International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Effect of Soil Fertility Adjustments on Output of Food Crops through Combination of Lime, Sludge and TSP

Phyllis J. Lagat[1], Lusweti J. Kituyi[2], Titus M. Muthoka[3]

[1, 2, 3]University of Eldoret, Kitale - Cherangani Rd, Eldoret, Kenya

Abstract: ***The population of Kenya is among the fastest-growing in the world (estimated at 41 million inhabitants as of 2010) and with this increased population and the use of conventional agricultural methods, the country cannot cope with the food shortage problem. Though Agriculture is the backbone of the economy of Kenya contributing up to about 25% of the domestic product and about 60% export earnings, the sector is facing great challenges the main one being chemical degradation of agricultural soils from continuous use of inorganic fertilizers which make the agricultural soil acidic thus lowering output from the farms. Efforts need to be done to find innovative ways to improve the efficiency and safety of these fertilizers. Consequently, this study sought to assess the production of food crops by varying soil fertility through combination of lime, sludge and T.S.P. The study was done in UasinGishu Country, Kenya since it is the food hub of the country since it is the leading producer of maize and wheat.Randomized complete block design was adopted with treatments (lime/sludge/T.S.P.) being replicated in each block. There were five (5) treatments applied in three (3) test crops which were maize, wheat and beans. This made to a total of 30 plots per block. The experiment had two (2) blocks. All crops were planted after the onset of the long rains and harvested after reaching full maturity. Grain yield and Stover biomass were measured for the 3 crops.All fertilizer treatment combinations' effect on grain yield and biomass were statistically different form each other (P<.001). The combination of (TSP + lime + sludge) gave highest grain yields and stover biomass in maize of over 21 kg and 45 kg, respectively. The combination of TSP and lime produced highest grain yield and biomass in wheat and beans. There was no significant difference between a combination of (TSP + lime) and (TSP + lime + sludge) on wheat grain yields. The combination of (lime + sludge) gave the lowest yields for both grain and stover biomass for the 3 crops. It is recommended that the combination of (TSP + lime + sludge) should be used in maize production while (TSP and lime) production of wheat and beans as this will increase productivity by improving soil fertility and health of the crops.***

Keywords: Soil fertility, Inorganic fertilizers, Grain yield, Stover biomass

1.Introduction

The rate of population growth in Kenya is creating an alarming situation of food insecurity and immense poverty (Benson, 2004). The population of Kenya is among the fastest-growing in the world (estimated at 41 million inhabitants as of 2010) and with this increased population and the use of conventional agricultural methods, the country cannot cope with the food shortage problem (Anderson *et al.,* 2013). In the recent years, and especially starting from 2008, the country has been facing severe food insecurity problems. This is substantiated by a high proportion of the population having no access to adequate food. Though extreme weather is its immediate cause, the food security crisis in Kenya can also be attributed to the culmination of many years of mismanagement of the agricultural sector and associated climate risk (Konandreas, 2014).

According to FAO, more than 18 million people confront serious food insecurity in East Africa due to the combined effects of below-average harvests, high food prices, political insecurity, cumulative poor rains and use of archaic farming techniques (FAO, 2013). Malnutrition affected an estimated 33% of children under five as of 2014. The agricultural sector is the mainstay of the Kenya's economy. Over 80% of the population derives their livelihoods mainly from agriculture and agricultural allied activities (Oniang'o, 2001). An estimated 2.6 million persons in Kenya, up from 1.6 million in August 2010; require food and non-food assistance for the next six months, at least (McKenzie & Williams, 2015). Thus sustainable interventions are required urgently so as to alleviate the daunting food insecurity in Kenya and protect livelihoods.

Though Agriculture is the backbone of the economy of Kenya contributing up to about 25% of the domestic product and about 60% export earnings (Alila&Atieno, 2006), the sector is facing great challenges the main one being chemical degradation of agricultural soils from continuous use of inorganic fertilizer (Kherallah*et al.,* 2002). This practice lowers soil pH which adversely affects the uptake of major nutrients which are pH dependent for their solubility in the soil (Baligar*et al.*, 2001).

In UasinGishu County, Diammonium phosphate (D.A.P.), Triple superphosphate (T.S.P.), Urea and Monoammonium Phosphate (M.A.P.) are the most commonly traded phosphate fertilizers. The major problem with these fertilizers is that theymake the agricultural soil acidic thus lowering output from the farms. Efforts need to be done to find innovative ways to improve the efficiency of these fertilizers. Consequently, this study sought to assess the production of food crops by varying soil fertility through combination of lime, sludge and T.S.P. The study was done in UasinGishu Country, Kenya since it is the food hub of the country since it is the leading producer of maize and wheat.

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

2.Materials and Method

The study was conducted at the University of Eldoret farm, which according to Jaetzold and Schmidt (2006), is classified as lower highlands zone 3 (LH3). The site is positioned at an elevation of 2185 m with precipitation of 900-1100 mm p.a. The field experiments were carried out during the long rains of the year 2006 and 2007.

Randomized complete block design was adopted with treatments being replicated in each block. This was important to control nuisance factors. Nuisance factors included specific treatment and time of application. Randomization was done to reduce contamination or mixing of the treatments. There were five (5) treatments applied in three (3) test crops which were maize, wheat and beans. This made to a total of 30 plots per block. The experiment had two (2) blocks.
The treatments were replicated twice and applied in plots measuring 4 m x 4 m as shown in table 1.

Table 1: Types of treatments applied

Maize	**Wheat**	**Beans**
Control	Control	Control
Lime + sludge	Lime + sludge	Lime + sludge
TSP + lime	TSP + lime	TSP + lime
TSP + sludge	TSP + sludge	TSP + sludge
TSP + sludge	TSP + sludge	TSP + sludge

Planting was done after onset of long rains. Lime was applied in plots one week before planting the crops at 1.5 tonnes per hectare. Sludge was applied at 2 tons per hectare. T.S.P. was applied at 20 kg per hectare. All crops were harvested after reaching full maturity. Grain yield and Stover biomass were measured for the 3 crops. Maize was harvested when cobs had ripened and dried with moisture content >15%. Wheat was harvested manually using sickle when grain moisture content > 14%. Bean pods were harvested early in the morning when they were still turgid to avoid shattering and dried to moisture > 20% before weighing. Analysis of the collected data was done using ANOVA and mean separation. This was aimed at establishing the best treatment for agricultural purposes.

3.Results and Discussion

Crop productivity: Grain yield

The effect of different treatments on grain yield for maize, wheat and beans was highly statistically significant ($p<.001$). A combination of TSP and lime was significantly different from a combination of (TSP, lime and sludge) in maize but not for wheat and beans (Fig 1, 2, 3 and 4). Combination of (TSP, lime and sludge) gave highest yields in maize (Fig 1) while combination of (TSP, lime) gave highest yields in wheat and beans (Fig 2 and 3). A combination of (lime and sludge) and that of (TSP and sludge) was statistically significant in maize but not for wheat and beans.

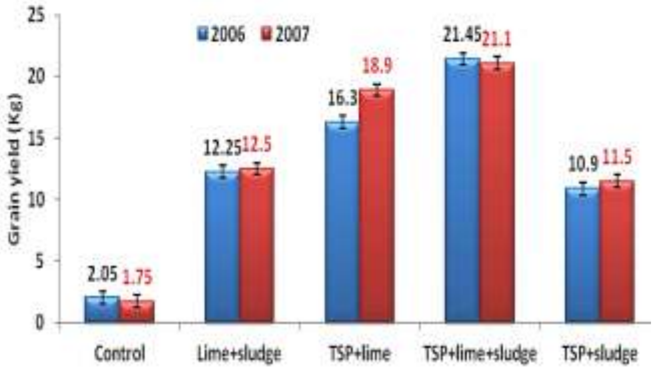

Figure 1: Maize grain yields (kg) for 2006 and 2007 seasons

TSP +lime +sludge combination gave highest maize grain yield followed by TSP + lime then lime +sludge and finally TSP +sludge. The absolute control gave the least grain yield. There was significant difference between TSP +sludge and finally lime +sludge (Figure 1). The difference in grain production over the two growing seasons was not statistically different. Productivity was ten (10) times more in TSP +lime +sludge combination than the control (Figure 1).

Wheat grain yield productivity followed the same trend like that of maize. TSP + lime was the best treatment but not significantly different from TSP + lime + sludge combination. TSP + sludge and lime + sludge were far much behind but giving grain yields more than double that of control. TSP + sludge and lime + sludge were not statistically different in terms of productivity Figure 2.

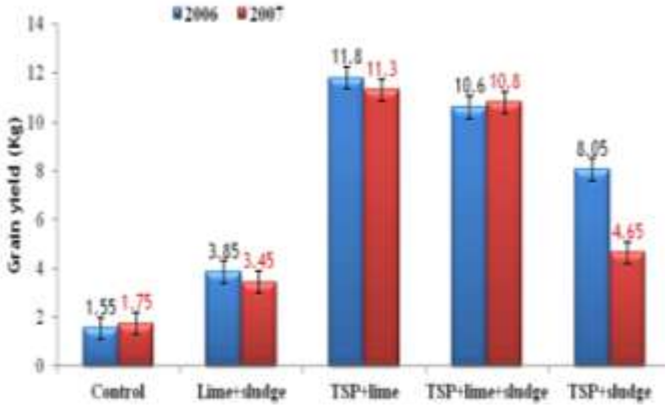

Figure 2: Wheat grain yields (kg) for 2006 and 2007 seasons

Unlike in maize and wheat, TSP + lime combination gave the highest yields followed by TSP + lime + sludge but the productivity between the two treatments was not statically significant. In addition, the productivity from the two treatments was five (5) times more than that produced without use of fertilizer (control). TSP + sludge and lime + sludge were different and gave more than double compared to that of control.

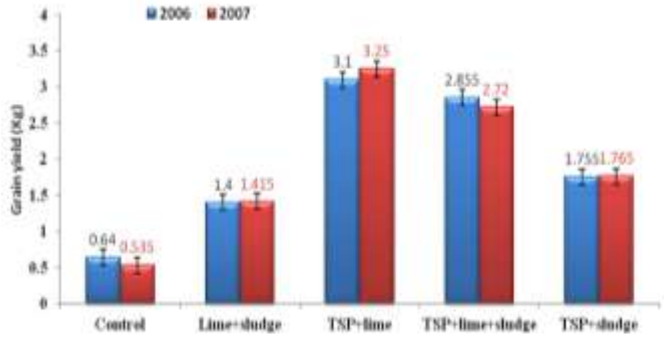

Figure 3: Bean grain yields (g) for 2006 and 2007 seasons

Crop productivity: Biomass

The effect of different treatments as per Table 13 on biomass for the 3 crops (maize, wheat and beans) was highly statistically significant (*p<.001*). A combination of TSP and lime was significantly different from a combination of TSP, lime and sludge) for the 3 crops (Fig 4, 5, and 6). Combination of TSP and lime gave highest biomass in all the 3 crops followed by the combination of TSP, lime and sludge. A combination of TSP and sludge and that of lime and sludge were not statistically significant on bean biomass but significant on maize and wheat biomass.

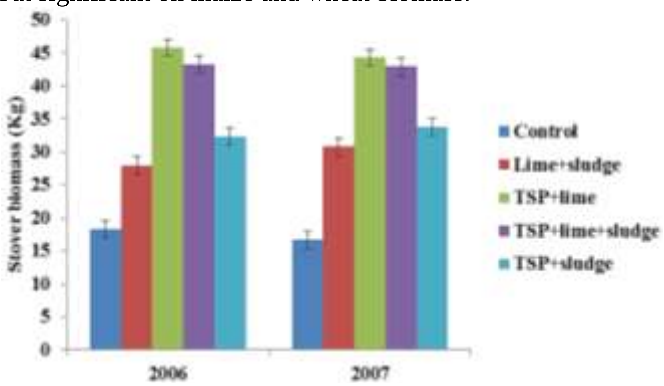

Figure 4: Maize Stover biomass (kg) for 2006 and 2007 seasons

The effect of different treatments on maize biomass was highly significant (*p<.001*). The biomass produced from TSP and lime treatment was highest and was nearly triple that of absolute control. This was followed by TSP, lime and sludge) but the difference was not statistically significant between the treatments. Combining TSP + sludge and lime + sludge did not give statistically different results for the two seasons as shown in Figure 4. The difference in the two years (growing seasons was not significant).

The effect on wheat of different fertilizer materials on wheat biomass gave the same trend as in maize. A TSP and lime combination gave highest straw biomass which was double that of absolute control. TSP, lime and sludge combination gave second highest biomass yields followed by TSP and sludge and then lime and sludge. The control gave the least biomass (Figure 5).

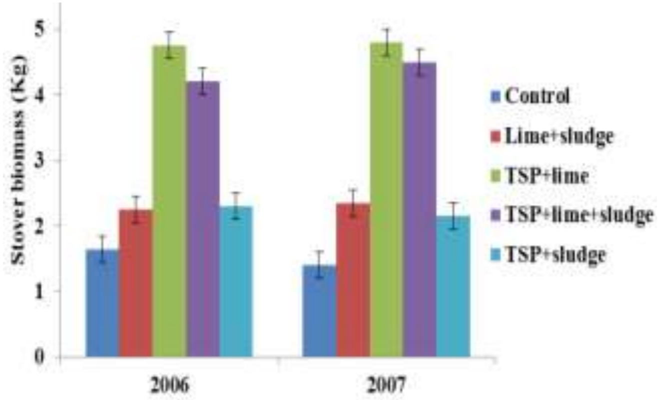

Figure 5: Wheat straw biomass (kg) for 2006 and 2007 seasons

Bean biomass was greatly affected by treatments. A TSP and lime combination was the best and five (5) times more than control. TSP and sludge was second followed by lime and sludge while absolute control was the least (Figure 6). The difference between TSP and sludge and lime and sludge was significant statistically unlike in maize and wheat.

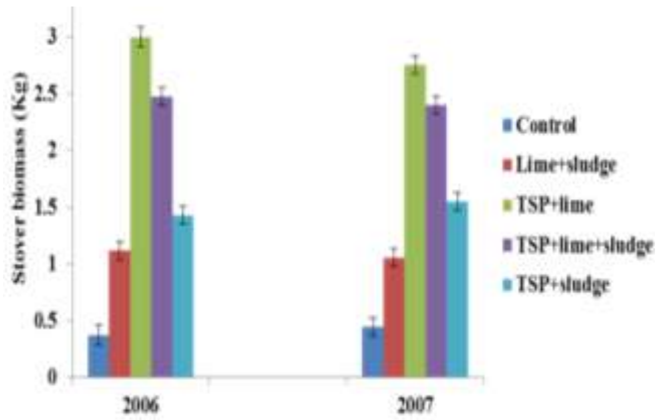

Figure 6: Bean biomass (kg) for 2006 and 2007 seasons

4.Discussion

The effect of combined use of lime, TSP and sludge on crop productivity differs with the type of crop and even the type of soil. Maize and wheat are cereals while common bean is a legume that fixes nitrogen in the soil. Deep rooted crops like maize mines more nutrients from the soil than wheat despite all are cereals. TSP fertilizer is soluble in the soil and it releases phosphorus immediately for plant use compared to lime or sludge. Sludge, as a fertilizer releases nutrients very slowly because it's an organic material that has to undergo mineralization before enriching the soil. Mineralization is a process that is a function of various environmental factors like; soil moisture, the type of the decomposing agents. In addition, the source and storage conditions of the organic material used to make manure sludge greatly influences nutrient content of sludge. Lime as a soil amendment improves several conditions of a given soil. It improves the soil structure of a soil due to the effect of Ca which improves the aggregate structure. In addition, lime increases soil pH hence improving the fertility although on a slow basis. The main use of lime in agriculture is to raise the pH of acid soils and reduce the Al hence making phosphorus available to crops. According to Sawyer, (2003), lime corrects problems from excessive acidity ranging from reduced Al and other metal toxicities, improved soil physical condition, increased microbial activity like the symbiotic bacteria that fix N to improving availability of essential nutrients such as Ca and Mg for plants. This was confirmed by the study conducted in western Kenya.

Combining lime, TSP and sludge for use as a fertilizer material seemed the best choice as it gave the highest yields. Lime is basic pH 11.2 while TSP is acidic pH 2.47 in solution. Combination of the two gave a pH of 6.0, hence the acidic conditions of TSP increases the solubility of lime in the soil therefore improving the efficiency of lime. When the two are applied in the soil, TSP releases phosphorus immediately for better root development hence good crop establishment.

Lime will cater for phosphorus needs at later stages of growth besides providing calcium. The pH increase caused by lime will create favorable soil conditions for crops to absorb and utilize essential cations like K and Mg. This combination lime + TSP will need additional nitrogen source to cater nitrogen deficiencies as done in this experiment where CAN fertilizer was applied in all treatments. Using a combination of lime and sludge as a fertilizer was less effective as both are slow nutrient releasers and limited in terms of quantity or amount of nutrient required by the crops. Sludge as an organic matter is a good option to manage problems associated with soil acidity as it increases the cation exchange capacity of the soil mostly increasing the base saturation. In addition, sludge forms strong bonds, known as "chelating effect," with aluminum which reduces the solubility of aluminum and soil acidity.

Sludge acts as buffer for nutrient concentration in the soil when applied in combination with inorganic fertilizer whereby nutrients are not released immediately to crops. This causes relatively low yields especially in crops with short growing cycles. However, with time, this will change making this combination the best fertilizer material for crops with longer growing seasons like maize in cold and high altitude areas. In this regard, the combination of lime + TSP + sludge would be preferred to that of lime + TSP. Research in soya beans by Serafim*et al.* (2013) revealed that manure and lime significantly reduced exchangeable acidity and increased soil pH. Application of manure alone or combined with lime or P fertilizer also increased Mg and K. In addition, lime alone or lime combined with manure and manure combined with P applied gave a significant increase in exchangeable Ca. Soybean responded well and significantly to application of manure either alone or combined with lime, P or both.

The application of manure significantly has an impact on the chemical, physical and biological properties of the soil due to an increase in the levels of soil organic matter (Liang *et al.*, 2011; Bakayoko*et al.*, 2009) resulting from manure application. Mwangi*et al.* (2001) indicated that agricultural lime reduced soil acidity while farmyard manure did improve soil pH but the change was not as instant as was for lime.

Kidanemariam*et al.* (2013) indicated that yield and yield attributes of wheat showed significant response to lime and fertilizer applications. In addition, a fertilizer-lime interaction was significant in grain yield, total biomass and N and P uptakes.

According to a study conducted in the mid and highlands of Ethiopia, application of lime with fertilizer generally increased maize production. This also is in agreement with Okalebo*et al.* (2009) who stated that combined application of lime with nitrogen and phosphorus significantly increased maize yield in Kenya. Therefore, .instead of applying only fertilizer on acidic soil, it is better to integrate with lime for better production of maize.

Fertilizer material made from combining lime and sludge gave low yields because of its slow release of nutrients for plant use. The nutrient composition is limited and it will require huge amounts of both lime material and sludge for successful crop production and therefore starter inorganic fertilizer would be needed to supply essential nutrients to crops at early stages of growth. The residual effect of both lime and sludge are very important in soil fertility sustainability as both can be applied in soils and provide nutrients for many growing seasons without additions, residual effects last for several years before application again. The fineness of lime is important in determining how quickly it reacts with soil acidity. Smaller particle size reacts quickly since there is more exposed surface area for chemical reaction. Larger particles are slower to react, but provide a sustained, longer term source of acid neutralization. In addition, lime is more soluble in acid soils than in neutral or alkaline soils (Kabata-Pendias, 2010). According to studies done by Jones (2001), lime made of calcium carbonate ($CaCO_3$) is insoluble in water but its solubility increases in acid conditions. These studies further suggest that poor crop growth in acid soils is largely due to soluble Al that affects the root system of plants making them stubby.

5.Conclusion

The productivity of the two food crops (maize and wheat) was enhanced greatly by the combined use of lime, TSP and sludge as a fertilizer material. To improve the combination lime and TSP, additional nitrogen source is required to cater for nitrogen deficiencies. Sludge when used alone acts as buffer for nutrient concentration in the soil but when applied in combination with inorganic fertilizer, nutrients are not released immediately to crops which cause relatively low yields especially in crops with short growing cycles. In this regard, the combination of lime, TSP and sludge would be more preferable to that of lime and TSP.

6.Recommendations

1) The combination of (TSP + lime + sludge) should be used in maize production as this will increase productivity by improving soil fertility and health. In addition, this combination (TSP + lime + sludge) should be used in long term strategy cropping systems while the combination of (TSP and lime) should be adopted for short term strategies for crops grown.

2) The use of TSP and lime should be adopted in production of wheat and beans as it gave highest yields. TSP will provide instant phosphorus for better root establishment while increased lime solubility will provide calcium and additional phosphorus needed for better grains.
3) A combination of TSP + lime + sludge would be preferred for growing maize for grain yields while TSP and lime for growing maize for Stover for use as animal feeds either as fresh fodder, silage or hay especially in dairy farming systems.
4) This study was limited to only three crops .Therefore more studies on other crops should be done so as to establish how they respond to the same treatment.

References

[1] Alila, P. O., &Atieno, R. (2006, March). Agricultural policy in Kenya: issues and processes. In *Future Agricultures, A paper for the Future Agricultures Consortium workshop, Institute of Development Studies* (pp. 20-22).

[2] Anderson, P. M., Okereke, C., Rudd, A., & Parnell, S. (2013). Regional Assessment of Africa. In *Urbanization, biodiversity and ecosystem services: Challenges and opportunities* (pp. 453-459). Springer Netherlands.

[3] Bakayoko, S., Soro, D., Nindjin, C., Dao, D., Tschannen, A., Girardin, O. and Assa, A. (2009).Effects of cattle and poultry manures on organic matter content and adsorption complex of a sandy soil under cassava cultivation (*Manihotesculenta*, Crantz).*Afric. J. Environ. Sci. Technol*., 3*(8)*: 190-197.

[4] Baligar, V. C., Fageria, N. K., & He, Z. L. (2001).Nutrient use efficiency in plants.*Communications in Soil Science and Plant Analysis*, *32*(7-8), 921-950.

[5] Benson, T. D. (2004). *Africa's food and nutrition security situation: where are we and how did we get here?*(Vol. 37). Intl Food Policy Res Inst.

[6] Brown, L. R. (2012). *Outgrowing the Earth: The food security challenge in an age of falling water tables and rising temperatures*.Taylor & Francis.

[7] Jaetzold, R. and Schmidt, H. (2006).*Farm Management Handbook of Kenya*, Ministry of Agriculture, German Agriculture Team (GTZ). Nairobi, Kenya. Volume IIIB

[8] Jones Jr, J. B. (2001). *Laboratory guide for conducting soil tests and plant analysis*.CRC press.

[9] Kabata-Pendias, A. (2010). *Trace elements in soils and plants*. CRC press.

[10] Kherallah, M., Delgado, C. L., Gabre-Madhin, E. Z., Minot, N., & Johnson, M. (2002).*Reforming agricultural markets in Africa: Achievements and challenges*. Intl Food Policy Res Inst.

[11] Kidanemariam, A., Gebrekidan, H., Mamo, T. &Tesfaye, K. (2013). Wheat Crop Response to Liming Materials and N and P Fertilizers in Acidic Soils of Tsegede Highlands, Northern Ethiopia.*Agriculture, Forestry and Fisheries.*Vol. 2, No. 3, 2013, pp. 126-135.

[12] Konandreas, P. (2014). Challenges Facing Poor Food-importing Countries.*Tackling Agriculture in the Post-Bali Context*, 61.

[13] Liang, W., Wu, X., Zhang, S., Xing, Y., Wang, R. (2011).*Effect of organic amendments on soil water storage in the aeolian sandy land of northeast China.* Proceedings of the Electrical and Control E Engineering (ICECE), International Conference on 16th – 18th Sept. 2011. pp. 1538-1540.

[14] McKenzie, F. C., & Williams, J. (2015). Sustainable food production: constraints, challenges and choices by 2050. *Food Security*, 1-13.

[15] Mwangi, T. J., Ngeny, J. M., Wekesa, F. and Mulati, J. (2001).*Acidic soil amendment for maize production in UasinGishu district, North Rift Kenya*.Kenya Agricultural Research Institute, Kitale, Kenya.

[16] Okalebo, J. R., Othieno, C. O., Nekesa, A. O., Ndungu-Magiroi, K. W., Kifuko-Koech, M. N., Tenywa, J. S., ... &Nampala, M. P. (2009). Potential for agricultural lime on improved soil health and agricultural production in Kenya. In *9th African Crop Science, Conference Proceedings, Cape Town, South Africa, 28 September-2 October 2009* (pp. 339-341). African Crop Science Society.

[17] Oniang'o, R. K. (2001). Enhancing people's nutritional status through revitalisation of agriculture and related activities.*African Journal of Food, Agriculture, Nutrition and Development*, *1*(1), 43-50.

[18] Serafim, B.V., Danga, O. B. and Njeri , J. M. (2013). Effects of manure, lime and mineral P fertilizer on soybean yields and soil fertility in a humicnitisol in the Central Highlands of Kenya.*International Journal of Agricultural Science Research*, Vol. 2*(9)*, pp. 283-291.

[19] Uchida, R., & Hue, N. V. (2000).Soil acidity and liming.*Plant nutrient management in Hawaiian soils, approaches for tropical and subtropical agriculture.Edited by JA Silva, and R. Uchida. University of Hawaii, Honolulu*, 101-111.