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Sensitivity of Barley (Hordeum Vulgare) to Phosphate Fertilizer Formulations under Acidic Soils in Kenya

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Abstract: *Soil acidity and fertilizer formulations are among the factors for low barley yields in Kenya. Five fertilizer formulations were tested for their efficacy in improving barley yield under acid soils. The objective was to determine the effect of fertilizer formulations on barley growth under acidic soils. One variety of barley was planted in two sites using five formulations for two seasons. Control plot had no fertilizer and randomized complete block design with four replications was used. Data on tillering ability, number of grains/ear, plant height and yield were subjected analysis of variance and means separated by contrast comparison on Genstat version 12.2. Top soil (0-15cm) and sub soil (16-30cm) were sampled to determine pH, percent nitrogen, percent carbon and available phosphorous. The effect of fertilizer composition was significant ($p < 0.001$) and 100% yield loss was observed in control plots at pH between 4.5 – 4.9. Soils with pH range of 5.2 – 6.0 recorded the best yields with respect to the fertilizer formulations. Mavuno formulation gave best yield in all pH range for the two seasons while Minjingu rock phosphate gave least score. Tillering ability, number of grains and height were also affected. Performance of Mavuno could be due to Ca^{2+} which amends soil acidity and trigger barley's response to potassium and sulphur. Therefore, barley is very sensitive to soil acidity and pH below 5.0 can lead to total yield loss. Soil testing is recommended in order to determine soil pH and fertilizer formulation to use.*

Keywords: *Barley, sensitivity, fertilizer formulation, acidic soils.*

1. INTRODUCTION

1.1. Background Information

Soil acidity renders 30 - 40% of the world's arable land unproductive especially for cereal crops including barley (Reynolds *et al*., 2001). In acidic soils, toxicities of aluminium (Al) and manganese (Mn) sets in as phosphorous (P), magnesium (Mg) and potassium (K) become deficient to crops. High concentration of aluminium cation Al^{3+} at low soil pH significantly reduce root and shoot dry matter production and chemical reactions in barley (Huttová *et al*., 2002; Loboda and Wolejko, 2006; Manoharan *et al*., 2007).

Poor soil fertility of acid soils has been related to mineral toxicities and deficiencies of important macro and micro nutrients. However, aluminium toxicity is the single most important factor limiting crop production on 67% of the total acid soil area (Buyukunal and Alkus, 2011; Koenig, 2008; Reynolds *et al*., 2001). Depending on soil pH, nutrient availability varies as well. For instance, as soils become acidic, the concentration of aluminium and iron cation increases in the soil. Similarly, increase in alkalinity cause corresponding increase in potassium, sulphur and molybdenum concentrations in the soil. However, the availability of some nutrients including nitrogen, phosphorous, calcium, manganese, boron, copper and zinc do not require too acidic or too alkaline soils. This imply that any pH change towards acidity or alkalinity would affect their availability to plants (Busman *et al*., 2009; Whiting *et al*., 2011).

Barley is a highly adaptable crop with good heat, drought and salt tolerance. This crop grows at soil pH between 5.0 and 8.3. It thrives in cool, dry conditions (Valenzuela and Smith, 2002). Research indicates that for every one ton of barley produced, 20, 2.7, 5.0, 1.5, 0.3 and 1.1 kilograms of N, P, K, S, Ca and Mg respectively are mined from the soil. Moreover, 3, 14, 11 grams of Cu, Zn and Mn respectively are removed from the soil for every tone of barley produced

(GRDC, 1998). This means that same quantities of nutrients must be supplied when planting barley in order to realize maximum yield potential.

Despite being adaptable to a wider range of soil physical and chemical conditions, barley is very sensitive to soil acidity. This can significantly reduce the yield when combined with other environmental factors including drought and nutrition (EABL-UoE, 2012). In addition, most of the soil requirement by barley are not found in high and medium altitude zones of Kenya where barley is grown both in large and small scale (EABL-UoE, 2012). Instead, the soils are characterized by low pH below 5.0 (acidity) and cation (aluminium and manganese) toxicity especially in medium altitude zones of Kenya (Obura *et al*., 2010; Okalebo *et al*., 2009). This may be responsible for the constantly low barley yields in Kenya, usually below 2.0 t/ha despite the release of high yield potential varieties.

Coupled with uncountable problems of soil acidity and mineral toxicities, nutrition is another important factor responsible for barley low yields in Kenya. This is due to a number of phosphate fertilizer formulations in the market and some of which do not meet the nutritional requirement by the crop. Moreover, the fertilizers with adequate supply of nutrients encounter the problem of nutrient fixation, making them unavailable to plants (EABL-UoE, 2012).

Based on the increasing trends of soil acidity, mineral toxicities and continuous production and supply of a number of phosphate fertilizer formulations especially in Kenya, addressing the combined effects of phosphate fertilizer composition on barley growth and yield and assessing the sensitivity of barley to soil acidity will be of great importance. This will guide barley farmers and scientists alike with the appropriate soil pH conditions and best nutrition required to realize maximum yield potentials.

2. METHODOLOGY

2.1. Study Sites and Characteristics

Two sites, located at high altitude (Mau-Narok –Purko farm) and medium altitude (University of Eldoret – Chepkoilel farm) were used in the study for two seasons. Purko site is located at an altitude of 2,900 m above the sea level and lies between latitudes 0°36’S and longitude 36°0’E and the area receives an average annual rainfall of 1,200-1,400mm. Minimum temperatures between 6-14°C and maximum of 22-26°C have been reported (Wanyera *et al*., 2010). The Chepkoilel site is located at an altitude of 2,140 m above sea level and lies between longitude 35°18’ E and latitude 0° 30’N. The site receives rainfall ranging between 900 to 1,300 mm with an annual average of 1,124 mm. The average annual temperature is 23°C with a minimum of 10°C (Okalebo *et al*., 1999).

2.2. Planting and Experimental Design

The study was initiated in May, 2011 and five granular fertilizers including MEA D.A.P (18:46:0); MAP (11:52:0); Yara Milla (12:11:18 + Mg, S, Mn, Zn and B); MRP (29-30% P_2O_5) and Mavuno (10:26:10 + Ca, Mg, S, B, Zn, Mn, Mo, Cu and K) were used. One barley variety (Quench) was used as the test crop across all the sites. Quench variety was planted in a randomized complete block design (RCBD) with four replications per site for the two seasons. At planting each of the five fertilizers was applied at 175 Kg/ha. For control treatment, no fertilizer was used and only the barley seed was drilled in previously prepared furrows. A plot size of 1.5 m by 7 m was used (10.5 m^2) and each plot was separated by 0.5 m from the other. Soil sampling was done for each site at planting and this was conducted only during the first season. The samples constituted top soil (0-15 cm) and sub-soil (16-30 cm) and these were subjected to chemical analysis to determine the pH, % N, % C and P (mg/Kg) (Okalebo *et al*., 2009) since they play very significant role in barley growth and development.

2.3. Data Collection and Analysis

Data on tillering ability, number of grains per ear, height and yield potential were collected and subjected to analysis of variance on Genstat statistical software version 12.2. The significant mean difference were tested at 95% confidence interval (5% level of significance) and mean separation done using contrast, comparison for precision and also to prevent biasness towards either Type I or II error. The effects of fertilizer composition on root growth and development was also assessed at physiological maturity by uprooting few plants per plot and does visual observation of the length of apical root. Results on soil analysis were presented on graphs to show the trends per site.

3. Results

3.1. Soil Chemical Characteristics for Chepkoilel and Mau Narok in 2011

In terms of chemical characteristics, Chepkoilel soils had higher percent nitrogen (N) than Mau Narok soils with top soils showing higher N than sub soil in both zones (Figure 1: A). Contrary to percent N results, Mau Narok recorded high percent carbon (C) than Chepkoilel soils. However, both sites expressed the same decreasing trend of percent carbon from top soil to sub soil (Figure 1: B).

Further results indicate that Chepkoilel soils recorded the lowest pH below 5.0 with a range of 4.5 – 4.9 in both top and sub soils, indicating that the soils were extremely acidic at the medium altitude zone. At high altitude zone of Mau Narok, pH above 5.0 was recorded with a range of 5.2 – 6.0, indicating that the soil at this site was slightly acidic (Figure 1: C)

The quantity of available phosphorous (P mg/Kg) was low for Chepkoilel site compared to Mau Narok site. In Mau Narok site, the available P was highly variable even within the same site while in Chepkoilel; there was no much variation in P between the top and sub soils (Figure 1: D).

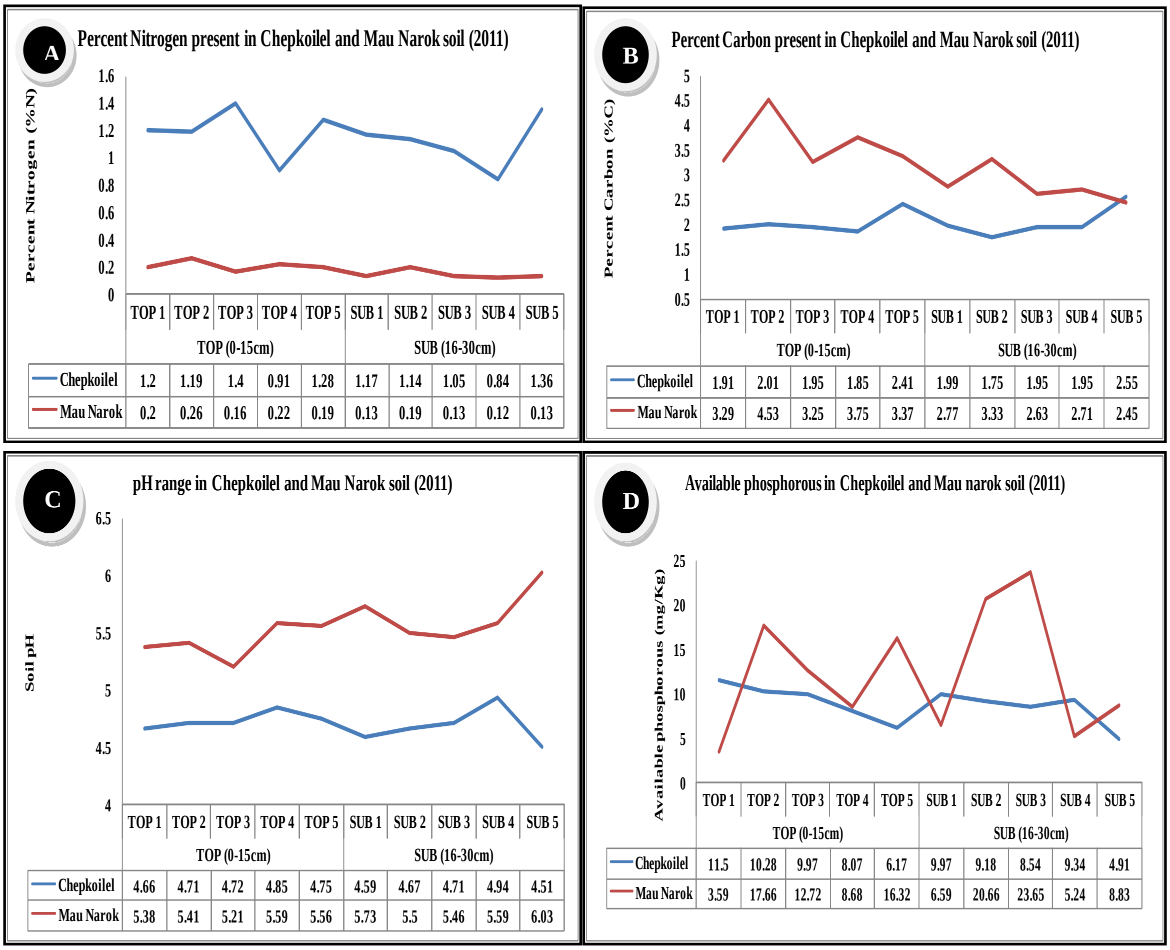

Figure 1: *The chemical characteristics of Chepkoilel and Mau Narok soil in terms of % N* ***'A'****, % C* ***'B'****, pH* ***'C'*** *and available phosphorous* ***'D'*** *during the 2011-2012 seasons*

3.2. Combines Effects of Fertilizer Composition and Ph on Growth Parameters of H. Vulgare

For growth parameters, all treatments showed significant differences ($p < 0.05$) in terms of tillering ability. However, only Control and M.R.P; MEA D.A.P and MAP Blend; Mavuno and

MAP Blend and Mavuno and Yara Milla comparisons recorded significant differences ($p < 0.05$) in terms of barley height. MEA D.A.P and MAP Blend as well as MEA D.A.P and Yara Milla comparisons did not differ significantly ($p > 0.05$) in terms of height. Just like stem height, ear length recorded the same significance tests (Table 1).

Table 1: *Contrast questions and answers in terms of F-probabilities for height, tillers, ear length, grains/ear and yield. '**NS**' means not significant*

NO.	CONTRAST QUESTIONS (COMPARISON)	F-propbabilities (*p*)				
		HEIGHT (CM)	TILLERS	EAR LENGTH	GRAINS/EAR	YIELD (t/ha)
Contrast 1	CONTROL and M.R.P	<.001***	<.001***	<.001***	<.001***	<.001***
Contrast 2	D.A.P and MAP BLEND	0.692 NS	<.001***	0.242 NS	<.001***	<.001***
Contrast 3	D.A.P and MAVUNO	0.001***	<.001***	<.001***	<.001***	<.001***
Contrast 4	D.A.P and YARA MILLA	0.458 NS	<.001***	0.118 NS	<.001***	0.131 NS
Contrast 5	MAVUNO and MAP BLEND	<.001***	<.001***	<.001***	0.002**	<.001***
Contrast 6	MAVUNO and YARA MILLA	<.001***	<.001***	<.001***	<.001***	<.001***
KEY						
CONTROL	Nothing					
M.R.P	29-30% P2O5					
MEA D.A.P	18:46:00					
MAP BLEND	11:52:00					
YARA MILLA	12:11:18 + Mg, S, Mn, Zn and B					
MAVUNO	10:26:10 + Ca, Mg, S, B, Zn, Mn, Mo, Cu and K					

The combined effects of fertilizer formulation recorded significant differences ($p < 0.05$) in terms of height, tillering ability and ear length across all the sites and seasons. For instance, Mavuno fertilizer that contains a number of macro and micro nutrients recorded the best growth in terms of height, enhanced tillering ability and ear length across all the sites and seasons. However, MEA D.A.P ranked the second in terms of height and tillering ability but fourth in terms of ear length. Yara Milla was the second best in terms of ear length after Mavuno but again, it did not differ significantly from MAP Blend. Control plot ranked last in terms of growth parameters namely height, tillering ability and ear length. Despite the fact that M.R.P contain vital plant nutrients, the scores for growth parameters did not vary much from those of control plot where nothing was applied especially at Chepkoilel site where the soils were more acidic with low P availability (Table 2, Figure 1).

Table 2: *Effects of different fertilizer composition on barley GROWTH parameters (plant height, tillering ability and ear length) in different sites and seasons.*

TYPE OF FERTILIZER	PLANT HEIGHT (CM)					TILLERING ABILITY (TILLERS/SEED)					EAR LENGTH (CM)				
	2011		2012		MEAN	2011		2012		MEAN	2011		2012		MEAN
	Chep	Purko	Chep	Purko		Chep	Purko	Chep	Purko		Chep	Purko	Chep	Purko	
CONTROL (0.00 Kg/ha)	24.0	64.3	47.0	62.3	**49.4**	2	11	4	12	**7.0**	4.5	5.3	4.8	5.0	**4.9**
D.A.P (175 Kg/ha)	58.8	69.5	66.0	70.8	**66.3**	16	21	19	21	**17.0**	8.2	8.8	8.0	8.4	**8.4**
MAP BLEND (175 Kg/ha)	57.3	72.5	59.5	73.8	**65.8**	15	18	17	19	**17.0**	8.4	8.6	8.8	8.8	**8.6**
MAVUNO (175 Kg/ha)	61.0	73.8	71.0	76.3	**70.5**	29	29	31	29	**29.0**	9.6	9.8	10.8	10.0	**10.0**
M.R.P (175 Kg/ha)	35.0	69.5	51.3	69.3	**56.3**	4	14	8	15	**10.0**	5.0	6.5	6.0	6.9	**6.1**
YARA MILLA (175 Kg/ha)	57.0	70.5	61.8	72.0	**65.3**	21	21	22	21	**21.0**	8.3	8.6	8.8	9.3	**8.7**
MEAN	**48.8**	**70.0**	**59.4**	**70.7**	**62.3**	**14.0**	**19.0**	**17.0**	**19.0**	**17.0**	**7.3**	**7.9**	**7.8**	**8.1**	**7.8**
F-probability															
Seasonal effect (Se)	<.001					<.001					0.021				
Site effect (Si)	<.001					<.001					0.003				
Fertilizer effect (F)	<.001					<.001					<.001				
Se x Si	<.001					0.009					0.154				
Se x F	0.009					0.304					0.216				
Si x F	<.001					<.001					0.057				
Se x Si x F	<.001					0.486					0.919				
S.E															
Seasonal effect (Se)	0.513					0.218					0.095				
Site effect (Si)	0.513					0.218					0.095				
Fertilizer effect (F)	0.888					0.378					0.165				
Se x Si	0.725					0.309					0.135				
Se x F	0.256					0.535					0.233				
Si x F	1.256					0.535					0.233				
Se x Si x F	1.776					0.756					0.330				
S.E.D															
Seasonal effect (Se)	0.725					0.309					0.135				
Site effect (Si)	0.725					0.309					0.135				
Fertilizer effect (F)	1.256					0.535					0.233				
Se x Si	1.025					0.437					0.190				
Se x F	1.776					0.756					0.330				
Si x F	1.776					0.756					0.330				
Se x Si x F	2.511					1.070					0.466				
% C.V	**5.7**					**8.8**					**8.5**				

Three-way interactions between site, season and fertilizer indicated significant ($p < 0.05$) effect on barley height. However, such interaction did not significantly affect ($p > 0.05$) tillering ability and ear length (Table 2).

In approximately fifteen days after planting at Chepkoilel site, combined symptoms of potassium and phosphorous nutrient deficiency was observed especially in plots treated with M.R.P and Control plots and germination was also hindered in such plots (Figure 2).

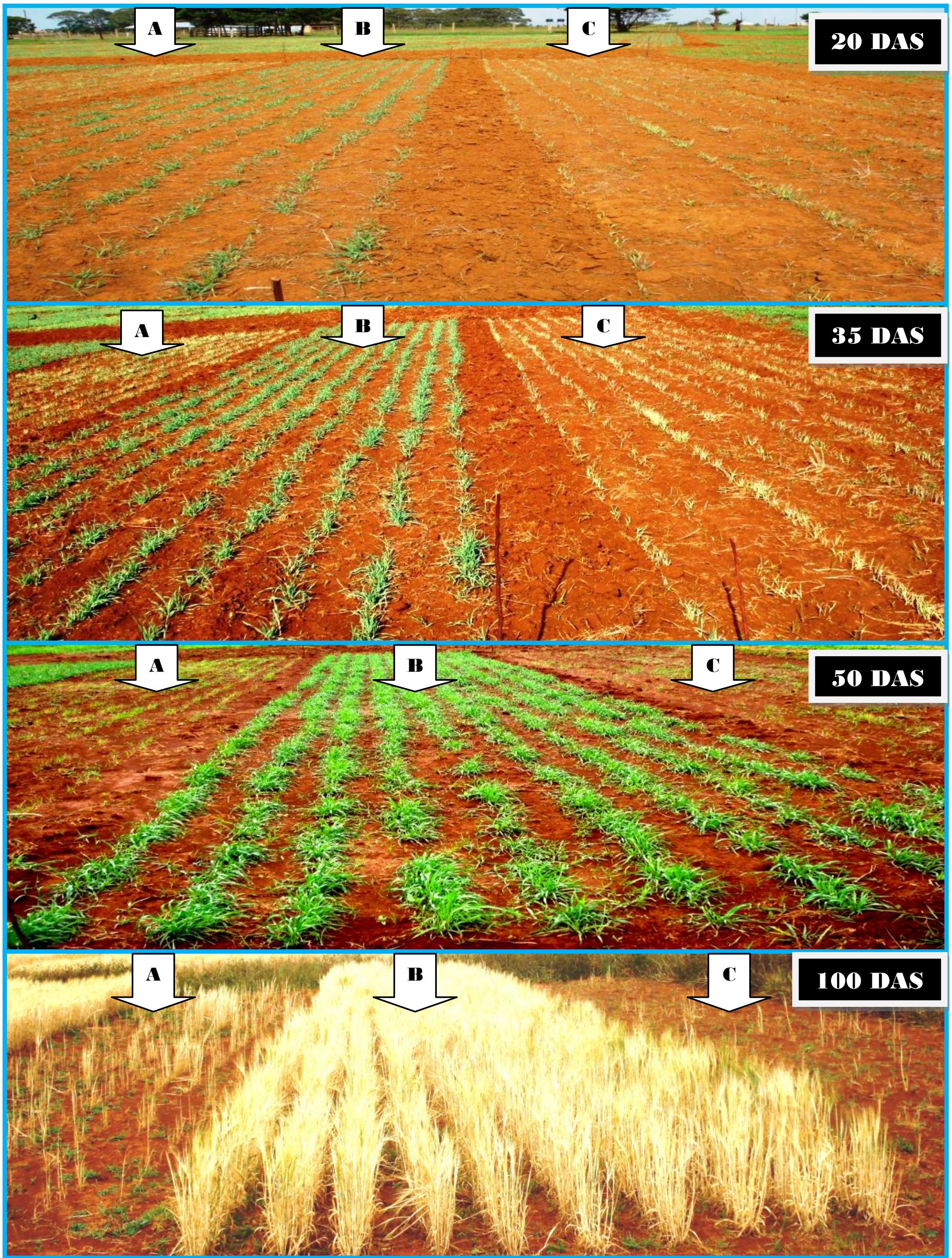

Figure 2: *Effects of fertilizer type on barley growth and yield where* ***A*** *= MRP,* ***B*** *= Mavuno,* ***C*** *= Control.* ***DAS*** *= Days after sowing. Quench variety was grown on soils with pH < 5.0.*

Moreover, immediately after crop emergence above the ground at Chepkoilel site (pH < 5.0), only plots planted with Mavuno, MEA D.A.P and MAP Blend fertilizes exhibited vigorous growth. Those plots where no fertilizer was applied dried off about one month after planting. M.R.P also expressed symptoms of nutrient stress at this site. MEA D.A.P, Mavuno and MAP Blend were observed to promote both vegetative growth and tillering in barley. On the other hand, Yara Milla promoted apical growth and exhibited reduced tillering ability under acidic soils of Chepkoilel site (Figure 2).

However, under the slightly acidic soils of Mau Narok (pH > 5.0), germination was not affected irrespective of the fertilizer used in planting. The crop emerged uniformly and the differences in were only exhibited from late vegetative phase, at grain filling stage and at physiological maturity. Mavuno still showed the best result in terms of height, tillering ability and ear length.

Other than growth parameters, fertilizer formulation was also noted to enhance maturity by shortening the time taken to attain physiological maturity. Plots treated with Mavuno recorded the shortest time to reach physiological maturity followed by MEA D.A.P in all the sites and seasons. Strong straws were also evident in barley planted with Mavuno fertilizer and some degree of disease tolerance and anti - lodging traits at Mau Narok and Chepkoilel sites.

3.3. Combined Effects of Fertilizers Composition and Ph on Yield Parameters of H. Vulgare

Like growth parameters, all treatment comparisons showed significant differences ($p < 0.05$) in terms of number of grains formed per head. The same scenario was reflected in the yields except in the MEA D.A.P and Yara Milla comparison that did not differ significantly ($p > 0.05$) in their effect on yield potential under field conditions (Table 1).

In as much as studies show that yield potential of barley is controlled by a number of genes, nutrition and soil chemical status also play a very significant role and controls the greatest percentage. In this study, the formulation of the fertilizer had significant effect ($p < 0.05$) on the yield parameters. Without fertilizer (e.g. Control), barley can only produce 13 grains per head on average while when the right fertilizer is used (e.g. Mavuno), up to 31 grains can be formed per head, an increase by about 58% (Table 3)

Table 3: *Effects of different fertilizer composition on barley* ***YIELD*** *parameters (number of grains formed per head/ear and yield potential) in different sites and seasons.*

TYPE OF FERTILIZER	NUMBER OF GRAINS PER EAR					YIELD (t/ha)				
	2011		2012		MEAN	2011		2012		MEAN
	Chep	Purko	Chep	Purko		Chep	Purko	Chep	Purko	
CONTROL (0.00 Kg/ha)	11	15	13	14	**13.0**	0.01	1.13	0.42	1.06	**0.7**
D.A.P (175 Kg/ha)	23	25	25	26	**25.0**	2.50	3.43	3.00	3.35	**3.1**
MAP BLEND (175 Kg/ha)	29	29	30	29	**29.0**	2.21	3.04	2.66	3.08	**2.8**
MAVUNO (175 Kg/ha)	30	32	32	31	**31.0**	3.78	5.48	4.46	5.13	**4.7**
M.R.P (175 Kg/ha)	15	20	17	18	**17.0**	0.39	2.18	1.17	2.22	**1.5**
YARA MILLA (175 Kg/ha)	27	28	28	27	**27.0**	2.71	3.51	3.06	3.40	**3.2**
MEAN	**22.0**	**25.0**	**24.0**	**24.0**	**24.0**	**1.93**	**3.13**	**2.46**	**3.04**	**2.60**
F-probability										
Seasonal effect (Se)	0.063					<.001				
Site effect (Si)	<.001					<.001				
Fertilizer effect (F)	<.001					<.001				
Se x Si	<.001					<.001				
Se x F	0.002					0.337				
Si x F	0.028					<.001				
Se x Si x F	0.597					0.159				
S.E										
Seasonal effect (Se)	0.234					0.027				
Site effect (Si)	0.234					0.027				
Fertilizer effect (F)	0.405					0.046				
Se x Si	0.331					0.038				
Se x F	0.573					0.065				
Si x F	0.573					0.065				
Se x Si x F	0.810					0.093				
S.E.D										
Seasonal effect (Se)	0.331					0.038				
Site effect (Si)	0.331					0.038				
Fertilizer effect (F)	0.573					0.065				
Se x Si	0.468					0.053				
Se x F	0.810					0.093				
Si x F	0.810					0.093				
Se x Si x F	1.146					0.131				
% C.V	**6.8**					**7.0**				

The number of grains strongly correlated with the yield potential for every fertilizer formulation used. The higher the number of grains per head, the higher the yield potential recorded. However, low yields were recorded for all fertilizes under the acidic soils of Chepkoilel when compared with Mau Narok site whose pH was higher than that of Chepkoilel. For instance, at pH below 5.0 (Chepkoilel), up to 100% yield low was recorded when no fertilizer was used. The observation was different for pH above 5.0 (Mau Narok) where up to 1.0 t/ha yield was recorded in all the seasons without use of any fertilizer. On average, the best yields were obtained by use of Mavuno fertilizer (4.7t/ha) while MEA D.A.P and Yara Milla recorded 3.1 t/ha and 3.2 t/ha respectively (Table 3)

Nutrients supplied by planting fertilizers played a very vital role as far as rood growth and development and grain formation and grain filling is concerned. For example, despite the fact that Mau Narok had slightly acidic soils with pH above 5.0, the fertilizers used in planting influenced rood growth and development as well as the tillering ability. Mavuno formulation which had the highest number of macro and micro nutrients exhibited the best results in terms of root growth and development. In addition, high number of roots showed strong correlation with tillering ability across all sites (Figure 3).

Like root growth and development, grain formation and grain filling was adversely affected by macro and micro nutrients supplied by the various granular fertilizers. For instance, without fertilizer application, both grain formation and grain filling was lowered in Control plots and plots planted using M.R.P (Figure 3).

Figure 3: Effect of nutritional components of phosphate fertilizers on growth and development of roots and ears of *Hordeum vulgare* at Mau Narok, Purko site with soil pH > 5.0

4. DISCUSSIONS

Soils at Chepkoilel were more acidic (4.5 – 4.9) than Mau Narok soils (5.2 – 6.0). This means that a number of crops including barley can perform better in Mau Narok than Chepkoilel since pH of 5.2 – 8.0 provides optimum conditions for most agricultural plants (Lake, 2000). However, sensitivity can vary even within the same plant species due to varietal differences (EABL-UoE, 2012; Perveen *et al*., 2008).

Other than sensitivity by crops, microbial activity in the soil is also affected by soil pH with most activity occurring in soils of pH 5.0 to 7.0. For instance, under extreme acidity or alkalinity, various species of earthworms and nitrifying bacteria disappear (Lake, 2000) and this may be the reason behind the varying percentages of carbon and nitrogen in two sites which also depend on the previous cropping seasons.

Soil pH affects the availability of nutrients and how the nutrients react with each other. At a low pH (acidic soils), elements such as molybdenum (Mo), phosphorus (P), magnesium (Mg) and calcium (Ca) become less available to plants. However, aluminium (Al), iron (Fe) and manganese (Mn) may become more available and Al and Mn may reach levels that are toxic to plants. Sensitive crops such as barley and lucerne can be affected by small amounts of exchangeable aluminium (Busman *et al*., 2009; Buyukunal and Alkus, 2011; Lake, 2000).

However, at soil pH is greater than 7.5; calcium carbonate concentration increases and fix phosphorus, making it less available to plants. This also causes zinc and cobalt deficiencies that lead to stunted plants, poor growth and reduced yields in some crops and pastures (Busman *et al*., 2009; Lake, 2000; Whiting *et al*., 2011).

An acidic soil makes important nutrients unavailable for plant use and if not supplied at the right time, high yield losses are likely to occur. Supplying the right nutrient require using the right fertilizer formulation that provide not only nutrients to plants but also contain soil amendment ingredients. All soils in Mau Narok and Chepkoilel were acidic, implying that a number of important nutrients were fixed and thus not readily available to barley growth and development (Busman *et al*., 2009; Huttová *et al*., 2002; Kimiti and Gordon, 2013).

The outstanding performance of Mavuno fertilizer in terms of growth parameters could be due to nutrient composition and additional calcium (Ca^{2+}) which raised the pH to a level required by barley especially at Chepkoilel site. The performance of other fertilizer formulation was low especially in pH range of 4.5 to 4.9. This may mean that the supplied nutrients were fixed by aluminium and manganese complexes due to lack of calcium, a unique element in Mavuno fertilizer (EABL-UoE, 2012; Koenig, 2008; McCauley *et al*., 2009).

The rate of nutrient release by planting fertilizer also has significant impact on growth and development as well as the final yield of barley. M.R.P supplies both nutrients and also plays a very important role in soil amendment elements as it contains calcium oxide. However, the slow releasing attribute of this fertilizer may have resulted in the poor growth and yield especially at Chepkoilel site where the soils were more acidic (EABL-UoE, 2012).

Apart from fertilizer composition, soil pH and acidity affected the results of this study and this is evident in the varied effect on growth and development in terms of height, tillering ability, earl length and root length at Mau Narok and Chepkoilel sites. Under the influence of soil acidity stress, physiological processes including photosynthesis, phosphorous uptake (Loboda and Wolejko, 2006), disease resistance (Barna *et al*., 2011) and germination (Bradford *et al*., 2008) are reduced in barley. These could be responsible for poor germination and low yields observed at Chepkoilel and Mau Narok sites under different treatments.

At low pH both soluble and complexes of aluminium and manganese cations inhibits proper root growth and development (Foy, 2008) apart from other negative effects on nutrient uptake and biochemical reactions in growing barley crop. As a result, leaf necrosis and drying of shoot tips due to phosphorous and calcium deficit is apparent and lead to total yield loss (Loboda and Wolejko, 2006). The observed drying of the leaves at early stages of growth and poor root development could be due to such effects which caused a lot of damage at high acidity than moderate acidity conditions.

5. Conclusion and Recommendations

The nutrient compositions of phosphate fertilizer coupled with soil acidity can significantly affect barley yield. In extreme acidity below 5.0, one hundred yield losses can be incurred especially when wrong choice of fertilizer is made. However, at pH between 5.2 - 6.5, barley growth and yield parameters are less affected and the sharp response to nutrient deficiency is reduced.

Therefore, knowledge of the soil pH, associated mineral toxicity and the nutrient composition of planting fertilizer is vital before planning to sow barley. This will improve not only growth but also yield of barley under different agro ecological zones.

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