

**INFLUENCE OF AGRICULTURAL LIME ON SOIL PROPERTIES AND WHEAT
(*Triticum aestivum* L.) YIELD ON ACIDIC SOILS OF UASIN GISHU COUNTY,
KENYA.**

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Abstract

A study was carried out to investigate the influence of agricultural lime (21% CaO) from Koru, Kisumu on soil properties and wheat yield on acidic soils of Uasin Gishu County. Field trials were conducted at Chepkoilel University College farm and in Kipsangui area of Uasin Gishu county. Soils were analyzed to determine their pH, available P and other nutrient levels before treatment application. The experiment was a split plot arrangement with two wheat varieties as the main plots and the lime treatments as the subplots. The two varieties were Njoro BW 2, which is tolerant to soil acidity and KS Mwamba moderately tolerant to soil acidity, were compared. Phosphorus and nitrogen were applied as a blanket treatment at the rates of 40 kg P₂O₅/ha⁻¹ and 46 kg N/ha⁻¹ respectively. Lime was applied at the rates of 0.0, 0.5, 1.0, 1.5 and 2.0 t/ha⁻¹. Soils from the two sites were acidic with low to moderate available P for Chepkoilel and Kipsangui sites respectively. Soil pH and soil available P increased with the increase in the rate of lime addition. Wheat grain yield increased significantly (p<0.05) due to soil acidity amendment, P and N addition above the control. There was a high positive correlation between wheat yields and soil available P at both sites at harvest. High cost of inorganic inputs, low wheat grain prices and the effects of the erratic rains made the majority of the treatments economically unviable for adaptation by farmers. However, the most profitable treatment was 40 kg P₂O₅/ha⁻¹ with 46 kg N/ha⁻¹ and 2 t/ha⁻¹ in Njoro BW 2 at Kipsangui site. There was no viable treatment at Chepkoilel site. Higher wheat yields may probably be achieved from rates of lime above 2 t/ha⁻¹.

Key words: Lime, wheat, soil acidity, nitrogen, phosphorus

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the first most important cereal cultivated in the world. It is the second most important cereal crop grown in Kenya after maize (Grain Economy Review, 2005). In contrast to sustained increases in wheat productivity in other parts of the developing world, per capita production in Kenya continues to stagnate while the consumption has been on the increase (Onsogo, 2003). Uasin Gishu county is a major wheat producing counties of Kenya, producing more than one-third of the total wheat produced in the country (DAO, 1996). However, over the recent years there has been a general decline of crop yields due to unpredictable weather particularly rainfall, declining soil fertility, diminishing land parcels as the consequence of rapid population growth, low and unsustainable market prices for the produce and poor crop husbandry (MOA, 2009). High costs of inputs mainly Di-Ammonium Phosphate and Calcium of Ammonium nitrate, diseases, weeds and poor crop husbandry, also contribute significantly to low grain yields in the county. In addition to the above constraints, the wheat crop in this county is mainly grown on ferralsols which are characterized by low pH (soil acidity) and low nutrient levels (FURP, 1994). These ferrous impervious soils also result in frequent water stagnation (Kenya Roads Authority, 2010). Nitrogen, calcium and magnesium deficiencies and toxicities of aluminum and manganese, which characterize these acidic soils, also limit crop production in this district ((Lwayo *et al.*, 2001). Further, continuous use of acidifying fertilizers like Di-Ammonium Phosphate and urea, worsen an already bad situation (Neil, 1991).

Soil acidity is attributed mainly to abundance of hydrogen (H^+), aluminum (Al^{3+}) and manganese (Mn^{2+}) cations in soils at levels that interfere with normal plant growth. Soil acidity has a negative effect on crops/yields mainly through P unavailability from P fixation in soils whereby the Fe and Al soil components (sesquioxides) fix sizeable quantities of P. Excess Al^{3+} ions, from soil acidity, tend to accumulate in plant roots and thereby prevent P, Mo and other ions translocation to the tops from the roots, as evidenced by the inhibition of root elongation and overall retarded crop development (Kochian, 2004; Kanyanjua *et al.*, 2002; Ligeyo and Gudu, 2005). The detrimental effect of H^+ ions is not as distinct as that of Al^{3+} cations, but excess of H^+ ions in acid soils affects plant root membrane permeability and therefore interferes with ion transport (Ligeyo and Gudu, 2005).

In acid soils and P deficient tropical soils where the plant capacity to scavenge the native or use added P with efficiency is critical (Swift *et al.*, 1994), correcting soil acidity and P fertilizer addition are important. Lime is widely known as the effective way of correcting soil acidity or inputs recommended for amelioration of acid soils (Anetor and Ezekiel, 2007). Its direct effect is soil pH increase (The *et al.*, 2006) In Kenya, management of soil acidity through liming is highly recommended (Kanyanjua *et al.*, 2002; Kisinyo, 2011). Lime reduces Al, H, Mn, and Fe toxicities and increased P, Mg, Ca and Mo ions in acidic soils (Kamprath, 1994; Kanyanjua *et al.*, 2002; Moody *et al.*, 1998). Therefore, in P fixing acid soils, combined lime and P application is necessary for increased availability of the applied P for plant uptake. Although, not permanent the direct effect of lime lasts longer than any other amendment, such as organic materials, thus the objectives of this study were to (1) To investigate the effects of agricultural lime (21% CaO),

on wheat production in acid soils of Uasin Gishu county. (2) To determine the response in terms of growth, changes in pH, available P and hence yields of two wheat varieties as affected by lime.(3) To evaluate the economic returns of the two wheat varieties from amelioration of depleted soils by application of lime.

Methodology

Study sites

Chepkoilel University College

The field experiment was conducted out at the Crop Seed and Horticultural Science Department Field, Chepkoilel University College, Moi University in Moiben division. The soils of Chepkoilel belong to a group of soils found on plateaus and high level structural plains. The soils are of igneous origin, acidic (pH: 4.5-5.0), and low in fertility and are underlain with murram. They are classified as Rhodic Ferralsols according to the FAO/UNESCO classification and Oxisols according to the USDA classification (Jaetzold and Schmidt, 2006; FURP, 1994)

Kipsangui

The experiment was also concurrently conducted out at Mrs Selina Maswai's farm in Kongasis location, Kipsangui sub-location, Soy division of Uasin Gishu county. The area receives a unimodal rainfall distribution pattern. The average amount of rains received in the area for the last ten years is 1171 mm. According to National Agricultural and Livestock Extension Programme Broad Based Survey (NALEP-BBS) report of 2011, the soils are sandy loam. They are classified as Rhodic Ferralsols according to the FAO/UNESCO classification and as Oxisols according to the USDA classification (Jaetzold and Schmidt, 2006, FURP, 1994).

Experimental design and treatments: Lime was applied at the rates of 0.0, 0.5, 1.0, 1.5, and 2.0 ton/ha⁻¹ as CaO from Koru, Kisumu. In addition P and N were applied as a blanket treatment at rates of 40 kg P₂O₅/ha⁻¹ (17.6 P kg/ha⁻¹) and 46 kg N/ha⁻¹ respectively. Experimental design was a split plot with varieties namely Njoro BW 2 and KS Mwamba forming the main plot and lime levels as the sub plot. Liming materials were obtained from Koru in Kisumu County, Kenya which contains about 21% CaO. The plot size was 4 m *4 m.

Soil Sampling: Prior to treatment application surface (0-15) cm depth soil samples were randomly taken using a soil auger from several points at the experimental sites and thoroughly mixed together to make a composite sample. Six weeks after planting and during harvesting composite samples were again taken from each plot at the depth of 0-15 cm to monitor changes in soil available P and pH mainly.

Field procedures: The plots were demarcated and inputs from treatment combinations evenly broadcast and thoroughly mixed with soil prior to planting during the long rains (LR) in the year 2009. The seed rate was 125 kg/ha⁻¹. Herbicide known as Puma Complete was sprayed a month after planting i.e. 4 leaf stage at the rate of 0.75 litres/ha⁻¹. Fungicide (Nativo 300 SC 0.75 litres/ha⁻¹) was also applied at 4 weeks after planting and urea foliar feed was sprayed just before booting stage. Harvesting of wheat was done at physiological maturity.

Laboratory analysis: All the soil samples were air-dried and sieved through 2 mm mesh. Soil samples were analysed for soil pH (Soil H₂O; 1:2:3), texture (hydrometer method), total carbon (C) %, total N (%) and Olsen available P. Samples taken after treatment application were also analysed for pH, available P, N and P uptake according to the procedures outlined in (Okalebo *et al.*, 2002).

Statistical analysis: The generated data on wheat grain yield was subjected to analysis of variance (ANOVA) with standard error SE using General statistics. Means were separated using least significance difference (LSD) whenever treatment difference were significant ($p < 0.05$).

RESULTS

Table 1 shows a summary of soil parameters of the surface soils (0-15 cm) of the experimental sites determined in the laboratory before treatment application. The soils pH in the study areas was 4.92 and 5.32 for Chepkoilel and Kipsangui sites respectively. The soils from Chepkoilel had organic carbon of 1.69% while those from Kipsangui had organic carbon of 2.66%. The soil available P was 9.88 mg kg⁻¹ for Chepkoilel site and 10.1 mg kg⁻¹ for Kipsangui site. For the soil particle size analysis, the soils from both sites were classified as sandy loam.

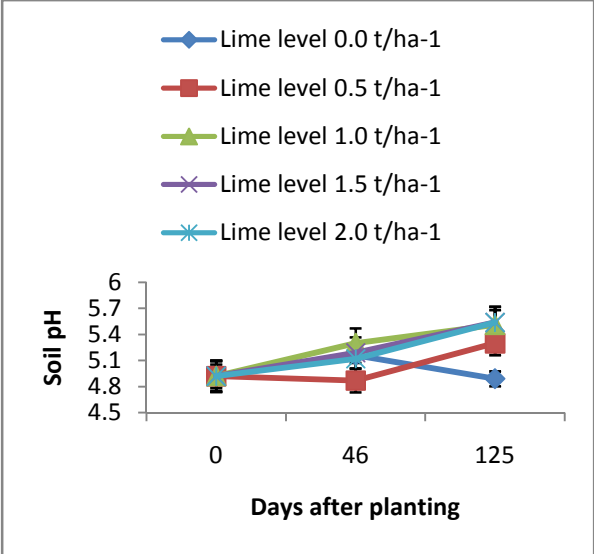
Table 1. Soil physical and chemical characteristics of surface (0-15 cm) soils taken before planting (2009 LR) at two study sites in Uasin Gishu district, Kenya

Soil Property	Chepkoilel site	Kipsangui site
%Sand	60	60
%Silt	16	18
%Clay	24	22
Textural class	Sandy loam	Sandy loam
pH (1:2.5 soil: water)	4.92	5.32
%N	0.17	0.28
%C	1.69	2.66
C: N	10.1	10.1
Olsen P (mg kg ⁻¹)	9.88	10.37

Effects of lime additions on soil pH during wheat growth

The effect of application of lime on the pH values of the soils taken at different time intervals of 46 days after planting and at harvesting for the Chepkoilel and Kipsangui sites are given in Figure 1 and 2. There was an increase in soil pH at both site and sampling dates with lime additions of 1.0, 1.5 t/ha⁻¹ and 2.0 t/ha⁻¹ in both wheat varieties. However, the soil pH in the control increased at 46 days after planting then reduced at harvesting for Njoro BW 2 wheat variety.

Chepkoilel site-Njoro BW 2 wheat variety



Chepkoilel site-KS Mwamba wheat variety

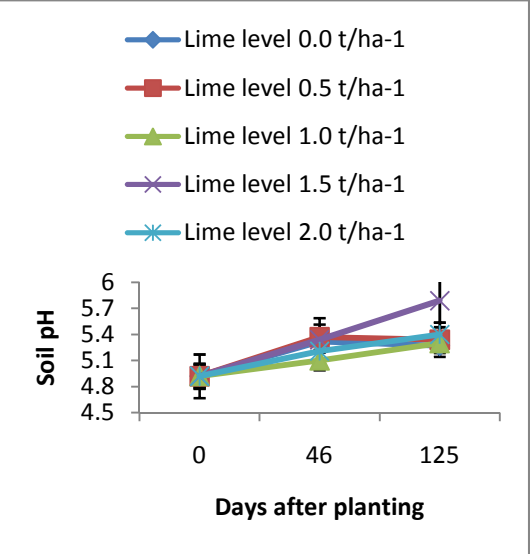
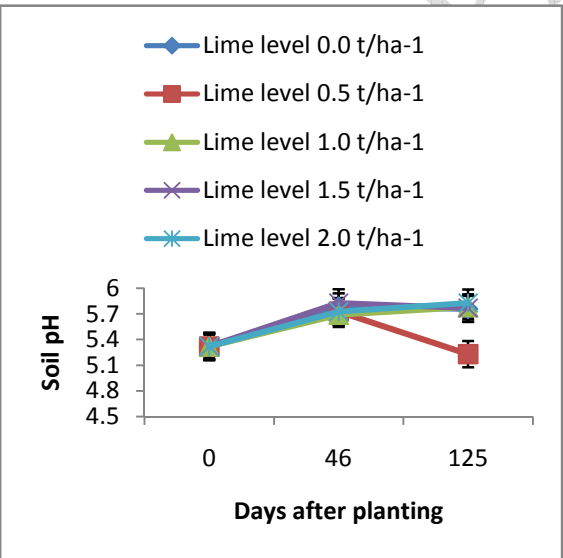


Figure 1: Soil pH changes during the 2009 LR season for Chepkoilel site as affected by treatment application

Kipsangui site-Njoro BW 2



Kipsangui site-KS Mwamba

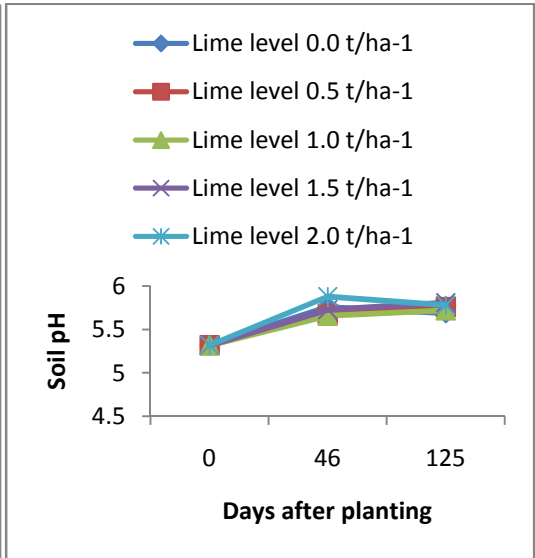


Figure 2: Soil pH changes during the 2009 LR season for Kipsangui site as affected by treatment application

Effect of lime on soil available P taken at wheat harvest

The results of available P taken at harvesting for Chepkoilel and Kipsangui sites as affected by lime and blanket P and N additions for the two wheat varieties are shown in the Figure 3. There was a significant difference ($p < 0.05$) of soil available P from treatments above the control with increase in the lime rate applied in both varieties and sites. The soil available P at Kipsangui site was higher than that at Chepkoilel site in both wheat varieties with the increase of lime levels. The soil available ($P \text{ mg/kg}^{-1}$) at both sites was lower in the control treatment when compared to all levels of lime additions. The soil available P was highest with lime addition of 2 t/ha in both varieties and sites.

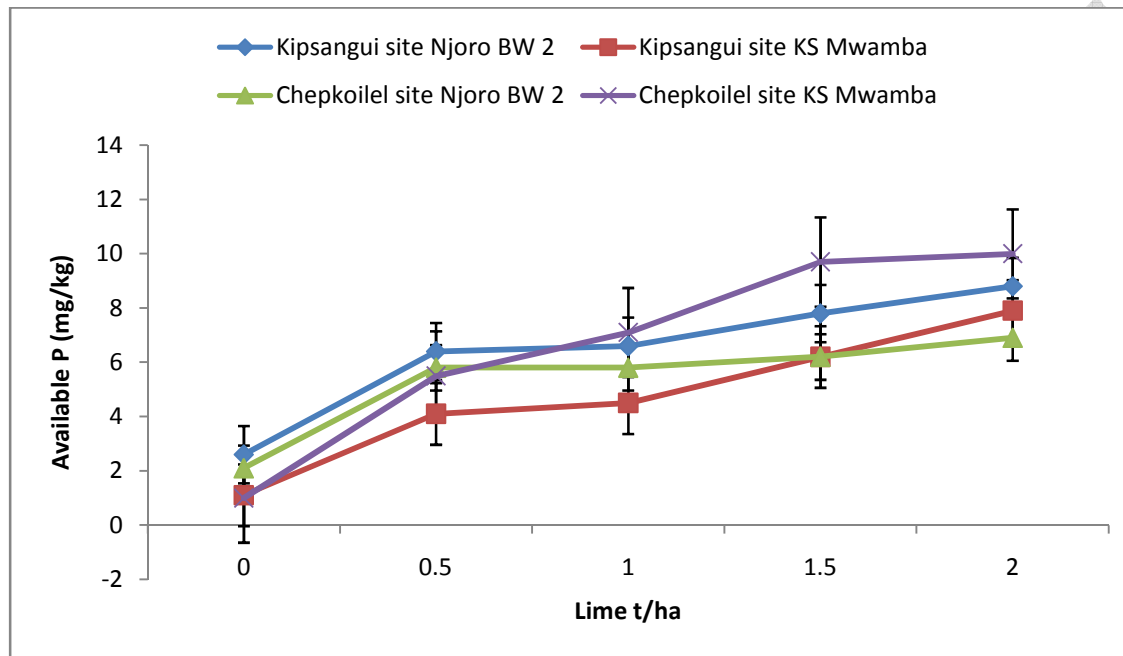


Figure 3. Changes in soil available P (mg kg^{-1}) at harvesting due to lime and P application during the 2009 LR for Chepkoilel and Kipsangui sites 125 days after application

Effects of soil amendments on wheat yield

Yields obtained from the test crop as a result of application of soil amendment materials; P, N and lime during the year 2009 LR are given in Figure 4 for Chepkoilel and Kipsangui sites. Amendment of soil acidity with lime plus P and N addition, increased grain yield significantly ($p < 0.05$) in Chepkoilel and Kipsangui. The lowest grain yield in Njoro BW 2 wheat variety of 1.18 t/ha^{-1} in Chepkoilel site and 1.27 t/ha^{-1} in Kipsangui site were found on control where there was only P and N additions without lime. The lowest grain yields in KS Mwamba variety of 0.78 t/ha^{-1} at Chepkoilel and 0.84 t/ha^{-1} at Kipsangui sites were found on the control treatment.

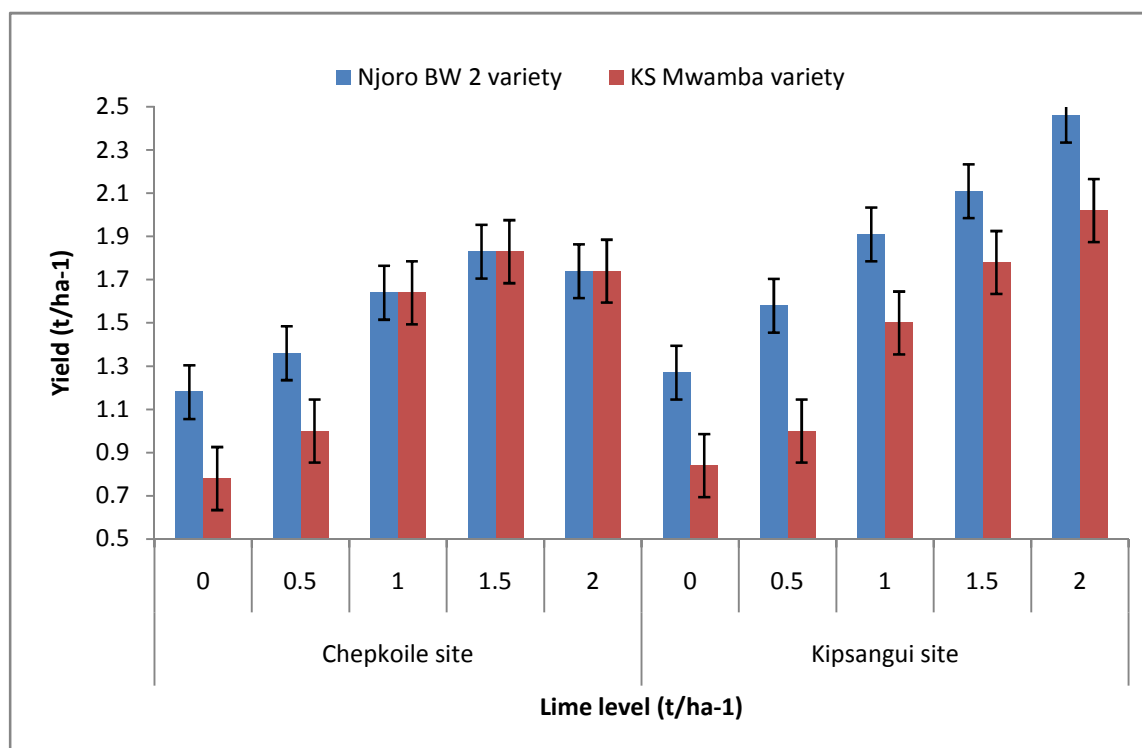


Figure 4. Wheat grain yields (t/ha^{-1}) per site as affected by treatment application for both sites during the long rains 2009.

Correlation between wheat yields and soil available P at wheat harvest

Correlation analysis was conducted between wheat yields and soil available P at harvesting and the results obtained are given in Figure 5 and 6. There was highly a positive and significant correlation between soil available P and grain yields i.e. $r = 0.97$ and $r = 0.94$ for KS Mwamba wheat variety at Chepkoilel and Kipsangui sites respectively. The correlation between soil available P and grain yields was also positive i.e. $r = 0.66$ and $r = 0.97$ for Njoro BW 2 wheat variety at Chepkoilel and Kipsangui sites respectively.

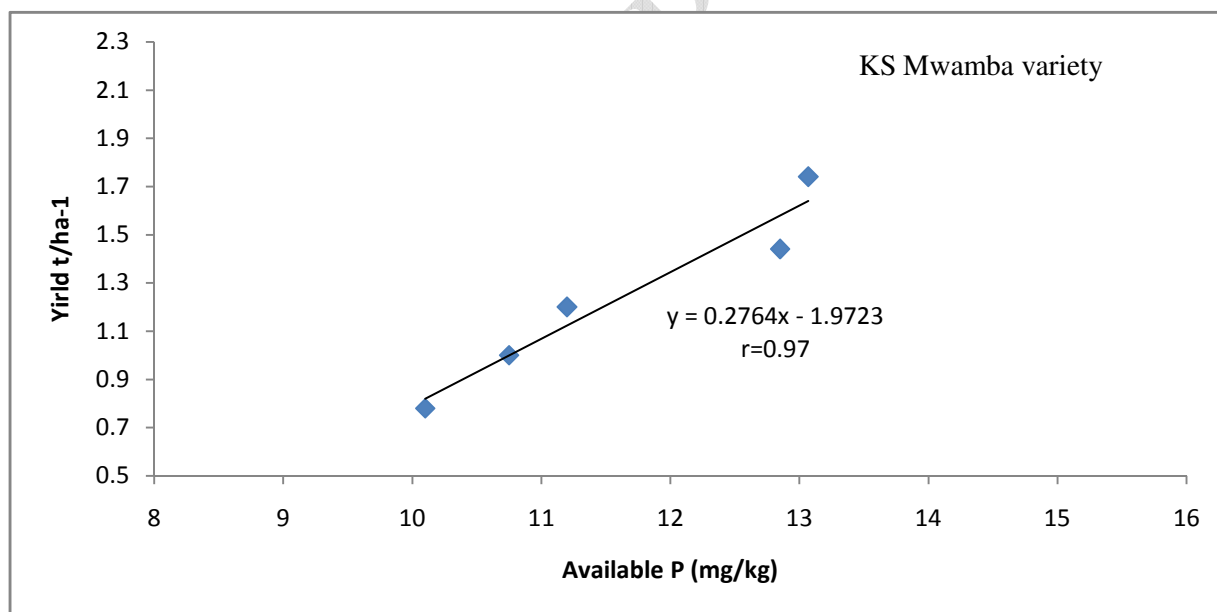
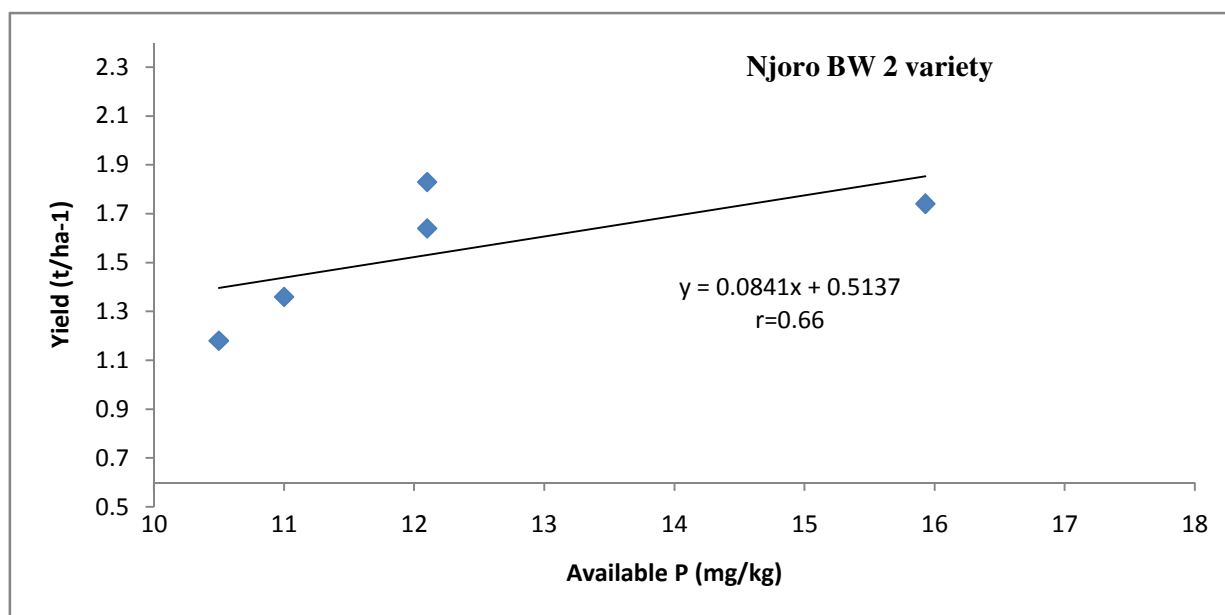
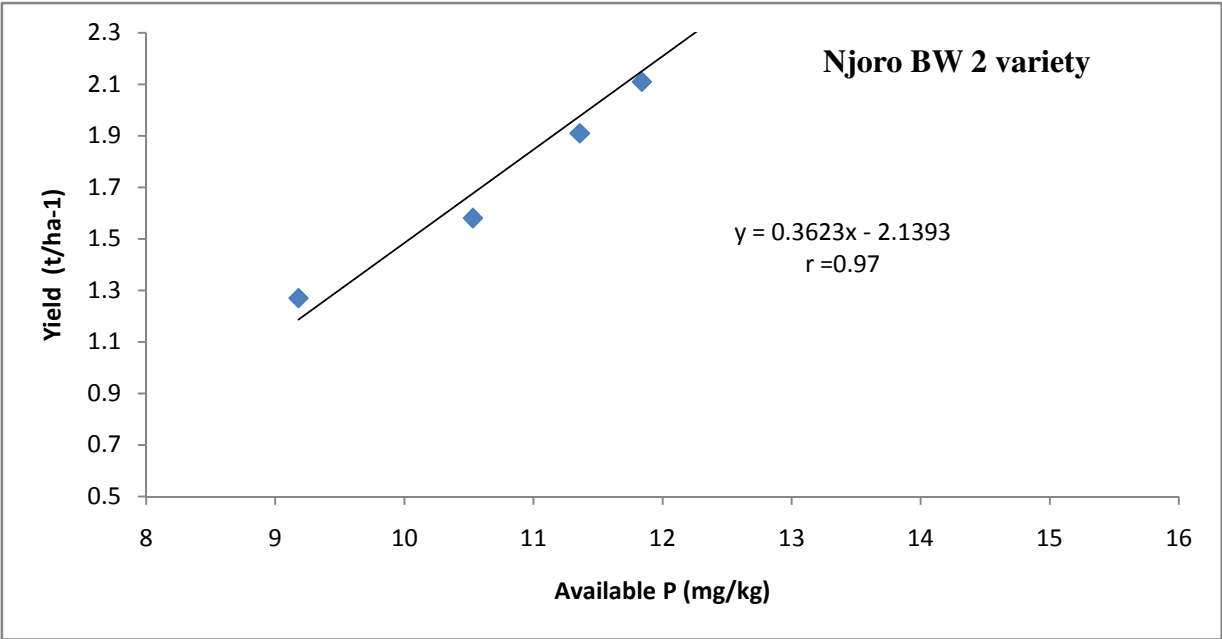
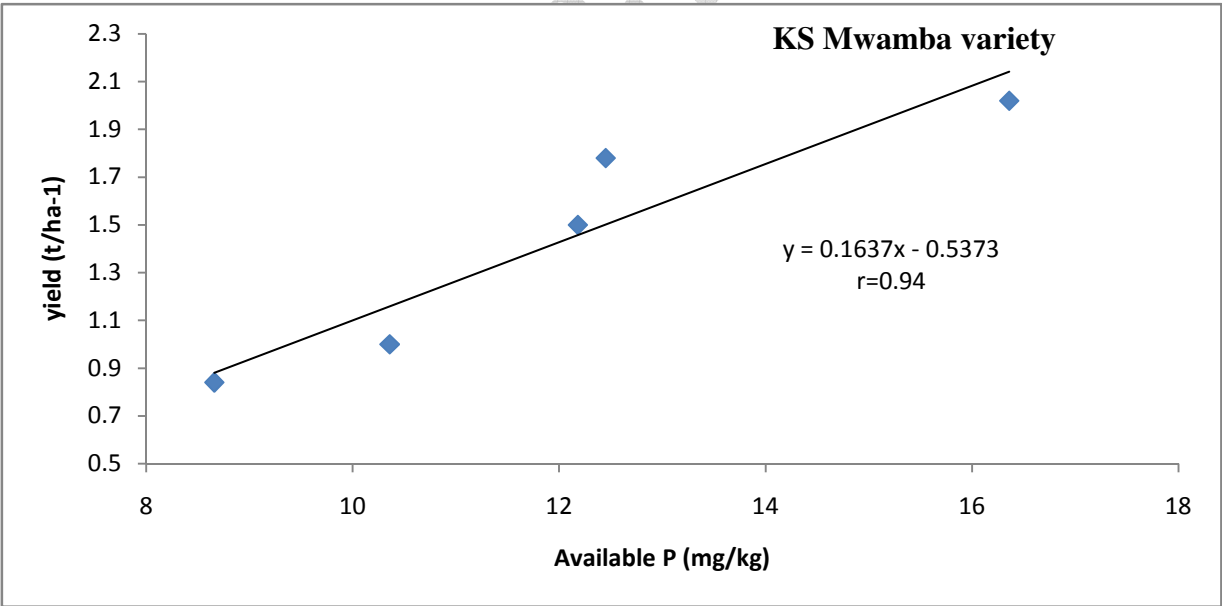


Figure 5. Relationship between soil available P (mg kg⁻¹) and wheat grain yields (t/ha-1) as observed at harvesting during 2009 LR for Chepkoilel site for Njoro BW 2 and KS Mwamba.

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Figure 6. Relationships between soil available P(mg kg⁻¹) and wheat grain yields (t/ha-1) as observed at harvesting during 2009 LR for Kipsangui site for Njoro BW 2 and KS Mwamba.

Uptake of P and N in wheat

Figure 7 and 8 show the effect of lime on the wheat grain N and P uptake. Lime had a significant ($p<0.05$) effect on grain N and P uptake. Soil amendment (lime) increased N and P uptake in both wheat grain at both sites.

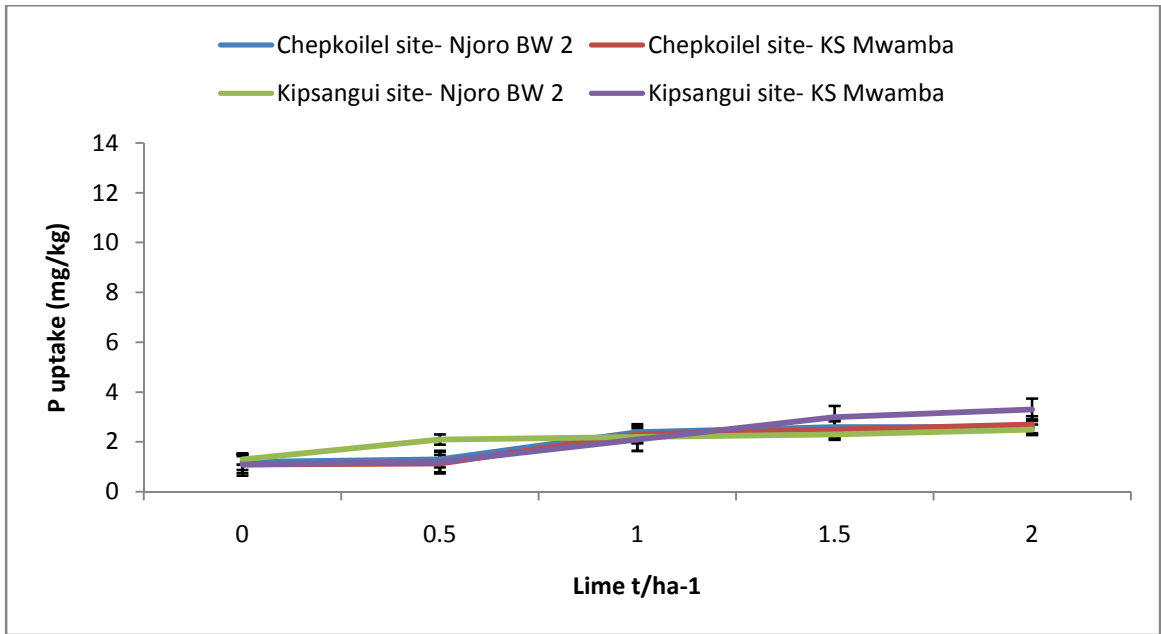


Figure 7 Nutrient P uptake (kg P/ha^{-1}) for wheat straw as affected by treatment application for Chepkoilel and Kipsangui sites

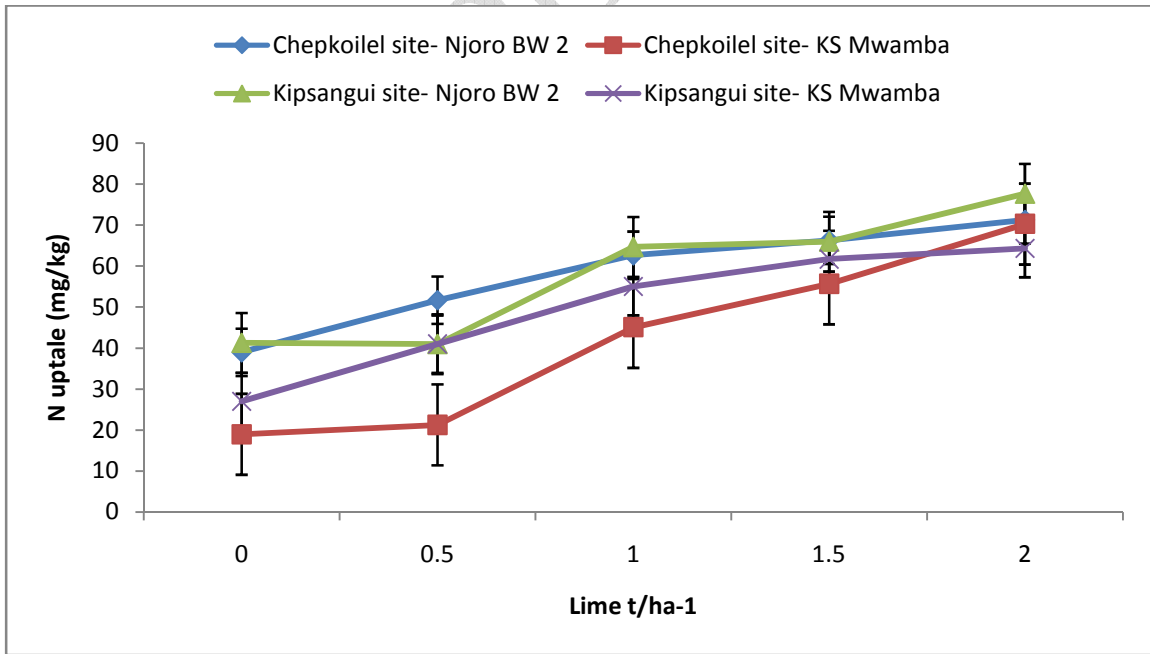


Figure 8. Nutrient N uptake (kg P/ha^{-1}) for wheat grain as affected by treatment application for the Chepkoilel and Kipsangui sites

Economic Analysis

Table 2 and 3 show economic analysis data of benefits, costs and marginal rate of return of treatments using partial budget techniques. The GFBs, NFBs, and TVC to investment were different among the sites. Treatments that produced lower NFBs were not worth for investment. They are known as dominated and were marked "D".

Most of the treatments did not realize economically viable returns. However, at Kipsangui site, for Njoro BW 2 wheat variety with treatment combination of 40 P₂O₅ + 46 N + 2.0 tons KL/ha⁻¹ and NFBs of Ksh 34,010 was the only viable treatment option (Table 3). At Chepkoilel site there was no viable treatment. Based on economic returns, the best treatment in Kipsangui site was Njoro BW 2 variety with 2 t/ha⁻¹ Koru lime.

Table 2: Economic analysis of wheat yields of the soil amendment materials incorporated into the soil during 2009 LR for Kipsangui site

Treatments	GFP(Ksh)	TVC (Ksh)	NFB (Ksh)	MRR(%)
Njoro BW 2 wheat variety				
40 P ₂ O ₅ + 46 N + 0.0 tons KL/ha	34,290	5,786	27,926	
40 P ₂ O ₅ + 46 N + 0.5 tons KL/ha	42,660	15,292	25,838	D
40 P ₂ O ₅ + 46 N + 1.0 tons KL/ha	51,570	20,183	29,369	9
40 P ₂ O ₅ + 46 N + 1.5 tons KL/ha	56,970	24,482	30,040	14
40 P₂O₅ + 46 N + 2.0 tons KL/ha	66,420	29,494	34,010	72
KS Mwamba wheat variety				
40 P ₂ O ₅ + 46 N + 0.0 tons KL/ha	22,680	3,827	18,471	
40 P ₂ O ₅ + 46 N + 0.5 tons KL/ha	27,000	12,650	13,085	D
40 P ₂ O ₅ + 46 N + 1.0 tons KL/ha	40,500	18,315	20,353	12
40 P ₂ O ₅ + 46 N + 1.5 tons KL/ha	48,060	22,978	22,784	47
40 P ₂ O ₅ + 46 N + 2.0 tons KL/ha	54,540	27,459	24,353	31

Table 3: Economic analysis of wheat yields of the soil amendment materials incorporated into the soil during 2009 LR for Chepkoilel site

Treatments	GFB(Ksh)	TVC (Ksh)	NFB (Ksh)	MRR(%)
Njoro BW 2 wheat variety				
40 P ₂ O ₅ + 46 N + 0.0 tons KL/ha	31,860	5,376	25,947	
40 P ₂ O ₅ + 46 N + 0.5 tons KL/ha	36,720	14,290	21,001	D
40 P ₂ O ₅ + 46 N + 1.0 tons KL/ha	44,280	18,953	23,432	D
40 P ₂ O ₅ + 46 N + 1.5 tons KL/ha	49,410	23,206	23,883	D
40 P ₂ O ₅ + 46 N + 2.0 tons KL/ha	46,980	26,184	18,178	D
KS Mwamba wheat variety				
40 P ₂ O ₅ + 46 N + 0.0 tons KL/ha	22,680	3,827	18,470	
40 P ₂ O ₅ + 46 N + 0.5 tons KL/ha	27,000	12,650	13,085	D
40 P ₂ O ₅ + 46 N + 1.0 tons KL/ha	32,400	16,949	13,756	D
40 P ₂ O ₅ + 46 N + 1.5 tons KL/ha	38,880	21,430	15,308	D
40 P ₂ O ₅ + 46 N + 2.0 tons KL/ha	46,980	26,184	18,178	D

GFB=Gross field benefits, TCV = Total variable cost, NFB = Net financial benefits, MRR = Marginal rate of return, KL = Koru Lime as CaO, D = dominated treatment (i.e. with less than or equal to treatment with lower TVC that were eliminated from further consideration since no farmer choose a treatment(s) with higher TVC and receive lower NFB), bold and underlined indicate economically viable treatment.

DISCUSSION

The soil for Chepkoilel was strongly acid since pH was 4.92, while at Kipsangui site the soil was moderately acidic with a pH of 5.32 according to Kanyanjua et al. (2002). The soil P and N levels were too low to sustain high crop production (Okalebo *et al.*, 2002) indicating that the soils would respond to P, N and lime additions. Lime increased soil pH (Figure 1 and 2) and P availability (Figure 3) and this confirms the works of Anetor and Ezekiel (2007) who indicated that lime increased pH and available P in Nigeria. The Ca^{2+} and Mg^{2+} in lime displaced Al^{3+} , Fe^{2+} and H^{+} ions from the soil sorption sites (not measured) as described by (The *at.*, 2006). Application of lime phosphorus and nitrogen increased grain yield above the control because of improved soil conditions such as increased soil pH, nutrient availability and soil organic matter. This is in agreement with Okalebo et al. (2009) who stated that combined application of lime with nitrogen and phosphorus significantly increased grain yield in Kenya. The positive correlation was due to the addition of nutrients (N and P), the crop was able to take up nutrients which are reflected in the yields. According to Ayalew (2011) findings better grain yield was obtained when lime was applied in combination with fertilizer. Phosphorus and nitrogen uptake by the two wheat varieties was significantly influenced by lime at all levels. Increase in the uptake of phosphorus and nitrogen due to liming was also observed in wheat by (Sharma *et al.*, 2002). In this study the majority of the treatments did not realize economically viable returns to investment due to high cost of inorganic inputs, low wheat prices offered and poor distribution of rainfall in the year 2009.

CONCLUSIONS

Acidity in the soils is a serious health problem. Integration of lime and phosphorus improved soil conditions resulting in increase in soil pH, available P, yield and nutrient uptake (N and P). The combination between Njoro BW 2 variety and soil amendment at the rate of 2 t/ha⁻¹ lime (plus P and N) gave the highest grain yield and thus viable economic returns. High production costs, particularly of inorganic inputs (P fertilizer, foliar feed and lime) and relatively low prices of wheat in year 2009, made the majority of the treatments not realize economically viable returns for adaptation by SHF. Further long-term studies in these soils to investigate the effects of lime and fertilizer on wheat yield, as a basis for fertilizer formulations and recommendation is necessary.

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