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Influence of NPK Blended Fertiliser on Soil Chemical Properties under Acidic Conditions of Western Kenya on Finger Millet Crop

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Soil acidity is a serious problem that affects crop productivity in Western Kenya region. The county governments of Kakamega, Bungoma, Vihiga, Busia and Trans-Nzoia are promoting the application of NPK blended fertilizer to enhance the soil acidity. Finger millet (*Eleusine coracana* L. (Gaertn) is one of the principal cereal crops in Kenya and can grow in stress conditions much better than other cereal crops, and it is for this reason that it is currently being popularized in efforts to address food security. NPK blended fertilizer, Commonly known as 'Mavuno Fertilizer' to locals contains the combination of macronutrients and micronutrients (10%N, 26%P_2O_5, 10%K_2O, 4%S, 8%CaO, 4%MgO and traces of B, Zn, Mo, Cu and Mn) that makes it unique to ameliorate this acidic soil conditions. The study was conducted at the crop and livestock research field at Kenya Agricultural and Livestock Research Organization (KALRO) Kakamega station. The design was Randomized Complete Block Design, with 0,25,50,75,100 kg application rates per acre of NPK blended fertilizer as the treatments applied in two equal split application. The application of NPK mixed fertilizer reduced the amount of aluminium in the soil consistently for both seasons with the highest reduction under the highest rate while the soil pH, soil calcium and soil magnesium significantly increased linearly with increasing fertilizer rates. The control had no significant influence on the soil pH

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compared to the treated plots as compared to the analytical results of the soil pH of 5.71-5.73 before planting. The soil aluminium content drastically reduced from 2.10 cmol/kg in control to 1.4 cmol/kg in the 100 kg/acre in both rain seasons under the local variety Gulu-E with slight differences from P-224. The highest application rate of 100 kg/acre significantly increased the soil calcium contents to 3.4% and 3.3% during the short and long rainy seasons respectively. The NPK blended fertilizer application from any rate can positively ameliorate the soils in western Kenya by reducing the acidity.

Keywords: Soil acidity; finger millet; NPK blended; aluminum; magnesium; calcium.

1. INTRODUCTION

Finger millet (*Eleusine coracana* L. Gaertn) originated from the highlands of Ethiopia and is presently grown in eastern and southern Africa [1]. It is an essential crop in east and southern Africa where small-scale farmers grow it in low input farming systems. The crop has food security, nutritional, cultural, medicinal, and economic value with high industrial potential. It has been found to adapt better to poor soils, erratic weather conditions and droughts than main food grains such as maize and wheat [2]. While its production has been declining, there is still a significant demand for the crop, and finger millet price has been much higher than other cereals in the past few years. Finger millet is extensively cultivated in the tropical and sub-tropical regions of Africa, Kenya inclusive and is known to save the lives of poor farmers from starvation at times of extreme drought. Interestingly, new food products made from finger millet are also becoming popular among younger people, including noodles, pasta, vermicelli, snacks, and different bakery products. The crop contains high nutritional value especially to pregnant women and children for weaning, and its seeds can be stored for more than five years due to low vulnerability to insect damage, it provides food security for poor farmers [3].

The potential of finger millet production in Kenya remains unknown. For instance, in Western Kenya, millets were grown on 65,000 hectares in 2010 with an average yield of 1.3 tons/hectare [4]. The former Western province is known to be the largest producer of finger millet in Kenya with production rates of 0.5 ton/ha per year [5]. These low yields are largely explained in terms of droughts and depleted nutrients in soils such as calcium and magnesium among other reasons. Thus the farmland soils in Western Kenya, mainly the Acrisols (Utisols) and Ferrassols (Oxisols) are highly weathered, with widespread N and P deficiencies. Most soils found in the highlands of East of Rift valley and Western Kenya regions has a pH of 4.5 to 5.0 and high exchangeable Aluminium (III) ions which limits the availability of Ca, Mg and P in the soils. [6] concluded that Western Kenya continues to experience food insecurity due to increasing soil acidity and consequent phosphorus deficiencies with 0.9 million hectares of land having pH < 5.5. NPK blended fertilizer (10%N, 26%P_2O_5, 10%K_2O, 4%S, 8%CaO, 4%MgO and traces of B, Zn, Mo, Cu and Mn) is one of the P-based fertilizers currently gaining popularity in the region and can offset nutrient deficiency and improve crop yield. NPK blended fertilizer is known to contain liming materials that contribute to liming effects and their application in soils enhances the availability of nutrients such as phosphorus to plants resulting in high yields and improved soil properties [7].

Several liming materials such as crushed limestone ($CaCO_3$), dolomitic lime ($CaMgCO_3$), slaked lime ($Ca(OH)_2$), quicklime (CaO) etc., can be used to reduce soil acidity. They can be used either singly or in combined form. Studies have shown that apart from reducing the acidity of the soil by counteracting the effects of excess H^+ and Al^{3+}, liming also has several other benefits including, its ability to reduce the toxic effects of some microelements by lowering their concentrations while increasing the availability of plant nutrients such as Ca, P, Mo, and Mg in the soil [8] and reducing the solubility and leaching of heavy metals.

In a research, [9] reported an increase of 0.7 to 0.8 units of soil pH after application of travertine which contains high components of calcium carbonate and calcium oxide in combinations with natural fresh plant biomass on acidic soils of Rwanda. Application of lime and Organic fertilizers in acidic soils had also shown an improved increase in soil pH, soil calcium and soil magnesium and a reduction in the soil aluminium [10]. In this experiment, significant good results were observed in lime fertilizers as compared to organic fertilizers. [11] found that liming raises soil pH, base saturation, and Ca and Mg contents, and reduces aluminium concentration in acidic soils. Therefore there is a need for a fertilizer that could offer both liming and nutrient provision to soils such as NPK blended fertilizer.

However, there is lack and limited research and documentation of how the NPK blended fertilizer enriched with liming components and micro-nutrients application influences the production of finger millet which is majorly grown under these limiting conditions and hence low yields. This study hypothesized that NPK blended fertilizer has a liming effect on soil chemical properties of western Kenya. Therefore, this study was conducted as an effort to improve the productivity of finger millet in the region through nutrient management by ameliorating the soil environment for increased efficiency of fertilizers and uptake by the crop.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted as an on-station experiment at the Kenya Agricultural and Livestock Research Organization (KALRO) field station located in the UM ecological zone in Kakamega County in western Kenya which borders Vihiga County to the South, Siaya County to the west, Bungoma County to the North and Nandi County to the east. The station lies on the latitude of (00^o 16' N; 34^o 45' E; 1585 m asl) in the western part of Kenya during short and long rains season of 2015 and 2016, the short rains (SR) season which starts in October to February and the long rains (LR) season which starts in March to August.

2.2 Experimental Design and Treatments

The experimental field was cleared, ploughed and harrowed to a fine tilth and laid out as a Randomized Complete Block Design (RCBD), replicated three times with five treatments. The treatments included five levels of NPK blended fertilizer (0, 25, 50, 75 and 100 kg per acre) applied in two equal splits, one at planting and another at four weeks after emergence. The experimental unit measured 2 m x 1.7 m (3.4 m^2) with a 2 m pathway between blocks and a 1 m pathway between plots where blocks measured 18 m x 1.7 m (30.6 m^2) translating to an experimental field of 18 m x 13.1 m (235.8 m^2).

2.3 Cultural Operations

Soil samples were taken on the plots at a depth of 0 – 30 cm before planting then after harvesting to monitor the change in soil chemical properties. The seeds were planted with 30 cm spacing between rows and later thinned after four weeks to a 10cm intra-row spacing. In each plot three rows of each of the two varieties (P-224 and Gulu-E) were planted. The varieties were obtained from the Kenya Agricultural and Livestock Research Organization, Kakamega. The seeds were drilled in each line. The first weeding was done 14 days after germination (DAG) and the second weeding 14 days after the first weeding. To ensure enough space for the individual plants thinning of the rows was done during the first weeding [12] to have plants with 10 cm gap between each individual plant.

2.4 Data Collection and Soil Analyses

Soil samples were taken from the depth of 0- 30 cm in a zig-zag pattern. The collected samples were air-dried and passed through 2 mm sieve to remove large particles and debris and taken to the laboratory for analysis of pH and concentrations of Ca, Mg and Al ions before planting and after harvesting. The pH value of the soil suspension was read and recorded using pH meter (pH-100 Digital controller, India). The soil calcium content was measured using the EDTA titration method as described by [13]. The magnesium content in the soil was estimated using the EDTA titration method as described by the [14]. The soil aluminum content was determined by the Oxine-Gravimetric method as described by the [14].

2.5 Statistical Analysis

Analysis of variance (ANOVA) was performed on the collected data using GenStat statistical software Version 15.1 to test treatment effect at 0.05 level of significance. The means were separated using the Fischer's Protected LSD test where significant differences between treatments were observed.

3. RESULTS AND DISCUSSION

3.1 Soil pH

The application of the NPK blended fertilizer increased the soil pH significantly compared to the control for both seasons under the two finger millet varieties (Fig. 1). During the short rains season, the soil pH increased with increasing NPK blended rates under both varieties. The highest increase was observed on the highest rate with more than 0.7 of a unit as shown on Fig. 1. The highest point was realized at the 100 kg/acre rate on Gulu-E variety with 6.44 units. As expected, the control had almost no significant influence on the soil pH compared to the treated plots as compared to the analytical results of the soil pH of 5.71-5.73 prior to planting. In the long rains the same trend as observed in the short rains was exhibited though with marginal differences with a peak at 6.07 units in the 100 kg/acre rate. The NPK blended fertilizer applied had liming effects where it led to neutralizing of soil acidity (raising soil pH). The CaO and MgO dissolved in moisture and formed alkaline solutions, $Ca(OH)_2$ and $Mg(OH)_2$ that neutralized the hydrogen ions in the soils to water thereby reducing the soil acidity and raising the soil pH. Use of fertilizers with liming components is an effective and dominant practice to raise soil pH and reduce acidity-related constraints to improve crop yields [8]. The significant increase in soil pH due to application of the NPK blended was mainly because the NPK blended fertilizer contained high calcium oxide and magnesium oxide component. The findings observed on soil changes of pH after application of the NPK blended are in tandem to that of [9] who reported the increase of 0.7 to 0.8 units of soil pH after application of travertine which contains high components of calcium carbonate. The soil pH results observed in this study were also in agreement with that by [10].

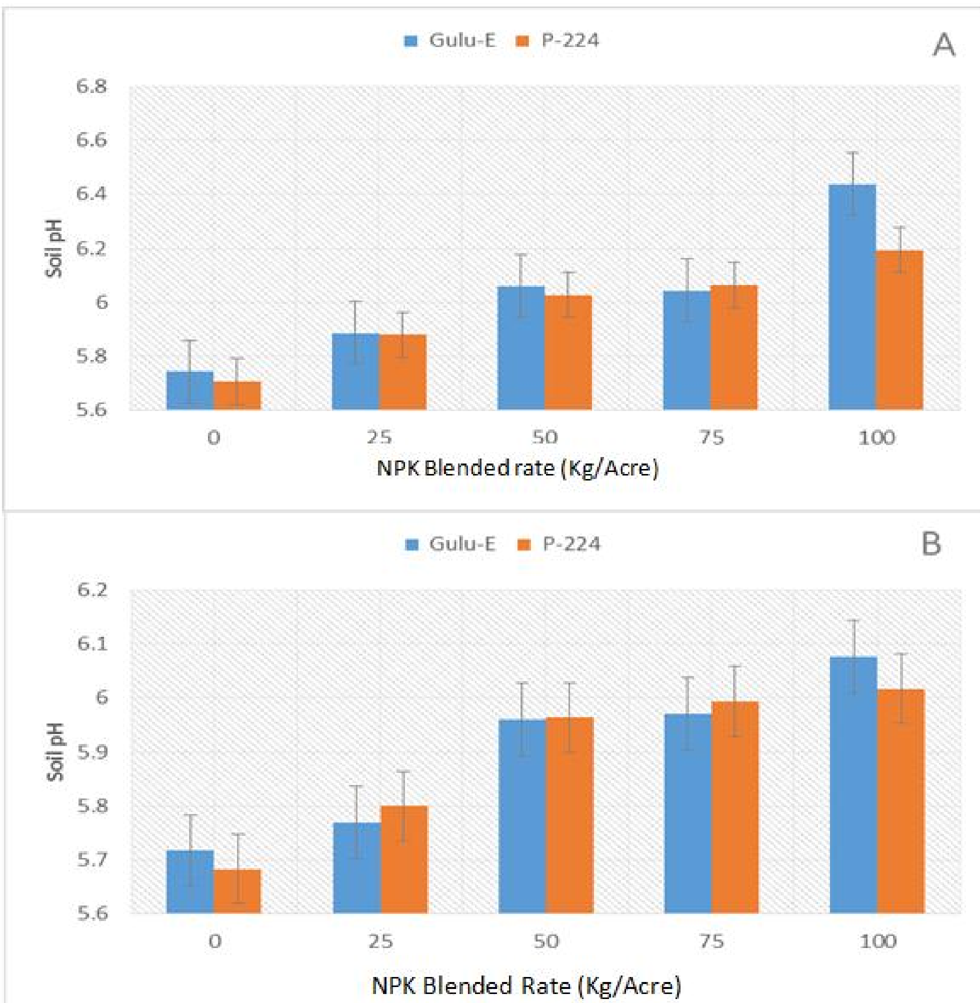

Fig. 1. The soil pH response to NPK blended rates under the two finger millet varieties at Kakamega during the short rains season (A) and long rains season (B).
Error bars indicate the LSD at P≤0.05

3.2 Soil Aluminium Content

The amount of aluminium in the soil significantly reduced with an increase in the application rates of NPK blended fertilizer for both seasons (Fig. 2). The content drastically reduced from 2.10 cmol/kg in the control to 1.4 cmol/kg in the 100 kg/acre during the short rains season under the local variety Gulu-E with marginal differences from P-224. The highest rate elicited the highest reduction of aluminum from 2.04 cmol/kg to 1.4 cmol/kg and from 2.1 cmol/kg to 1.38 cmol/kg (Fig. 2). During the long rains season, the soil aluminium content dropped from 2.15 cmol/kg in the control to 1.37 cmol/kg in the 100 kg/acre rate. At the start of the experiment, the amount of exchangeable aluminium in the soil was high as well as that of the control at the end of the experiment compared to that in the applied plots and steadily reduced with application of NPK blended. The effectiveness of the NPK blended fertilizer could be attributed to the increase of calcium and magnesium quantity released in the soil solution by the fertilizer and increase of soil pH that reduced the aluminium toxicity. The practice of correcting soil acidity reduced the available contents of Al, Fe, Mn, Zn, and Cu, but increases the availability of other essential nutrients.

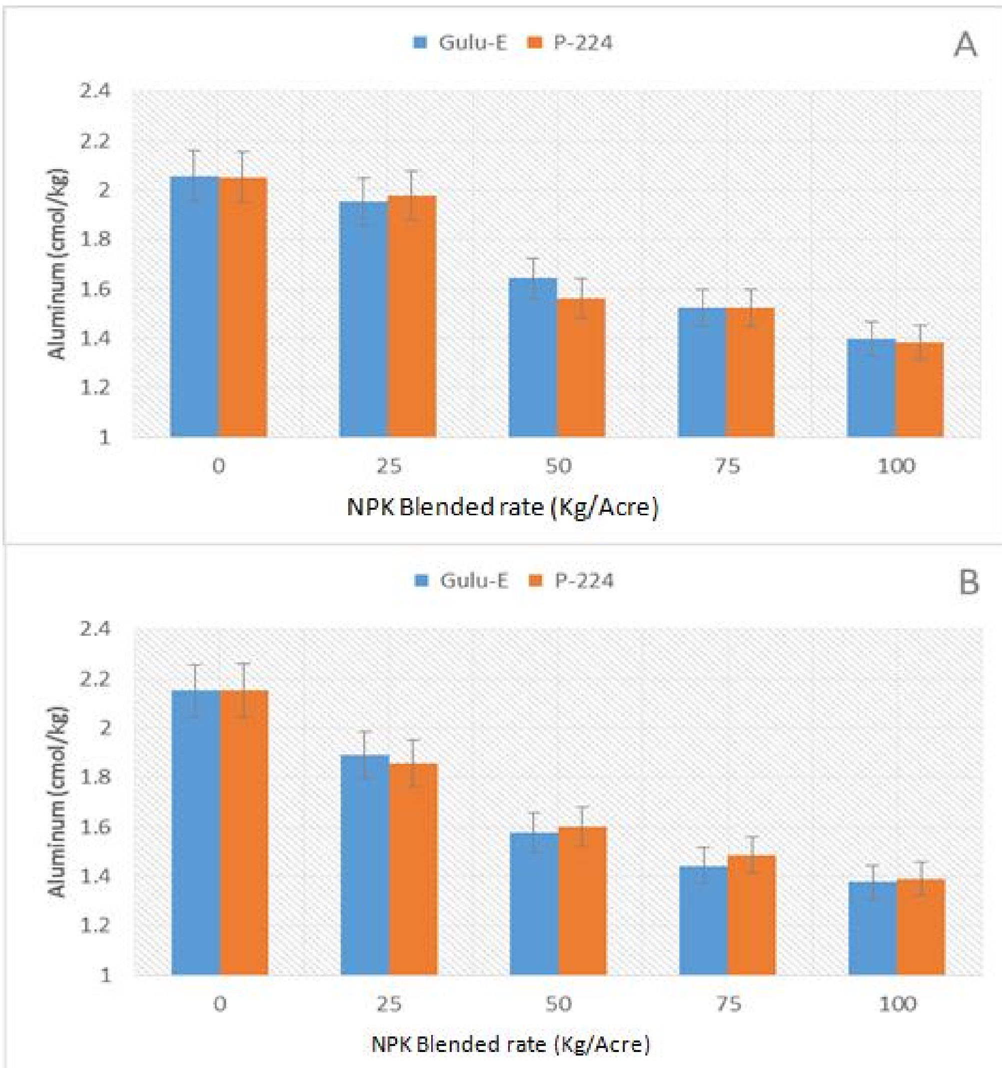

Fig. 2. Soil aluminum content during the short rains season (A) and long rains season (B) at Kakamega due to NPK blended fertilizer application

Error bars indicate the LSD at P≤0.05

3.3 Soil Calcium Content

The amount of calcium in the soil increased linearly for both seasons with increase in NPK blended fertilizer rate under the finger millet varieties for both seasons (Fig. 3). Before planting, during the short rainy season, the calcium content was 2.4% and 2.3% during the long rainy season. The highest application rate of 100 kg/acre significantly increased the contents to 3.4% and 3.3% during the short and long rainy seasons respectively. In the short rains season, the calcium content in the soil increased with increasing NPK blended rates with the highest elicited in the 100 kg/acre rate (3.47%) while the 0 kg/acre had the lowest soil calcium content (2.40%). For the long rains season, increase in the NPK blended rate led to an increasing calcium content in the soil with a peak in the 100 kg/acre rate. The control had the lowest influence on the calcium balances in the study soils for both seasons. Increase in soil calcium content was due to increased soil pH that let to reduced nutrient leaching and hence its availability in the soil. This is in accordance to other studies [9,10,11] that reported an increase of exchangeable calcium following application of fertilizers that contained liming effects in acidic soils.

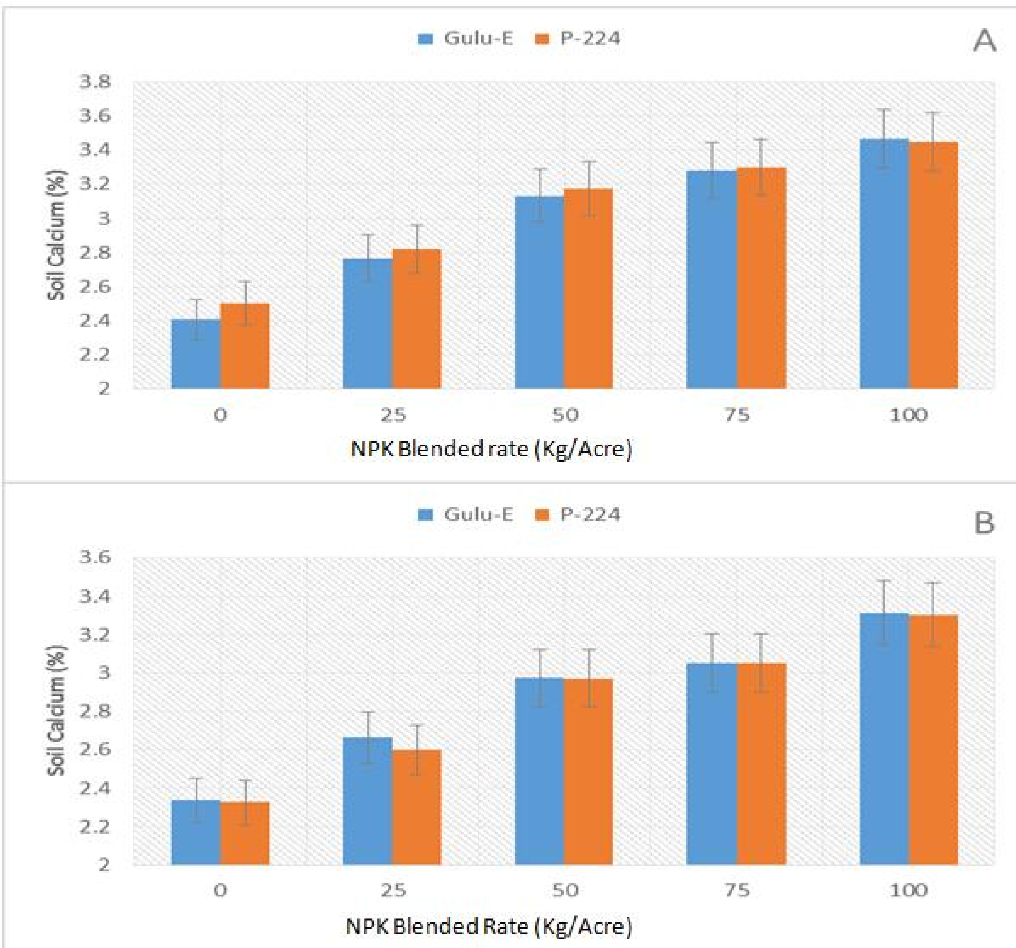

Fig. 3. The influence of NPK blended levels on the soil calcium content during the short rains season (A) and long rains season (B).

Error bars indicate the LSD at P≤0.05

3.4 Soil Magnesium Content

Magnesium content in the soil increased linearly for both seasons as the NPK blended fertilizer rate increased under the finger millet varieties for both seasons as shown on Fig. 4. During the short rainy season, before planting the magnesium amount in the soil stood at 1.14% and significantly increased to 2.24% under Gulu-E and 2.3% under P-224 both at the 100 kg/acre rate. During the long rainy season, prior to planting the magnesium content was 1.29% and rose to 2.33% under the Gulu-E variety and 2.32% under P-224 variety in the highest rate of NPK blended fertilizer. The calcium and magnesium contents in the soils were significantly higher in the NPK blended applied plots compared to the control probably due to the high CaO and MgO contents in the fertilizer. The increase of Ca saturation in the plots with the NPK blended could also be attributed to the fact that calcite contained in the fertilizer which released more Ca in the solution while the control had none. The results could also be due to reduced nutrient leaching caused by increased soil pH. The observed increase in magnesium level was in agreement with the findings of [11] which reported an increase of Mg and Ca content in acidic soils as a result of fertilizer application enriched with dolomite.

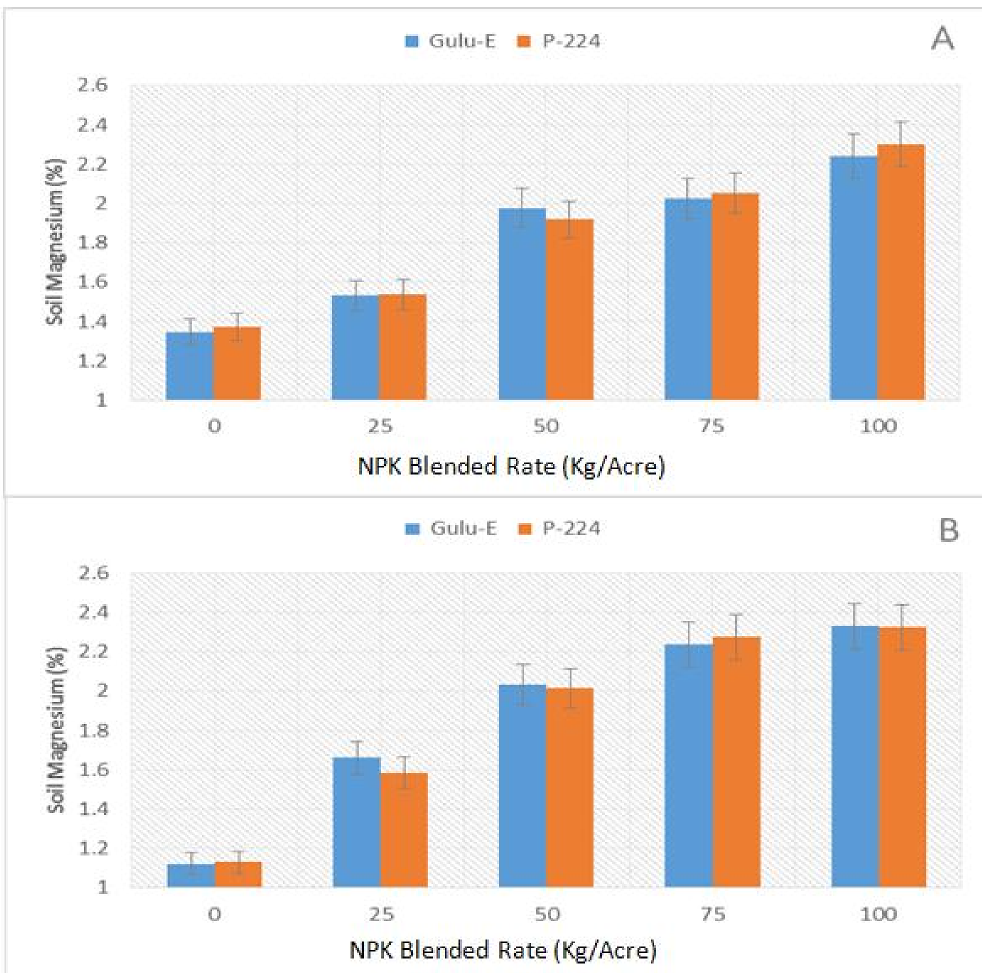

Fig. 4. NPK Blended levels effect on the soil magnesium during the short rains season (A) and the long rains season (B) at the KALRO Kakamega soils.

Error bars indicate the LSD at P≤0.05

4. CONCLUSION

The soil aluminium significantly reduced with the application of NPK blended fertiliser which increased the soil pH that does not favour aluminium accumulation which therefore impacted positively on the toxicity of the element while soil pH, soil calcium content and soil magnesium content steadily increased with the increase of NPK blended rates. The liming effects of the fertilizer were distinctively highlighted from the results of this study and thus the application of the NPK blended fertiliser rate is recommended from 25 kg/acre.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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