Evaluation of Fertilizer Formulations on Yield and Quality of Malt Barley Varieties in Mau, Kenya

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Abstract

Appropriate nutrition is essential for unlocking the yield potential of malt barley varieties and grains with malting quality within the required levels. Obtaining optimal yield, malting, and brewing quality of malt barley has been a major bottleneck in the brewing industry and seems not easy to obtain. A study was conducted in the Mau escarpment region to determine the influence of novel fertilizer formulations at different rates on the yield and quality of malt barley varieties in the Mau escarpment region. Balanced, soil informed fertilizer formulations (Baraka formulation 1 and 2) were developed then tried in two sites: Mau Narok and Olokurto to assess their influence yield, malting, and brewing quality of two malt barley varieties. The experiment was laid out in a split-plot arrangement in Randomized Complete Block Design with 3 replications. The varieties (Grace and Quench) were the main plots, fertilizer rates were the subplots (120 kg, 175 kg, 230 kg, and 290 kg/ha). Data was collected on yield and yield attributes, malting and brewing quality, recorded then subjected to Analysis of Variance using R to determine the significant difference, whereas means were separated by the Duncan Multiple Range Test at a 5% level of significance. In this study, the varietal effects were significant in Olokurto but not in Mau in terms of yields; Grace was the better performing variety in Olokurto. 175 kg/ha was the optimal rate for both Baraka formulations. Both variety and the fertilizer rates had grains that met their malting and brewing quality requirements. The performances of the two fertilizer blends were at par with the standard control, however, Baraka formulation 1 was the best of the two blends and it can be used as alternatives for DAP fertilizer at the rate of 175 kg /ha. The fertilizer blends should however be tried more seasons to determine their stability.

Keywords: Barley, Fertilizer rates, Malting quality, Yield

INTRODUCTION

Barley (*Hordeum vulgare* L.) is an important crop widely used as food and animal feed. However, it's mostly used for malting and brewing. According to FAO statistics for 2000 – 2012, barley is the fourth most produced grain in Kenya by a dry weight basis (FAOSTAT, 2014; Viergever & Tipper, 2014). Barley is widely grown in areas with high altitude and latitudes and closer to desert edges (Jaetzold, Schmidt, Hornetz, & Shisanya, 2006). With regards to soil requirements, malt barley requires well-drained loam soils, moderate rainfall (400 – 800mm), and moderate temperature regimes (15 – 30 ºC) (Jaetzold, Schmidt, Hornetz, & Shisanya, 2006).

The areas under production in Kenya has been increasing (FAOSTAT, 2014), and this has been attributed to the ever-increasing demand for malt barley in the country. However, malt barley farmers fail to achieve the breeder's yield potential of 6.5 tons/ha. The national average yield in Kenya lies at 2.7 tons/ha (Viergever & Tipper, 2014). This shortfall in yield has been the major problem faced by barley farmers in Kenya. Most farmers solely rely on DAP fertilizer for crop nutrition and this could be the root cause of this problem, especially considering its acidifying effects on the soils and the ever-declining soil fertility status which occurs over time due to crop harvest, leaching, soil erosion, and etcetera. Apart from the low yields realized in most farms, the malting and brewing industry is faced with a myriad of quality challenges which include high nitrogen content and low fine grind extract in malt barley (Viergever & Tipper, 2014). These quality characteristics are mainly genetic (Amare, 2015), however, agronomic factors especially fertilization are also involved (Pomeranz, Schreck, & Dreier, 1975).

To counter this, a soil survey of the Mau escarpment regions was done to determine the soil nutrition status of this region. Thereafter, two balanced nutrition fertilizer formulation informed by the soil analysis results were developed for the production of malt barley in this region. The developed formulations are Baraka formulation 1 and Baraka formulation 2 endowed with the following nutrient composition respectively: (14:26:3:3 S + 2 CaO + 2.5 MgO + 0.2 B + 0.2 Cu) and (13:34:4 + 4 S + 3 Ca + MgO + 0.2 B + 0.2 Cu). Therefore, this study aimed to evaluate this novel fertilizer formulation on their effect on malt barley yield and quality of the currently grown malt barley varieties in the Mau escarpment region.

METHODOLOGY

Study site characteristics and Treatments

This study was conducted in two sites: Mau Narok and Olokurto. Mau – Narok has an altitude of 2740 m above the sea level and receives an average rainfall of 1400 mm per annum and with an average temperature of 12.9 °C. Olokurto on the other hand has an elevation of 2731 m above the sea level and it receives a mean rainfall of 1039 mm per annum and a mean temperature of 12.7 °C (https://en.climate-data.org). These two sites are different agro-ecological zones in the Mau escarpment region and their environmental differences impact the performances of the malt barley varieties.

Materials used were, Grace and Quench varieties which have yield potentials of 6.8 t/ha and 6.5 t/ha respectively, fertilizers, Diammonium Phosphate (DAP), Baraka formulation 1, and 2. CAN (Calcium Ammonium Nitrate, 46% N as a top dress for DAP treatments) Calcipril (NPK 32:0:3 + S + CaO + MgO) as a top dress for the Baraka formulations treatments).

The treatments in this study were varieties Grace and Quench, Baraka formulation 1 and 2, all at the rates of 120, 175, 230, and 290 kg/ha. DAP was used as a standard control at the rate of 175 kg/ha.

Experiment and Experimental design

This experiment was laid out in split-plot in Randomized Complete Block Design (RCBD) with the three replicates. The varieties were the whole plot, whereas fertilizer rates were the subplot.

The experimental field was prepared following the conventional tillage practice before planting. A 1m space was left between blocks, whereas between the plots within a block will be 0.5 m. The net plot size was 2.5 m × 1 m. Each plot consisted of 6 rows with a length of 2.5 m and 20 cm apart. A commercially recommended seed rate of 100 kg/ha was used. A blanket application of Calcipril and CAN (Calcium Ammonium Nitrate) was applied to their respective plots at the rate of 120 kg/ha (Baraka formulations and DAP respectively).

Data collection and Analysis

Data collected was on yield and yield attributes: these encompassed data on tillering, ultimate yield, and 1000 kernel weight (kw). Tillering was taken from 5 randomly selected plants per plot when the crop is at physiological maturity. The number of tillers from these 5 plants was counted then the average calculated. The total yield of the plots of the same treatment compounded. All the rows from the plots were harvested when the crop appeared to be completely dry, winnowed, and then their weight is taken. 1000 kernel weight was taken from 10 random samples of 1000 kernels were taken from samples of the yield of each treatment, weighed then the 1000 kernel weight determined.

The set data was on malting and brewing quality: percentage germination, nitrogen content, and fine grind extract. Percentage germination was computed from the average of two samples of 100 seeds were used in this test. The seeds were germinated in Petri dishes fitted with moist paper towels then left to germinate at room temperature. Assessment for percentage was done after seven days, where the germinated seeds were counted, expressed as the number of seeds that germinated out of the 100 seeds. For nitrogen content and fine grind extract, a sample of 2 kg from each treatment was sent to EAML determination of grain nitrogen content and fine grind extract. Protein analysis was done according to (Johansson, Holm, & Malik, 2012) whereas fine grind quality was according to (Henry & McLean, 1984).

The data collected on the yield and yield attributes will be subjected to Analysis of Variance using the R at 5% level of significance and the means separated by Duncan Multiple Range Test.

RESULTS

The effect of variety and fertilizer rates on yield and yield attributes

Table 1: Effect of the Baraka formulation fertilizers at different rates on malting and brewing quality

	Tillering				1000 kw				Yield			
Variety	**Olokurto**		**Mau**		**Olokurto**		**Mau**		**Olokurto**		**Mau**	
Grace	13.2	a	12.5	a	47.1	a	50.6	a	5.9	a	6.4	a
Quench	12.6	a	11.9	b	44.9	b	51.5	a	4.3	b	6.1	a
F probability	NS		*		***		NS		**		NS	
% CV	3.9		2.2		2.5		4.9		10.3		4.5	

There was no significant difference (p>0.05) observed in the fertilizer rate in both sites in terms of tillering ability (Table 2). However, the varietal effect was significant but only in the Mau Narok site (Table 1). Grace had a higher tillering compared to Quench. The variety × rates effect was significant (Table 3).

Table 2: Effects of fertilizer rates on yield and yield attributes

Rate	Tillering (numbers)				1000 kw (grams)				Yield (tons)			
	Olokurto		Mau		Olokurto		Mau		Olokurto		Mau	
230	14.1	a	12.5	ab	45.5	c	51.6	b	5.2	b	6.8	a
290	12.9	a	12.5	ab	44.3	d	50.1	c	5.0	b	6.5	ab
120	13.2	a	11.5	b	46.4	b	49.1	d	4.9	c	5.2	c
175	11.5	a	11.8	ab	46.9	b	52.4	ab	6.3	a	6.8	a
DAP	12.8	a	13.2	a	47.8	a	53.1	ab	4.9	b	5.6	b
F probability	NS		NS		***		***		***		***	
% CV	21.8		13		1.7		1.3		8.7		9.6	

The effect of the fertilizer rates was significant (p<0.05) as far as 1000 kw is concerned (Table 3). In Olokurto, DAP had the heavier kernels, 47.8 g followed by a rate of 175 kg/ha with 46.9 g, whereas the rate 125 kg/ha had the lightest kernels, 44.3 g. In Mau Narok, DAP also had the heaviest kernels, 53.1 g, however, this was not significantly different from those of rate 175 kg/ha, 52.4 g. Rate 120 kg/ha had the lightest kernels, 49.1 g. Variety×rate interaction had additive effects on the 1000 kw in all the sites. (Table 3). It was also noted that kernels from Mau Narok were slightly heavier than those obtained in Olokurto.

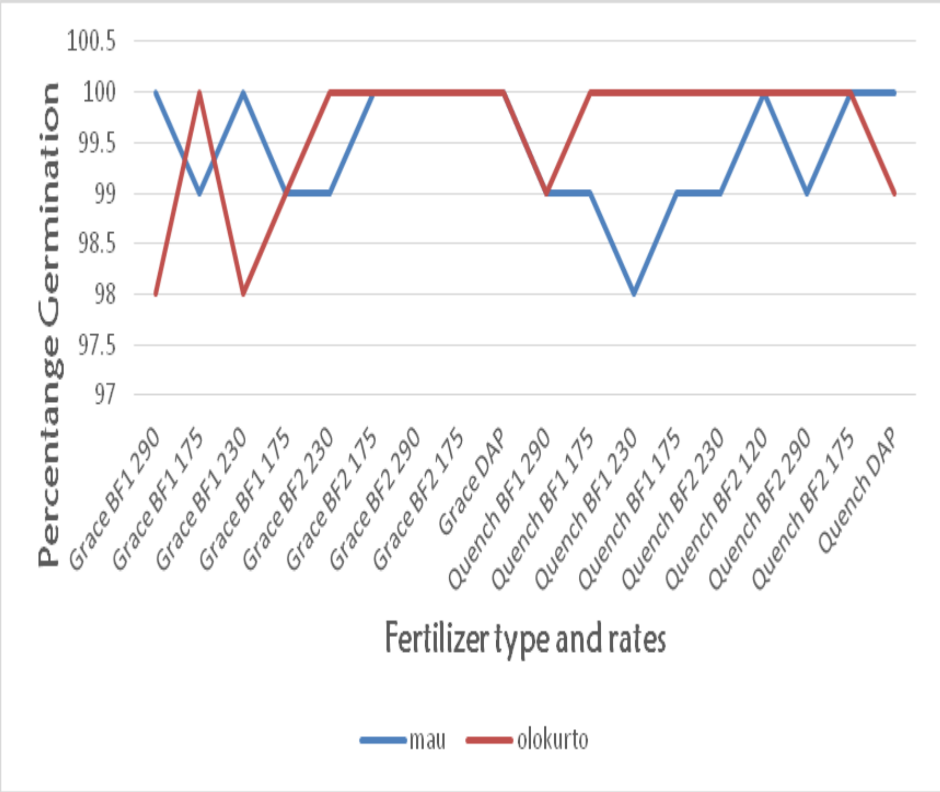
Table 3: Effects of variety × fertilizer rates interaction on yield and yield attributes

Variety × Rate	Tillering				1000 kw				Yield			
	Olokurto		Mau		Olokurto		Mau		Olokurto		Mau	
Grace×230	13.3	a	12.2	abc	45.4	bc	51.6	bc	6.3	b	6.5	ab
Grace×290	13.3	a	12.5	abc	45.7	bc	49.6	d	5.9	bc	6.3	ab
Grace×120	13.7	a	11.5	bc	48.6	a	47.1	e	4.4	d	5.1	d
Grace×175	11.5	a	13	ab	49.0	a	52.4	b	7.2	a	6.8	a
Grace×DAP	13.7	a	14	a	46.3	b	53.9	a	5.6	c	5.7	bcd
Quench×230	14.8	a	12.8	ab	45.6	bc	51.5	bc	4.0	d	7	a
Quench×290	11.8	a	12.5	abc	42.8	e	50.6	cd	4.1	d	6.6	a
Quench×120	12.6	a	11.5	bc	44.2	d	51.2	bc	3.8	d	5.4	cd
Quench×175	11.5	a	10.5	c	44.8	cd	52.4	b	5.5	c	6.9	a
Quench×DAP	12.0	a	12.3	abc	49.2	a	52.4	b	4.2	d	6.1	abc
F probability	NS		NS		***		***		***		NS	

In terms of yield, there was a significant difference in the fertilizer rates in both Olokurto and Mau Narok (Table 2). Rate 175g/ha had the highest yields of 6.3 t/ha, followed by 100 kg/ha with 5.2 t/ha. Performances of DAP were at par with those of 290 kg/ha, 5.0 t/ha. In Mau Narok, rates 230 kg/ha and 175 kg/ha had the highest yield of 6.8 t/ha. DAP as a check had a mean yield of 5.6 t/ha. However, the varietal effect on yield was statistically significant (p <0.05) in Olokurto alone (Table 1). Grace had a mean of 5.9 t/ha whereas Quench had 4.3 t/ha. In Mau Narok, Grace was also the high yielding variety with 6.4 t/ha while Quench had 6.1 t/ha. A significant difference (p

<0.05) was only observed in Olokurto in terms of variety × rate interaction effect on yield (Table 3).

Figure 1: Influence of Fertilizers at different rates on germination of the resultant grains of malt barley varieties



The influence of the Baraka formulation fertilizers on percentage germination is shown in (Figure 1). The results show that the percentage germination of the grains from all the treatments was above the minimum required thresholds of 95%. All the treatments had percentage germination of above 98%. This, therefore, means that resultant grains are not dormant and perfect for malting as far as germination is concerned. Grace had nitrogen content levels within the required thresholds for both sites. In Mau Narok, all the fertilizer treatments for Grace had nitrogen content levels within the required levels (1.50% to 1.85%) except for Baraka Formulation 2 at 120 kg/ha (Table 4). In Olokurto, all treatment had grains with nitrogen content within the required levels except Baraka formulation 2 at 290 kg/ha with 1.88% and DAP with 1.86%.

Table 4: Effects of fertilizer types and rates on nitrogen content and fine grind extract of Grace and Quench in Olokurto and Mau Narok, expressed in %

Treatment	% of Nitrogen content				Fine Grind Extract			
	Grace		Quench		Grace		Quench	
	Mau Narok	Olokurto	Mau Narok	Olokurto	Mau Narok	Olokurto	Mau Narok	Olokurto
Baraka form. 1, 175 kg/ha	1.78	1.77	1.68	1.57	82.2	82.5	83.2	82.6
Baraka form. 1, 120 kg/ha	1.70	1.71	1.78	1.74	82.3	83.2	81.2	80.1
Baraka form. 1, 290 kg/ha	1.71	1.72	1.7	1.71	83.5	83.4	81.0	80.9
Baraka form. 1, 230 kg/ha	1.76	1.75	1.82	1.78	82.0	82.1	81.4	80.7
Baraka form. 2, 175 kg/ha	1.71	1.73	1.79	1.76	81.2	81.4	82.1	81.7
Baraka form. 2, 120 kg/ha	1.92	1.84	1.58	1.46	81.2	81.4	82.9	83.4
Baraka form. 2, 290 kg/ha	1.83	1.88	1.70	1.74	81.9	81.6	81.1	81.5
Baraka form. 2, 230 kg/ha	1.73	1.74	1.75	1.74	82.2	82.4	81.7	81.6
DAP	1.82	1.86	1.69	1.68	81.6	81.8	82.4	81.9

Quench had all its treatments for Baraka formulation 1 and 2 and DAP with nitrogen content results within the acceptable limits except for Baraka formulation 2 at the rate of 120 kg/ha in Olokurto. It had a nitrogen content of 1.46% and this slightly below the lower limit.

All the fertilizer treatments had fine grind extract levels above 80% for both Quench and Grace in both Mau Narok and Olokurto (Table 4). This is the required level by maltsters worldwide. In Mau Narok, the highest fine grind extract levels were scored in Baraka formulation 1 at the rate of 290 kg/ha, 83.5% for Grace, and Baraka formulation 1 at 175 kg/ha, 83.2% in Quench. The standard check, DAP had fine grind extract levels of 81.6 % for Grace and 82.4 for % for Quench.

In Olokurto, Baraka formulation 1 at the rates of 120 kg/ha and 290 kg/ha had the highest fine grind extract levels for Grace, 83.2% and 83.4% respectively, whereas, Baraka formulation 2 at the rate of 120 kg/ha had the highest for Quench, 83.4%. However, it was also observed that this parameter didn't vary systematically with the fertilizer rates. It was also noted that for variety Grace, Baraka formulation 1 was the best fertilizer in terms of fine grind extract in both Mau Narok and Olokurto, whereas for Quench it was DAP and Baraka formulation 2.

DISCUSSION

The effect of variety on malt barley yield and quality

Grace had a higher tillering ability compared to quench in the Mau Narok site. The two varieties showed variation in tillering across the sites. Similar recordings were made by

(Moreno, Moreno, Ribas, & Ceballo, 2003) who were investigating the influence of nitrogen fertilizers in grain yields in barley under irrigation conditions. Tillering varies with one variety to another and therefore it is genetically controlled (Bian, *et al*., 2015; Anbessa & Juskiw, 2012). Rodriquez, *et al*., (2001) also made similar observations in their study on the effects of phosphorous in tillering in wheat. Phosphorous is the most important nutritional element integral in tillering (Cassells, Reuss, Green, Willis, & Nischwitz, 2012) and by significant difference being observed at the variety level, it can be presumed that the amount of available phosphorous in the soils after the application of the fertilizer at the lower rate is sufficient enough for the crop to express its tillering optimally. The variety × rate interaction had no significant effect on tillering ability meaning it had no additive effect on tillering. This could mean that the initial nutrients in the soil together with the supplemented nutrients were enough for the trait to be expressed fully.

Varietal factors weren't important as far as 1000 kernel weight is concerned and this was observed both in Mau Narok and Olokurto. Quench had slightly heavier kernels in Mau Narok compared to Grace, whereas in Olokurto, Grace had significantly heavier kernels than Quench. These results show that kernel weight is affected more by environment than genotype and these observations are similar to those made by (Shahnaj, Moushumi, & Belal, 2014). The kernels from the crop at Mau Narok were heavier than those from the crop at Olokurto. The performance of these varieties in terms of kernel weight in the respective sites was corresponding to the borne yields and not tillering of the various varieties. This, therefore, suggests that variety selection should be based on 1000 kernel weight rather than on other morphological components of grain yield as also reported by Sukram, *et al*., (2010). The variety × rate interaction had addictive effect on the 1000 kW of Grace and Quench grains as the kernel weight increased with increase in fertilizer rate. This could be associated with the phosphorous effect on grain filling and nutrient use efficiency. The level of phosphorous increased with increase in fertilizer rate.

Different varieties are known to have different yield potentials as projected by the breeders (Glen, Kelly, Inkerman, & Henry, 2006). The varieties used in this study Grace and Quench have a yield potential of 6.5 t/ha. The varietal effect registered statistical significance only in the Olokurto site but not Mau Narok. Zenebe (2019) observed that the varietal effects were significant in terms of yield in his experiment, however, in his study the difference was in both sites. This variation in yield can be linked to the genetic differences of the varieties and their responses to the environmental factors. This varietal variation in yield can also be associated with the difference in the response of the varieties to fertilizers and the fertilizer rates. The performances of these varieties were decent considering the national average and the yield potential of the varieties.

Nitrogen is the most important nutrient for achieving higher yields, whereas phosphorous is the second limiting element for achieving yields and the three fertilizers have just a sufficient amount of phosphorous (Syed, *et al*., 2015). Potassium is also important in achieving higher yields, whereas trace like zinc, copper, and boron contained in the Baraka fertilizers are vital in the reproductive growth of barley. They also aid in the uptake of nitrogen, phosphorous, and potassium which have a positive effect on yield and grain quality (Dordas, 2008). The non-significant variety × rate interaction in Mau Narok site could be associated with original nutrient in the soil plus the sufficient moisture that was available during the study time thus the treatments could have an edge over the other. In Olokurto however, the interaction was significant and it could be associated with the varying fertility levels and inadequate and poorly distributed moisture during the study time.

The effects of fertilizer rates on malt Barley yield and quality

Tillering was not affected by the fertilizer rates in both sites. This observation was made on the two varieties. This could insinuate that tillering is mostly genetically controlled in the two varieties or the initial nutrients in the soil were sufficient for optimal tillering. The same findings were reported by Lo´pez-Bellido, *et al*. (2006). Tillering was higher in Mau Narok compared to Olokurto and could be due to the moisture stress that was experienced in Olokurto which was more severe than in Mau Narok. Suppressed tillering increases risks of tillering at the late grain filling stage (Lauer & Simmons, 1998). (Rashid, Khan, & Khan, 2007) Also found out that, yield and tillering in barley varies with the environment and variety in their experiment on comparative effect of varieties and fertilizer types on barley.

1000 kW was not significantly affected by the fertilizer rates. This is in contrast to (Moreno, Moreno, Ribas, & Ceballo, 2003) findings show that kernel weight varied with different fertilizer doses significantly. Kernel weight is a highly stable trait in barley and it can be attributed to the capacity of the crop to mobilize and redistributed resources stored in the stems. DAP and Baraka formulation at the rate of 175 kg/ha was the best in terms of the kernel weight. The lowest rate for the Baraka formulation might not have supplied enough nutrients for better kernel development whereas the higher rates could be supplying excess nitrogen for the crop, which according to Moreno, *et al*. (2003), establishes an inverse relationship with kernel per ear and kernel weight since increased kernel number leads to a competition of the unlimited resources.

The applied fertilizer rates affected the phenological traits and yielding potential of the two barley varieties and this result is in agreement with (Mengistu & Abera, 2014). Rates 175 kg and 230 kg/ha had the highest yields, albeit the two did not differ significantly from the other rates. The former had an average of 6.84 t/ha while the latter had 6.75 t/ha. Baraka formulation 1 and 2 at the rate of 175 kg/ha was superior to DAP by 0.9 t/ha whereas 230 kg/ha was 0.814 t/ha. The Baraka formulations at the rate of 120 kg/ha had the least yields meaning the nutrition wasn't sufficient enough to supplement the nutrient in the soil for the crop to perform well. In Olokurto, Baraka formulation at 175 kg/ha, was the best performing rate in terms of yields, 6.3 t/ha. The Baraka formulations at 120 kg/ha recorded the least yields again in this site implying that the rate is low for malt barley production in the Mau escarpment region.

Grains from both varieties had average percentage germination of 99% and these results were identical in both sites. Evenness in germination for malting barley can be classed as quality factors. The complex physiological processes involved in germination are not only under genetic control but different barley varieties have been found to possess a wide range of germination behaviors. Grains from the experiment in Olokurto had an excellent germination behavior despite experiencing soil moisture stress during the growth phase of the crop. However, this is not in agreement with (Finlay, 1991) who worked with Southern Australia varieties. He states that the germination behavior of barley varieties can be influenced by the environment, particularly moisture stress during the maturation of the seed.

Grain nitrogen content tolerance margins as required by the malting industry ranges from 1.44 – 1.85% (Viergever & Tipper, 2014). The two varieties in this experiment had nitrogen content with this limit on average regardless of the fertilizer treatments.

However, the nitrogen content levels in variety Quench were slightly lower compared to Grace. These results are in agreement with (Herb, Filichkin, Fisk, Helgerson, & Hayes, 2017) who found out that the stability of nitrogen content varied with the malt barley varieties. In both Mau Narok to Olokurto, there was no significant difference in nitrogen content in both varieties. This could mean that the genes controlling nitrogen content in these varieties are not influenced largely by the environment. (Jung-cang, Jin-xin, & Jun-mei, 2005), however, found out that nitrogen content levels varied in the varieties from one site to another.

Fine grind extract indicates maximum soluble yield for the malt. It's also one of the key quality parameters measures in malt barley. Grace and Quench had decent average percentages of this parameter apart from not being significantly different in this study. (Galano, Bultosa, & Finins, 2011) their experiment found out that different varieties had different fine grind extract levels for the different varieties, whereas, (Kefale & Abushu, 2017) did not find a significant difference in the varieties they used. Fine grind extract is a genetically controlled trait; conversely, it is hugely influenced by the environment (Mather, Tinker, LaBerge, & Edney, 2000).

CONCLUSION

From this study, it was evident that Grace was a more productive variety than Quench in both Mau Narok and Olokurto, although Quench had slightly heavier grains. Both varieties also had grain nitrogen content and fine grind extract levels within acceptable limits. Baraka Formulation 1 was a better fertilizer than Baraka formulation 2 and it can be alternative fertilizer to DAP at the optimal rate of 175 kg/ha. All the fertilizers, however, had grains with nitrogen content and fine grind extract within acceptable limits, whereas all the rates also had grains with required malting and brewing quality except Baraka Formulation 2 at the rate of 120 kg/ha in Quench. The variety × rate interaction only had additive effects on 1000 kernel weight in both sites and on yield in Olokurto site only.

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