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Wheat Spikelet Length Response to Phosphate Fertilizers on Acid Soils in Uasin Gishu County, Kenya

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Abstract: ***The study aimed at investigating response of wheat spikelet length, grain yield, grains per spikelet, and soil chemical properties as influenced by liming at 2tha^{-1} (main plots), P sources NPK (23:23:0), DAP (18:46:0), and SSP (0:20:0) (SSP)- (sub-plots) and, P rates (sub sub-plots) P0; 0 kg P ha^{-1}, P1; 8.8 kg Pha^{-1}, P2; 17.6 kg Pha^{-1} and P3; 26.4 kg Pha^{-1}. A split-split plot arrangement laid out in a RCBD experiment was set up in two county sites; Chepkoilel and Kipsangui in 4 m^2 plots, replicated 3 times. Data collected on spikelet length, grain per spikelet and grain yields were subjected to ANOVA using SAS 9.1 for Windows 2012 statistical package. Separation of means was done at 95% confidence level using Tukeys. Lime application significantly increased ($p \leq 0.05$) the spikelet length and grains/spikelet in both Chepkoilel and Kipsangui. Phosphorus rich fertilizer NPK application resulted in a significant ($p \leq 0.001$) increase in spikelet length and grains/spikelet in Chepkoilel and Kipsangui. NPK at 26.4 kg P/ha yielded a significantly high grains/spikelet (37.0k and 36.17g grains/spikelet) in Kipsangui and Chepkoilel respectively. The study recommends NPK (23:23:0) fertilizers at a rate of 26.4 kg P ha^{-1} for Chepkoilel and Kipsangui plus lime at 2tha^{-1} as most effective in improving spikelet length, grain per spikelet and grain yield.***

Keywords: soil acidity, Spikelet length, Lime, wheat, Phosphorus

1. Introduction

Wheat (*Triticum aestivum* L.) yield is affected by many factors: nutrient management system, genetic, environment and their interaction (Hatfield and Walthall, 2015; Jat *et al.*, 2014). The value of yield may vary depending on yield components such as stem height, leaf area, spikelet length, number of spikeletlets per spikelet and number of kernels per spikelet were also found associated with the vegetative growth period (Muhammad *et al.*, 2014). According to Knezevic *et al.* (2007) and Madic *et al.* 2009), the number of kernels per spikelet associated by the number of spikeletlets per spikelet, number of florets per spikeletlet as well efficiency of pollination and seed developing in florets are in direct connection with productivity in wheat and barley. However, these can be modified under different fertilizer application use at varied levels.

Phosphorus and nitrogen nutrition influences the plant growth, development, seed size and yield among other qualities of wheat (Ullah *et al.*, 2018; Muhammad *et al.*, 2014). Other researchers (Anwar *et al.*, 2015) pointed out that phosphorus application to wheat crop increases plant height and grain yield among other components. However, information on the effect of phosphorus fertilizer application and rate in combination with lime on physiological attributes is meager. Thus, this study aimed to investigate the impact of different phosphorus fertilizers sources and application rates in combination with lime on wheat yield and its quality. The main attributes investigated in this research were variability of wheat grain yield, spikelet length and number of grains per spikelet, under different phosphorus fertilizers sources, application rates and lime application.

2. Methodology

2.1 Study sites description

Experimental was set up in two sites; the University of Eldoret (0^0 31’ 0” N, 35^0 17’ 0” E) and Kipsangui (0.73^0 N, 35^0 04’ 00” E), on a smallholder farm. The soils are acidic, attributed to continuous use of acidifying fertilizers (Lwayo *et al.*, 2001). Rhodic ferralsols are dominant in both sites (Jaetzold *et al.*, 2011).

2.2 Experimental treatments and design

Lime was applied at a blanket rate of 2 t ha^{-1}(Kisinyo *et al.*, 2013) excluding the control. Nitrogen (CAN) was applied at 46 kg N ha^{-1}(FURP, 1994). Three P sources mainly DAP, NPK (23:23:0) and SSP was applied each at 8.8, 17.6 and 26.4 kg P ha^{-1}.The treatments were laid out in Randomized Complete Block Design in a2* 3* 4 split-split plot arrangement, with lime or without lime in main plots, P sources in the sub-plots and P rates in sub-sub plots and replicated three times.

2.3 Agronomic practices

After ploughing and harrowing, 16 m^2 (4 x 4) plots were demarcated at 0.5 m apart. Lime was broadcasted and thoroughly mixed with the soil. Using pointed sticks, the rows measuring 2.5 – 3 cm deep were made, then fertilizers were incorporated with the soil and mixed thoroughly.

Certified wheat seed variety Njoro BW2 was manually sown with a row spacing of 20 cm by drill (Acland, 1971). Hand weeding as well as an herbicide, puma komplete was used to control weeds while pesticides, metasystocks and fungicides; Folium was used to control pests and diseases respectively.

2.4 Soil sampling and laboratory analysis

Soil samples per site were taken from the top 0-20 cm depth randomly from each experimental site to obtain a composite sample. Soil samples were air-dried, ground and passed through a 2-mm sieve for physical and chemical soil properties. Subsequent soil samplings were done at two other crop growth stages, vegetative stage and at harvesting stage to evaluate the effect of various treatments on soil properties as affected by the wheat crop and treatments. Particle size distribution was determined by hydrometer method [6] after dispersing soil with sodium hexametaphosphate and textural classes determined using the USDA textural triangle [31]. Soil pH in water was measured potentiometrically using a soil: water ratio of 1:2.5 weights to volume basis [25]. Available phosphorus was extracted using Olsen extraction method [18] and determined by spectroscopy at 884 nm following colour development by the Molybdenum blue method [20]. Organic carbon was determined by Walkey-Black wet oxidation method [23] and total nitrogen and phosphorus were determined by micro-Kjeldahl digestion method [3].

2.5 Crop yields

Crop yields were collected according to (Zečević *et al.*, 2007) at physiological maturity of wheat.

The yield was calculated using the relationship

Wheat straw yields per hectare were determined and chemical analysis was done to determine N and P contents, and their use efficiencies according (Okalebo *et al*, 2002).

2.6 Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS 9.1 for windows (2012). Separation of means was done at 95% confidence level. Correlation analysis was done for the grain yields versus the soil total N, organic carbon, pH and available phosphorus.

3. Results

3.1 Effect of fertilizer on spikelet length

The highest mean spikelet length was recorded under lime application and NPK fertilizer in Spikelet length was highest under liming at 2t/ha and NPK fertilizer at 26.4kg P/ha with a mean of 6.104cm length (Table 1). The least level was recorded at control (o kg P/ha) with a mean of 4.033cm.

Table 1: Spikelength at Chepkoilel
Means with same letter had no significant difference.

Lime						Mean	Mean
Rate	P-Rate	Control	DAP	NPK	SSP	P-Rate	Lime
0 t/ha	0 Kg/ha	4.033a				4.033	
	8.8 Kg/ha		5.308cde	5.317cde	5.236cde	5.287	
	17.6 Kg/ha		4.953c	5.540def	5.493def	5.329	
	26.4 Kg/ha		5.377cde	5.707efg	5.512def	5.532	
	Mean Fertilizer	4.033	5.213	5.521	5.414		5.045
2 t/ha	0 Kg/ha	4.108b				4.108	
	8.8 Kg/ha		5.250cde	5.383cde	5.043cde	5.225	
	17.6 Kg/ha		5.334cdef	6.104g	5.160c	5.533	
	26.4 Kg/ha		5.297cd	5.650cdef	5.881fg	5.609	
	Mean Fertilizer	4.108	5.294	5.712	5.361		5.119
	L	F	P	LxF	LxP	FxP	LxFxP
S.E.	0.0286	0.0405	0.0405	0.0572	0.0572	0.0405	0.0572
S.E.D	0.0405	0.0572	0.0572	0.0809	0.0809	0.0572	0.0809
LSD	0.0798	0.1129	0.1129	0.1597	0.1597	0.1129	0.1597
% CV	5.8						

*-L-Lime; F-Fertilizer; P-P Rate: Means with same letter within each row or column are not significantly different (p≤0.05); *P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001; ns- not significant*

Lime application at 2t/ha significantly (P≤0.05) increased spikelet length from 5.045cm to 5.119cm (Table 1).

A similar result was recorded at Kipsangui, with lime application having a higher spikelet length mean of 4.957cm. Among the fertilizers, NPK at rate of 26.4 kg P/ha had the highest spikelet length of 5.381cm (Table 2). The least mean spikelet length was realized under absolute control (0 t/ha lime and no fertilizer) (Table 2).

Table 2: Spikelet length at Kipsangui

Lime						Mean	Mean
Rate	P-Rate	Control	DAP	NPK	SSP	P-Rate	Lime
	0 Kg/ha	4.313a				4.313	
	8.8 Kg/ha		4.936defg	4.638bcd	4.731bcdef	4.768	
	17.6 Kg/ha		4.97efg	4.573bc	4.927defg	4.823	
	26.4 Kg/ha		4.917defg	4.444ab	4.702bcde	4.688	
0 t/ha	Mean Fertilizer	4.313	4.941	4.552	4.787		4.648
2 t/ha	0 Kg/ha	4.917efg				4.917	
	8.8 Kg/ha		4.737bcdef	5.084*gh*	4.771*cdefg*	4.864	
	17.6 Kg/ha		4.718bcdef	5.358*hi*	4.667*bcde*	4.914	
	26.4 Kg/ha		4.977*efg*	5.381*i*	5.034*fg*	5.131	
	Mean Fertilizer	4.917	4.811	5.274	4.824		4.957
	L	*F*	*P*	*LxF*	*LxP*	*FxP*	*LxFxP*
S.E.	0.0285	0.0403	0.040	0.057	0.057	0.0698	0.0987
S.E.D	0.0403	0.057	0.057	0.0806	0.0806	0.0806	0.114
LSD	0.0795	0.1124	0.1124	0.1589	0.1589	0.1589	0.2248
% CV	6.2						

Means with same letter had no significant difference.

*-L-Lime; F-Fertilizer; P-P Rate: Means with same letter within each row or column are not significantly different ($p \leq 0.05$); *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; ns- not significant*

Effect of fertilizer on grain per spikelet

In Chepkoilel, the lime application increased number of grains per spikelet at 30.225grains as compared to 28.823 at 0 t/ha lime application (Table 3). The NPK fertilizer applied at 26.4 kg P/ha realized an increase in number of grains per spikelet. This yielded a significantly high mean of grains per spikelet at 30.225 grains (Table 3). Amongst the fertilizers, NPK had the highest mean grains per spikelet at liming of 2 t/ha. This had a mean of 33.527 grains (Table 3).

Table 3: Grain per spikelet at Chepkoilel

Lime Rate	P-Rate	Control	DAP	NPK	SSP	Mean P-Rate	Mean Lime
0 t/ha	0 Kg/ha	22.38a				22.380	
	8.8 Kg/ha		26.40bc	30.14cde	31.25def	29.263	
	17.6 Kg/ha		29.17cd	33.65defg	32.71defg	31.843	
	26.4 Kg/ha		29.24cd	34.70efg	31.48def	31.807	
	Mean Fertilizer	22.380	28.270	32.830	31.813		28.823
2 t/ha	0 Kg/ha	25.07b				25.070	
	8.8 Kg/ha		30.47cde	33.06defg	30.60cde	31.377	
	17.6 Kg/ha		30.24cde	31.35def	30.43cde	30.673	
	26.4 Kg/ha		29.35cd	36.17g	35.82fg	33.780	
	Mean Fertilizer	25.070	30.020	33.527	32.283		30.225
	L	*F*	*P*	*L x F*	*L x P*	*F x P*	*L x F x P*
S.E.	0.263	0.373	0.373	0.527	0.527	0.645	0.913
S.E.D	0.373	0.527	0.527	0.745	0.745	0.745	1.054
LSD	0.735	1.039	1.039	1.47	1.47	1.47	2.079
% CV	9.3						

Means with same letter had no significant difference.

*-L-Lime; F-Fertilizer; P-P Rate: Means with same letter within each row or column are not significantly different ($p \leq 0.05$); *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; ns- not significant*

Table 4: Grain per spikelet at Kipsangui

Lime Rate	P-Rate	Control	DAP	NPK	SSP	Mean P-Rate	Mean Lime
0 t/ha	0 Kg/ha	26.23a				26.230	
	8.8 Kg/ha		32.23ij	30.31cdefghi	28.97bcd	30.503	
	17.6 Kg/ha		31.86ghi	28.52bc	29.87bcdefgh	30.083	
	26.4 Kg/ha		31.53fghi	27.75ab	29.43bcdef	29.570	
	Mean Fertilizer	26.230	31.873	28.860	29.423		29.097
2 t/ha	0 Kg/ha	31.04efgh				31.040	
	8.8 Kg/ha		29.83bcdefgh	32.41ij	32.00hij	31.413	
	17.6 Kg/ha		29.17bcde	37.00k	29.62bcdefg	31.930	
	26.4 Kg/ha		31.02defghi	34.21j	32.07hij	32.433	
	Mean Fertilizer	31.040	30.007	34.540	31.230		31.704
	L	*F*	*P*	*L x F*	*L x P*	*F x PL x F x P*	
S.E.	0.208	0.294	0.294	0.415	0.415	0.509	0.719
S.E.D	0.294	0.415	0.415	0.587	0.587	0.587	0.83
LSD	0.579	0.819	0.819	1.158	1.158	1.158	1.638
% CV	7.1						

*Means with same letter had no significant difference. -L-Lime; F-Fertilizer; P-P Rate: Means with same letter within each row or column are not significantly different (p≤0.05); *P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001; ns- not significant*

Control treatment recorded the least amount of grains per spikelet in Kipsangui (Table 4). Lime application resulted into 31.704 grains per spikelet (Table 4). This was high as compared to 29.027 grains under 0 t/ha lime. Fertilizer NPK recorded the highest grains per spikelet among the tested fertilizers at 34.540 grains per spikelet. The significantly highest grain per spikelet mean (37.0k grains) was recorded from the 17.6 kg P/ha (Table 4).

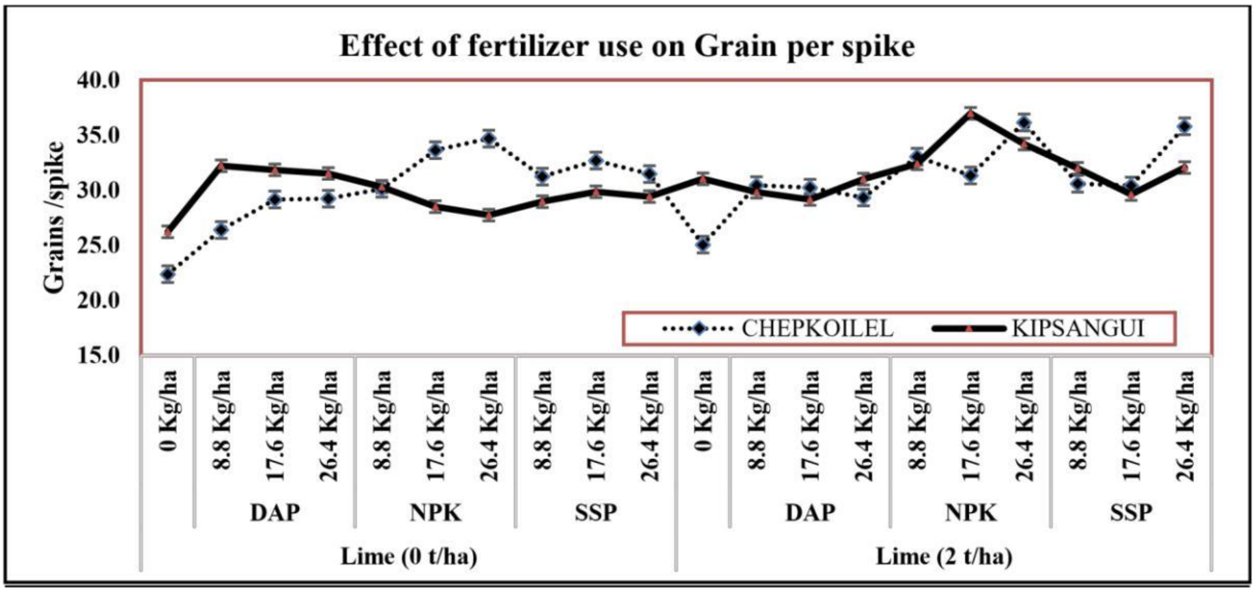

Figure 1: Number of grains per spikelet in Chepkoilel and Kipsangui

DAP had the mean grains per spikelet at a stable rate of above 30 grains per spikelet under 0 t/ha lime application (Fig 1). However, with application of lime at 2 t/ha, number of grains per spikelet were reduced. Fertilizer NPK had the lowest means of grains per spikelet with 0 t/ha lime (Fig 1). This however increased to 37.0 grains per spikelet at 17.6 kg P/ha (Fig 1).

Effect of fertilizer on grain yield

Lime application in Chepkoilel had a significant effect (P≤0.05). This was evident with an increase in yield from 2.919 t/ha (under 0 t/ha lime) to 3.606 t/ha (under 2 t/ha rate of liming). Among the fertilizers, NPK at rate 17.6 kg/ha recorded a high yield of 7.71c t/ha (Table 5). Also, a general increase in grain yield was achieved under NPK. This was highest among the tested fertilizers. In Kipsangui, there was a significant difference (p≤0.05) in wheat grain yield levels at 0 t/ha and 2 t/ha lime application (Table 6). Fertilizer NPK (at rate of 26.4 kg P/ha) recorded 4.64 t/ha wheat grain yield (Table 6). This was however not significantly different ($p \leq 0.05$) to 4.67t/ha (from NPK at rate of 17.6 kg P/ha) (Table 6).

Table 5: Grain yield in Chepkoilel

Lime Rate	P-Rate	Control	DAP	NPK	SSP	Mean P-Rate	Mean Lime
0 t/ha	0 Kg/ha	0.98a				0.980	
	8.8 Kg/ha		2.81ab	3.35ab	3.01ab	3.057	
	17.6 Kg/ha		3.26ab	3.65abc	3.64abc	3.517	
	26.4 Kg/ha		3.72abc	4.61bc	4.04abc	4.123	
	Mean Fertilizer	0.980	3.263	3.870	3.563		2.919
2 t/ha	0 Kg/ha	1.24a				1.240	
	8.8 Kg/ha		3.21ab	3.70abc	3.54ab	3.483	
	17.6 Kg/ha		3.57ab	7.71c	4.10abc	5.127	
	26.4 Kg/ha		4.12abc	5.39bc	4.21abc	4.573	
	Mean Fertilizer	1.240	3.633	5.600	3.950		3.606
	L	*F*	*P*	*L x F*	*L x P*	*F x PL x F x P*	
S.E.	0.232	0.329	0.329	0.465	0.465	0.569	0.805
S.E.D	0.329	0.465	0.465	0.657	0.657	0.657	0.93
LSD	0.648	0.917	0.917	1.296	1.296	1.296	1.833
% CV	14.8						

-Means with same letter had no significant difference.
*-L-Lime; F-Fertilizer; P-P Rate: Means with same letter within each row or column are not significantly different ($p \leq 0.05$); *P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001; ns- not significant*

Table 6: Grain yield in Kipsangui and Chepkoilel

Lime Rate	P-Rate	Control	DAP	NPK	SSP	Mean P-Rate	Mean Lime
0 t/ha	0 Kg/ha	0.830a				0.830	
	8.8 Kg/ha		3.26b	3.74bcd	3.27b	3.423	
	17.6 Kg/ha		3.41bc	3.98cdef	3.82bcde	3.737	
	26.4 Kg/ha		3.55bcd	4.03def	3.82bcde	3.800	
	Mean Fertilizer	0.830	3.407	3.917	3.637		2.948
2 t/ha	0 Kg/ha	1.15a				1.150	
	8.8 Kg/ha		3.89cde	4.38efg	4.39efg	4.220	
	17.6 Kg/ha		4.36efg	4.67g	4.54fg	4.523	
	26.4 Kg/ha		4.66g	4.87g	4.66g	4.730	
	Mean Fertilizer	1.150	4.303	4.640	4.530		3.656
	L	*F*	*P*	*L x F*	*L x P*	*F x P*	*L x F x P*
S.E.	0.035	0.049	0.049	0.069	0.069	0.085	0.12
S.E.D	0.049	0.069	0.069	0.098	0.098	0.098	0.138
LSD	0.096	0.136	0.136	0.193	0.193	0.193	0.273
% CV	10.9						

Means with same letter had no significant difference.

*-L-Lime; F-Fertilizer; P-P Rate: Means with same letter within each row or column are not significantly different ($p \leq 0.05$); *P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001; ns- not significant*

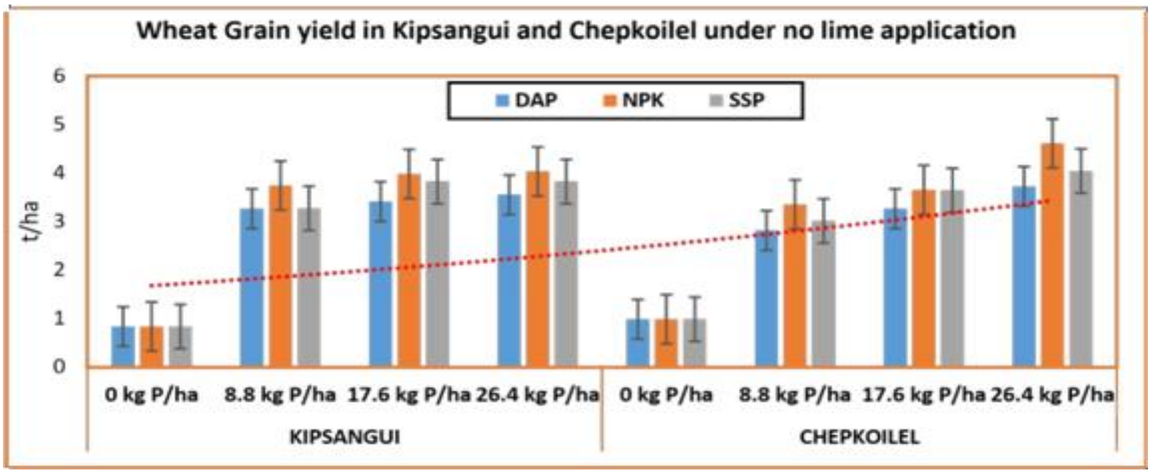

Figure 2: Grain yield in Kipsangui and Chepkoilel without lime application

In Kipsangui, the lowest mean was recorded under 0 t/ha liming rate at 0.83 t/ha (Fig 2). Addition of lime at 2 t/ha increased yield to 1.15 t/ha without adding any fertilizer (Fig 3).

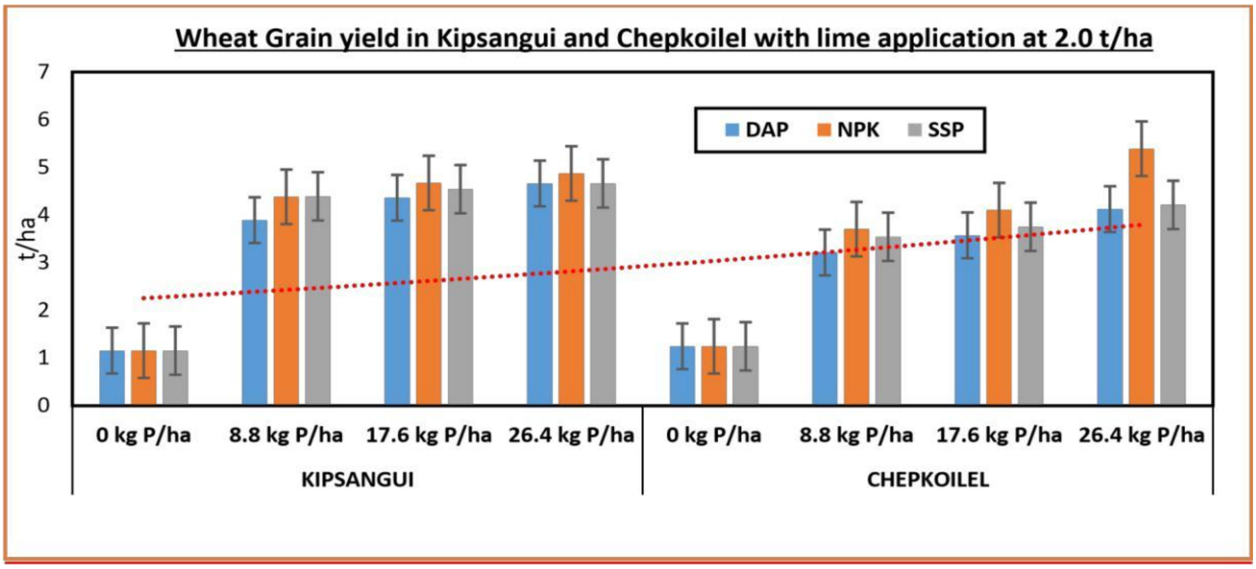

Figure 3: Grain yield in Kipsangui and Chepkoilel with lime application

A similar result was reported in Chepkoilel. Application of lime recorded higher yields (Fig 3) as compared to 0t/ha lime treated plots (Fig 3).

The trend was similar across all the sites, with liming resulting into 50% increase in wheat grain yields (Fig 1 and 2).

In Kipsangui, the lowest mean was recorded under 0 t/ha liming rate at 0.83 t/ha (Fig 1). Addition of lime at 2 t/ha increased yield to 1.15 t/ha without adding any fertilizer (Fig 3).

4. Discussion

Spike length

The results (Table 1 and 2) demonstrated that spike length decreased significantly ($p \leq 0.05$) under different P sources and liming during the floral initiation to anthesis period. The results are in contrast to the reports of Noonari *et al.* (2016); Ali *et al.* (2012) and Khan *et al.* (2010) who denuded that P application results in lengthy spikes. Reduction of the spike length under increased P levels causes a decrease in some of the spike traits. It can therefore cause some changes in the number of spikelets and florets per plant. Main and interactive effect of the phosphorus source and rate of P-fertilizer application, significantly ($p \leq 0.05$) affected spike length. The data obtained is in conformity with findings by Valizadeh *et al.* (2002) who opinioned that improved growth of wheat is influence by the source and rate of phosphorus application. Fertilizer and lime applied at the rate of 2 t/ha and 26.4 kg P ha^{-1} respectively, contributed 1.68 and 0.96 cm increment in spike length than control. The results corroborate with Moges *et al.* (2018) who researched on lime and phosphorus fertilizer levels on wheat and reported increase in spike length and grain yield at 30 kg P ha^{-1} and 4-ton lime ha^{-1}. The increase in spike length was reported in Chepkoilel and Kipsangui sites respectively. These findings highlight P fertilizer application has a significant effect ($p \leq 0.05$) on panicle length of wheat while combined effect optimum amount of P fertilizer and phosphorus source has significant effect ($p \leq 0.05$) on growth of spike length. While researching on maize in an acid soil in Western Kenya, Opala (2017) reported an increase in plant height with lime application at 2-ton ha^{-1} with 30 kg P ha^{-1}. The increase in spike length with lime application in combination with phosphorus levels is attributed to increase in solubilized P and availability of nutrients in the acidic soils.

Results obtained by (Alcoz *et al.*, 1993), in which higher spike length of wheat was achieved by phosphorus rich fertilizer applied 26.4 kg P ha^{-1}. The report is in agreement with the findings of this study, with P application at 26.4 kg P ha^{-1} recording highest mean spike length as compared to 17.6 kg P $ha^{-1.}$ Another researcher (Genene, 2003) pointed out spike length of wheat as directly affected by amount of available nutrients and water. However, excessive application of N fertilizer has toxic effect on wheat growth and results for stunted growth and reduced spike length (Pan *et al.*, 2006).

Grains per spikelet

Number of seeds per spike recorded in wheat under three sources and levels of phosphorus application revealed that there was significant difference in the mean values of seed per spike. Lime application at 2 t/ha had a positive significant effect ($p \leq 0.05$) on grains per spike in both Kipsangui and Chepkoilel, as compared to the control (Table 3 and 4). The highest number of seeds per spike was recorded in 26.4 kg P/ha and lowest was under control (0 kg P/ha). A similar result was reported by the authors (Gouis *et al.*, (2010); Mohammadpour *et al.*, (2016); Noonari *et al.*, (2016) and Anwar *et al.*, (2015); who found that use of higher doses of phosphorus in wheat crop increased the number of grains per spike among other attributes. This is attributed to the increase in phosphorus, a prerequisite for better crop and development. The results corroborate with Endalkachew (2014) who denuded that P deficiency reduces tillering, head and grain numbers. The results are also supported by the findings of a research report by Singh (2001) on N and P application effect on response of late sown weight to row spacing-cum-population densities and levels of nitrogen and irrigation.

Treatments effect on Wheat Grain Yield

The NPK (23:23:0) fertilizer gave higher wheat grain yields, followed by SSP and DAP in Kipsangui (Table 9). In Chepkoilel, P source and P rate in combination with lime application significantly raised wheat grain yields (Table 9). Lime application significantly ($p \le 0.05$) influenced wheat grain yields. Results show that fertilizer application had a significant ($p \le 0.05$) effect on wheat grain yields and rates of P application also had a significant ($p \le 0.05$) influence in wheat grain yields (Table 5 and 6). Application of NPK (23:23:0) fertilizer with lime at 2t ha^{-1}gave the highest mean grain yields. Generally, fertilizer application increased wheat grain yields in Chepkoilel and Kipsangui in all the P sources as compared to control. Increase in P rates resulted to increase in the grain yields with lime application performing better than no lime (Table 5 and 6). Erkeno, (2014) found that P application has significant role in increasing water use efficiency of the wheat crop. The uptake of water by plants results into the uptake of the nutrients there within the solution. This leads to improved soil fertility and in turn wheat grain yield due to possibly released after lime application and hence high P levels in the soil (Genene, 2003). This increase in P content was accompanied with higher wheat grain. Other researchers (Zenebe *et al.,* 2019; Moges *et al.,* 2018)) researched on malt barley and concluded that fertilizers amendments in combination with lime result in increased plant height, grain yield and straw yield. Similar findings were echoed by Noorari *et al.* (2016) and Dereje *et al.* (2019) who reported increase in grain yield with increased levels of P fertilizer and increased levels of lime and P fertilizers respectively.

5. Conclusions and Recommendations

Effective soil P management is important to optimize crop yield potential. Plants require adequate P from the very early stages of growth for optimum crop production. Phosphorus supply to the crop is affected by soil P and by soil and environmental conditions influencing P phyto-availability and root growth. Fertilizer use in wheat production played a major role towards improving wheat production in both Chepkoilel and Kipsangui. When coupled with lime application at rate of 2 t ha^{-1}, fertilizer NPK (at 26.4 kg P/ha) improved spike length and number of grains per spikelet at both sites. The most economical fertilizer was NPK (23:23:0) for Chepkoilel site while DAP was the most economically viable fertilizer to use for wheat production in Kipsangui. Because there was no significant difference between the two fertilizers, a less acidifying fertilizer NPK (23:23:0) at rate of 26.4 kg P/ha could be the most effective fertilizer for wheat production in Chepkoilel and Kipsangui sites.

6. Competing Interests

Authors have declared that there are no existing competing interests.

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