (<4.0%). The agronomic nutrient use efficiency of nitrogen and phosphorus was in diamonium phosphate + lime treatment at an average of 14.41 kg grain/kg P and 5.14 kg grain/kg N while it was lowest in Minjingu plots at an average of 11.60 kg grain/kg P and 4.02 kg grain/kg N. Although there was no significant (p<0.05) effect, DAP + lime plot still gave the highest mean yields recorded at 5.56 t ha⁻¹ while the Rotuba with ½ DAP plots had the lowest yields among the plots with treatments at a mean of 4.83 t ha⁻¹. There was no significant (p<0.05) difference in the yields of the treatments but there was a significant difference between the treatments and the control plots realising a mean of 1.75 t ha⁻¹. In conclusion, agronomic studies have shown that DAP does not perform better alone but increase yields when applied together with lime. In the experiments, DAP + lime or MPR + CAN performed better in both grain and stover yield. I would recommend that more studies be done to study the current relevance of DAP in farming in western Kenya in order to find ways to enhance its productivity.

Key words: soil acidity, nitrogen, phosphorus, rotuba, lime.

Introduction

Soil fertility depletion has been identified as the major cause for declining per capita food production in sub-Sahara Africa with the original fertile soils yield of 2-4 bags per hectare of maize into infertile soils hardly exceeding one bag per hectare (Ayaga 2003). In Kenya, main causes of low and declining maize yields are soil acidity and nutrient deficiencies. Nitrogen is a vital plant nutrient and a major yield determinant for maize production (Adediran and Banjoko, 1995).

Nutrient use efficiency is defined as yield per unit input. Various measurements have been used to assess the efficiency of nitrogen (N) and phosphorus (P) to determine crop response (Cassman et al., 2002; Hussein, 2009). This is based on the difference in crop yield and total nutrient uptake above ground biomass between fertile and infertile control plots (Dobermann, 2005).

Mineral fertilisers tend to be rapidly solubilised to forms assimilated by plants while organic inputs have to be mineralised first then subjected to plant uptake or less from the soil. Nitrogen is limiting to crop production lost through uptake and removal by crops, volatilisation, leaching, denitrification and loss from soil surface through runoff. It is replenished through use of inorganic fertilisers, biological nitrogen fixation (BNF) and use of organic materials (Stoorvogel and Smaling, 1990).

Soil acidity causes manganese (Mn), iron (Fe) and aluminium (Al) toxicities to plant roots, low levels of basic cations; potassium (K), calcium (Ca) and magnesium (Mg) and deficiencies of nutrients like manganese and boron (Eswaran et al., 1997). Now that nutrient depletion has been the major cause of
poor nutrient use efficiency hence affecting maize crop yield hence need for nutrient depletion to be addressed. This has been dealt with using Integrated Soil Fertility Management (ISFM) to replenish soil nutrients which involves application various soil fertility management options for productive and sustainable agro ecosystems to improve the agronomic nutrient use efficiency. This has led to low and unsustainable crop productivity in these soils. Nonetheless, substantial interventions to improve soil fertility have been done, especially in sub-Saharan Africa.

These have yielded crop increases, for example in western Kenya, where maize staple yield increases of 3-5 t ha\(^{-1}\) per season are as a result of fertiliser or with its combinations with organic inputs at on-farm level. However, most farmers, particularly smallholders who constitute about 90\% of the farming communities, have not adopted the technologies.

The study aimed at improving adoption of fertilisers in maize production. Famers could choose from several recommended fertiliser options including chemical (Di-ammonium phosphates (DAP), (NH\(_4\))\(_2\)HPO\(_4\)), organics and phosphate rocks. Because of the complexity in influencing adoption of the fertiliser recommendations by farmers, multidimensional strategies need to be used to influence farmers’ decision making. Field trials were used to act as farmer field schools (FFS) which is an effective tool to extend knowledge to farmers (Pontius et al., 2002).

The study was based on the broad objective of improving nutrient use efficiency in maize production for sustainable yields through use of fertilisers. The other objectives were to determine the effects of various treatments on soil pH, available P, organic carbon and total N, to determine the agronomic nutrient use efficiencies with respect to the various treatments applied and to determine the best combination of the inputs that gives maximum yields.

**Materials and methods**

**Description**

Soil acidity is attributed to the abundance of hydrogen (H\(^+\)) and Aluminium (Al\(^{3+}\)) cations in soils, at levels that interfere with normal plant growth. Soil acidity causes reduced maize yields on nearly 40\% of the total arable land (Gudu et al., 2005). In Kenya, 13\% of the total arable land, covering about 7.8 million hectares is acidic. This covers the high agricultural potential areas characterised by high altitudes and high rainfall (Kanyanjua et al., 2002). Western Kenya in particular has acidic and P-deficient soils occupying about 0.9 million hectares of land on which about 5 million people cultivate (Woomer et al., 1997).

**Study sites**

To achieve the objectives, on-farm experiments were conducted in Siaya County (0°30’ and 0°20”N and 0°34” and 34°30’E at 1140-1400 m) with bimodal rainfall distribution pattern encouraging two growing seasons in a year. The area is characterised by a mean minimum temperature of 15-17°C with a mean maximum of 27-30°C. The soils are developed from basalt volcanic rocks with the predominant soil being ferralsols, nitisols and acrisols.

Uasin-Gishu County (0°30’S and 0°55’N and 34°50’E and 35°37’W at 1500-2100 m) receives 900-1100 mm rainfall which is unimodal and mean annual temperatures of 22°C.

The soils developed on intermediate volcanic and basement rock system with predominant soil types as nitisols, ferralsols and acrisols. Trans-Nzoia (0°52’ and 1°18” N and 34°38’ and 35° 23”E experiences highland equatorial climate with average fairly annual distributed rainfall of 1296 mm. The soils are deep, red and friable clays and sandy clays derived from the basement complex. Black cotton soils occur along Koitobos River in the Endebess plain (Jaetzold and Schmidt, 2006).

**Experimental design and layout**

Test maize H6210 suitable for Trans-Nzoia and Uasin-Gishu Counties and H513 were planted in an incomplete randomised block design (Figure 1).
Transforming rural livelihoods in Africa: How can land and water management contribute to enhanced food security and address climate change adaptation and mitigation?


Figure 1: The experimental layout

Treatments were applied at 75 kg N ha⁻¹, 60 kg K ha⁻¹ and 26 kg P ha⁻¹ (FURP, 1994). Lime at 2 t ha⁻¹ was also used (Kisinyo, 2011). MPR was applied at a blanket rate of 60 kg K ha⁻¹ in all plots.

Results and discussion

The soils in Trans-Nzoia, Siaya and Uasin-Gishu were strongly acidic (pH 4.5 - 5.0) with low total N content (<0.2% N), low organic carbon content (<0.4%C) and deficient in P (<10 mg P kg⁻¹) (Table 1).

Table 1: Initial soils characterisation

<table>
<thead>
<tr>
<th>Soil parameters</th>
<th>Siaya</th>
<th>Trans-Nzoia</th>
<th>Uasin-Gishu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Ph</td>
<td>4.84-5.06</td>
<td>4.50-4.62</td>
<td>4.75-5.16</td>
</tr>
<tr>
<td>Available P(ppm)</td>
<td>1.57-1.98</td>
<td>1.41-1.76</td>
<td>1.54-1.86</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.15-0.17</td>
<td>0.17-0.19</td>
<td>0.16-0.18</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>1.32-1.65</td>
<td>1.57-1.82</td>
<td>1.49-1.77</td>
</tr>
</tbody>
</table>

Soil available P was low due to high rate of fixation caused by Al³⁺ and Fe³⁺ ions present in the acidic soils. The organic carbon was low due to continuous cultivation of land without nutrient replenishment. Burning of vegetation before tillage as a land preparation measure also contributing towards the low organic carbon content (Okalebo et al., 2002). Since most N is derived from organic matter mineralisation, then low organic matter has also contributed to low soil N. The low N and P contents may also be due to inadequate fertilisers (Okalebo et al., 2002).

After, DAP + lime had the highest contents of organic carbon content because lime reduces concentrations of H⁺, Fe³⁺ and Al³⁺ ions responsible for soil acidity (The et al., 2006). Phosphorus was also highest in this plot since lime decreased the exchangeable Al³⁺ ions that resulted to reduced sorption of the applied and the available P in the soil. Soil pH was greatly increased but Total Nitrogen remained constant in all the plots at 0.16% N. Plot 4 had the lowest pH and available P content while plot 3 had the lowest organic carbon content.

Organic carbon was generally low in all the sites and since it is a precursor of soil N, the total N content was generally low and was constant in all the treatments at 0.16%.
Figure 2: Effect of the various treatments on soil pH, available P, total N and organic carbon

The applications on agronomic nutrient use efficiencies showed DAP + lime having a significant effect (p≤0.05) in both agronomic P use efficiency (APUE) and agronomic N use efficiency (ANUE) by the grain giving a mean of 14.41 kg of grain per kilogramme P and 5.14 kg of grain per kilogramme N, respectively, followed by DAP at 13.26 of grain per kilogramme P and 4.60 of grain per kilogramme N then Rotuba at 12.20 of grain per kilogramme P and 4.28 of grain per kilogramme N and Minjingu which had the lowest effect on both APUE and ANUE had 11.60 of grain per kilogramme P and 4.02 of grain per kilogramme N (Figure 2).

Figure 2: Effect of the various treatment applications on agronomic nutrient use efficiencies

The plot with DAP + lime had the highest yields at 5.564 t ha⁻¹ followed by DAP (5.23), Minjingu (4.90), Rotuba (4.82) and the control (1.75).

Conclusion

The treatments enhanced seedlings growth which led to production of large cobs as compared to the control plots. The plot which recorded the highest yields was DAP + lime plot which had a mean of 5.56 t ha⁻¹ while the lowest yield was in the control plots at 1.75 t ha⁻¹. This is because lime ameliorated the adverse soil conditions hence enhanced utilisation of nutrients hence increased crop yields. The initial low nutrient levels (N, P and organic carbon) and the high soil acidity are the major causes of low declining maize grain yield as evidenced by the wide difference in yield between the yield in the controls and the plots with treatments.
The DAP + lime treatment had the best combination as per the response to the soil chemical properties analysed: soil pH, organic carbon, total N and available P. It also gave the best response to the agronomic N and P use efficiencies however, there was no significant (p<0.05) effect at between the treatments but there was a significant effect between the treatments and the control plots.

References


