Evaluation of Promising Malting Barley Varieties Using Agronomic and Quality Traits in Kenya

Okacha J.S. Jairus

Prof. Elmada O. Auma

Dr. Lucas Ngode

Department of Seed
Crop and Horticultural Sciences
University of Eldoret
Kenya

Abstract

A study to select promising malting barley varieties was conducted at the University of Eldoret and Mau Narok in Kenya from June 2011 to July 2012. Two varieties due for release were compared with one commercial variety. Data on yield and quality components was subjected to ANOVA using SAS. Means were separated by LSD at α = 0.05. HKBL 1385-13 had superior grain yield than the control variety at both the Mau Narok and University of Eldoret sites by 500 kg ha^{-1} (25%) and 1400 kg ha^{-1} (37.8%) respectively. HKBL 1512-5 had significantly higher grain yields than the control at the Mau Narok site by 400 kg ha^{-1}, but at the University of Eldoret, it had inferior yields, shorter spike length and a lower number of grains spike^{-1}. However, it had consistently heavier grains throughout the study. Both HKBL 1512-5 (2.33 %) and HKBL 1385-13 (2.21 %) accumulated grain N-content beyond the acceptable level of 2.2 % at the Mau Narok site compared to 1.97 % and 1.87 % respectively at the University of Eldoret. Site differences were observed for the proportion of maltable grains. HKBL 1512-5 has inferior agronomic traits at both sites, except for plant stand establishment, 1000 kernel weight and % - nitrogen accumulation in the grain at the Mau Narok site. The superior grain size of test variety HKBL 1512-5 can be used to improve barley varieties with superior yields but with inferior kernel size. Choice of appropriate variety for Mau Narok could be determined by the 1000 grain weight and % - nitrogen accumulation in the grain, whereas, at the University of Eldoret, variety choice can be based on grain yield, the number of productive tillers per plant and grains per spike.

Keywords: Varieties, yield components, agronomic traits, Mau Narok, University of Eldoret

Introduction

Many studies have been conducted on the relationship between barley varieties and their yield and malting qualities. The yield and quality specifications of a given malting barley variety are determined by its genetic makeup and the physical conditions during growth, harvesting and storage (Fettel *et. al.*, 1999; Glen *et al.*, 2006; Australian Govt., 2008). Farmers in Northern Ethiopia, selected malting barley genotypes on the basis of differences in the agronomic traits of crop stand establishment, number of tillers per plant, spike length, number of kernels per spike, and 1000 kernel weight (Aynewa *et al.*, 2013; Soudabeh *et al.*, 2013). Statistical analysis in this study confirmed that, these traits were indeed different across genotypes (Aynewa *et al.,* 2013). Differences in kernel and dormancy characteristics among varieties will influence germination percentage (Fettel *et al.,* 1999; Glen *et al.,* 2006; Australian Govt., 2008) and by extension, determine the plant stand establishment (Mackenzie *et al.,* 2005). However, in similar studies, no varietal differences were observed for plant stand establishment (Aynewa *et al.,* 2013). This contrast may indicate a weak relationship between variety and plant stand establishment.

Differences of up to 20% in fertile tiller numbers per plant have been observed (Tambussi *et al.,* 2005). However, other studies show that environment has a lower influence on barley tillering and that genetics has more influence due to its low variability across different environments (Tamm, 2003).

O'Donovan *et al.,* (2011) did not find cultivar differences with respect to barley tillering, indicating a weak relationship between genotype and number of productive tillers per plant. Varietal differences in the number of grains per spike are associated with its relatively higher heritability of 98% when compared to other yield components (Rao *et al.,* 2012). Genetic effect on grain size was found to be greater than environmental effect even when experimental sites suffered terminal moisture stress, with retention (on 2.5 mm screen) value of 88 to 96% (Glen *et al.,* 2006). Similar studies also found a very high heritability value for 1000 kernel weight of 99.9% (Nanak, *et al.,* 2008). Large differences in grain yield have been observed by many studies but the yield stability across different weather conditions was high (Tamm 2003). However, other studies found highly significant differences among varieties, environment and variety by environment interaction, although the ranking across environments was not consistent, showing varying stability among varieties with respect to grain yield (O'Donovan *et al.,* 2011). This large differences could be associated with the relatively high heritability of 96 % (Rao *et al.,* 2012), although other studies show a lower heritability of 52.4% for grain yield, but with a high correlation between grain yield and productive tillers per plant and number of kernels per spike. Newer barley varieties are higher yielders than old ones (Bulman *et al.,* 1993). Barley varieties show different capacities to adapt to different environments e.g. moisture stress and soil fertility (Glen *et al.,* 2006; Aynewa *et al.,* 2013). This can lead to differences in yield and quality components with more fertile tillers per plant and number of kernels per spike making major contributions to yield (Jalal and Ahmad, 2011). These studies show that the agronomic traits of plant establishment, productive tillers, and grains per spike can be used as criteria for selecting barley varieties suitable for different environments. However, productive tillers per plant, number of kernels per spike and 1000 kernel weight would be more useful criteria for selecting evolving high yield barley varieties (Sukram *et al.,* 2010; Kavitha *et al.,* 2009).

Grain protein concentration is genetically controlled but easily affected by the environmental conditions (Jung-Cang, 2005). Other studies have confirmed this, but found that genetic control was much greater than environmental control (Jummei *et al.,* 2003; Shengguan *et al.,* 2013). This influence has been put at about 70% (Bleidere, 2008). The grain protein concentration decreases in newer varieties of malting barley due to increase in structural carbohydrates (Bulman *et al.,* 1993). Stability in grain protein concentration across locations is varied with variety, but variability is low (Bentayehu, 2013; Krizanova *et al.,* 2010 & Jung-Cang *et. al.,* 2005). The grain protein concentration shows a close relationship with other malt quality parameters indicating the need to select varieties with stable grain protein concentration (Shengguan *et. al.,* 2013). This varied response of barley yield and quality components to variety, environments and variety by environment interaction indicates the need to determine the response of specific varieties to these variables. Therefore, the purpose of this study was to evaluate promising malting barley (*Hordeum vulgare* L.) varieties using grain yield and quality components at medium and high altitudes in Kenya with the specific objective of selecting the most suitable variety for each of the altitudes.

Materials and Methods

Two experimental sites were used in this study during the 2011 to 2012 barley growing season. The University of Eldoret Farm, is located at 0^0 30' N and 35^0 15' E in the LH_3 agro-zone, with an elevation of 2180 m asl. The annual mean temperature of this site is 23^0 C with relative humidity of 45 - 55% and average annual rainfall of 900 – 1100 mm pa. The soils are shallow, well drained with low fertility and underlying murram (Jaetzold and Schmidt, 1982). The Mau Narok site is located at 0^0 20'S and 35^0 35'E in the UH_3 agro-zone with an elevation of 2829 m asl, mean annual rainfall of 1200-1400 mm p.a., and annual mean temperature range of 11 -13.5^0 C, (Newton *et al.,* 2011). Soils are well drained, deep and have high fertility but may lack copper (Jaetzold and Schmidt, 1982). Two promising barley varieties designated; HKBL 1512-5 and HKBL1385-13 were compared with the standard variety Nguzo in order to establish the most suitable variety based on yield and quality components. NPK 23:23:0 was used as basal fertilizer with triple superphosphate (TSP), 0:45:0 providing the additional phosphorus, whereas calcium ammonium nitrates (CAN), 26:0:0 was used to provide additional nitrogen. This was aimed at providing 40kg ha^{-1} P_2O_5 and 30, 40 and 50 kg ha^{-1} nitrogen. The soil was characterized by taking random core rings at the depth of 15 and 30 cm respectively. Measurements for, soil pH (H_2O), elemental P, soil-N and organic matter were done using procedures in the manual for soil and plant tissue analysis (Okalebo et al, 2002) (Table 1). Rainfall was monitored throughout the growing phase (Table 2). Seeding rates of 150, 200 and 250 viable seeds m^{-2} were determined according to the formula by (McClelland 2009). The seedbeds were prepared by conventional methods using a tractor.

A split-split factorial arrangement in a completely randomized block design was used in this study with varieties in the main plots. 8 rows with inter-row spacing of 20 cm were planted in each experimental unit measuring 3 m * 1.5 m. All the fertilizers were banded together with the seed as is done by farmers. Routine agronomic practices of weeding, insect pest and disease control were carried out. Plant stand establishment was determined by counting established seedlings in two 1 m length rows per experimental unit (McKenzie *et al.,* 2005). Productive tillers plant^{-1} was determined as described by (Gomez and Gomez, 1976). The same plant samples were used to measure the length of the spike from the base of the lowest to the tip of the highest kernel, but excluding the awn, and the number of filled grains per spike. Whole plots were harvested when the crop appeared to be completely dry. The harvesting was done by cutting the stems above the ground using sickles and drying them further in the sun for ease of threshing. The dried grains were threshed by hand, winnowed and the moisture content measured (FAO, 2003). The final grain yield was determined by correcting the moisture content to 13% (FAO, 2003). Ten random samples of 100 kernels each were weighed to determine the 1000-kernel weight of the Maltable barley. The ISTA (1996) protocol was followed in this procedure. Maltable grain or grain sizing was done using the EABL protocol. One kilogram of grain for each treatment was poured into a 2.2 by 20mm (McKenzie *et al.,* 2005), screen and put into a mechanical shaker which was then run for five minutes. The weight of the grains in grams, retained on the screen, was determined using an electronic balance. The grain nitrogen concentration in maltable barley was determined by the infrared method. The data collected was subjected to ANOVA using SAS procedure whereas mean separations were done using Least Significant Differences (LSD) at $\alpha = 0.05$.

Results and Discussion

While the mean temperatures at both sites in this study were conducive for barley growth and development (Table 1.), rainfall was inadequate at the Mau Narok site (444mm), when compared to the University of Eldoret site (719.4 mm). Barley requires 635 mm of rainfall in its growth phase (EPZA, 2005). Zadock's scale for crop growth and development recognizes moisture stress, and varietal differences as contributors to plant establishment in cereal crops (Zadock, 1974) at (http://www.fao.org.).ility

Soil fertility was varied at the two sites. The high altitude Mau Narok site had higher total soil nitrogen and organic matter. This means that continuous mineralization could add more nitrogen to the soil during the period of crop growth (Okalebo, *et al.,* 2002). In contrast, the soil at the University of Eldoret site had lower nitrogen levels, although they were above the critical level of 0.25% (Okalebo, *et al.,* 2002). Soil pH test results (Table 2) show strong acidity at Mau Narok in both top soil (5.4) and sub soil (5.3), whereas the soils at the University of Eldoret farm show very strong acidity in both top soil (4.75) and sub soil (4.7) (Panda, 2005). Barley requires soils tending towards alkalinity (pH 7.0 – 8.0). While the soil acidity at the University of Eldoret should be studied further to determine the necessary amendments to suit barley growth, acid tolerant barley varieties could be selected for the Mau Narok site. Soil acidity beyond pH of 5.0 may not need addition of lime as an amendment.

The results for the response of barley yield and quality to genotype is shown in table 3. Barley yield differences among varieties were modest in this study. The test variety HKBL 1512-5 (4.0 tonnes ha^{-1}) was inferior to the control variety, Nguzo (4.4 tonnes ha^{-1}) and test variety HKBL 1385-13 (4.9 tonnes ha^{-1}) at the Mau Narok site. However, the test variety HKBL1385-13 out-yielded both the control and the test variety HKBL1512-5 (Table 3). At the University of Eldoret site, test variety HKBL 1512-5 (3.8 tonnes ha^{-1}) was similar to the control variety Nguzo (3.7 tonnes ha^{-1}) but inferior to test variety HKBL 1383-13(5.1 tonnes ha^{-1}). Test variety HKBL 1383-13 was also superior to the control variety Nguzo (Table 3). The total grain yield for test varieties were above the national average of 2.2 tonnes ha^{-1} but below the grain yield potential of 7 tonnes ha^{-1} (EPZA 2005).

Barley varieties are known to have different yield potentials (Fettel, 1999; Mackenzie, 2005; EPZA, 2005). The genotypic variation in grain yield, in this study, can be associated with the different responses of the tested grain yield components of plant stand establishment (plants m^{-2}), productive tillers per plant, spike length (cm), number of grains per spike and 1000 kernel weight (g) as shown in table 3. Test variety HKBL 1512-5 (180 plants m^{-2}) had a superior plant stand establishment at the Mau Narok site when compared to both the control variety Nguzo (147 plants m^{-2}) and test variety HKBL 1385-5(140 plants m^{-2}). However, it (HKBL 1512-5) had lower productive tillers per plant (4.9) and number of grains per spike (25.7 grains) than both the control variety Nguzo (6.6, 29.3) and the test variety HKBL 1385-5 (8.6, 29.1) respectively. Test variety HKBL 1385-5 (6.1) had similar number of productive tillers per plant when compared to the control variety Nguzo (6.6) and a similar number of grains per spike (Table 3).

Based on these results, the difference in the grain yield between the test varieties HKBL 1512-5 (4.0) and the control Nguzo (4.4) can be explained by the significant difference between their respective productive tillers per plant and grains per spike (Table 3). The higher plant stand establishment (180 plants m^{-2}) and superior kernel weight (52.5g) for test variety HKBL 1512-5 at the Mau Narok site did not adequately compensate for its lower tillering capacity (4.9 tillers per plant) and lower number of grains per spike (25.7 grains). On the other hand, the difference in grain yields between the test variety HKBL 1385-13 (5.1 tonnes ha^{-1}) and the control variety Nguzo (4.4 tonnes ha^{-1}) at this site can only be explained by the significant difference between their respective kernel weights (Table 3). Test variety HKBL 1385-13 out yielded the test variety HKBL 1512-5 due to the significant difference between their productive tillers per plant and the number of grains per spike. The superior kernel weight for test variety HKBL 1512-5 was not adequate compensation for the lower tillering capacity and the number of grains per spike (Table 3).

At the university of Eldoret site, the similarity in grain yield between the test variety HKBL 1512-5 (3.8 tonnes ha^{-1}) and the control Nguzo (3.7 tonnes ha^{-1}) can be explained by the superior kernel weight of the test variety HKBL 1512-5 (49.9g) compared to the control (41.8g). The other yield components of plant stand establishment (172 plant m^{-2}), and number of grains per spike (24.8) for the test variety HKBL 1512-5 were inferior to those of the control (Table 3), but the superior kernel weight for this test variety adequately compensated for these inferior traits. On the other hand, the higher grain yields of the test variety HKBL 1385-13 (5.1 tonnes ha^{-1}) over the control (3.7 tonnes ha^{-1}), can be explained by the significant difference in their respective productive tillers and kernel weights (Table 3). Between the two test varieties, the yield components of plant stand establishment, 192 against 173 plants m^{-2}); number of productive tillers per plant at 5.8 against 2.7; and number of grains per spike at 28.8 against 24.8 for HKBL 1385-13 and HKBL 1512-5 respectively, explained the difference between their respective yields at the university of Eldoret site (Table 3).

The selection of variety for maximum grain yield at either of the sites can therefore be based on the capacity of the varieties to tiller and the number of grains per spike. These findings agree with (Sukram *et al.,* 2010 & Kavitha *et al.,* 2009) who reported that productive tillers per plant, number of kernels per spike and 1000 kernel weight are more useful criteria for selecting evolving high yield barley genotypes due to their high heritability values and direct effect on grain yield. Although test variety HKBL 1512-5 had superior kernel weight at both sites, it had lower tillering capacity and number of grains per spike at both sites. The results also agree with (Zadock 1974) who reported that plant establishment can be a yield component especially in areas experiencing moisture stress at sowing time

Two barley malting qualities of maltable grain (gm kg^{-1}) and grain nitrogen content (%) were determined in this study. the results of this determination are shown in Table 4. On average, the two test varieties; HKBL 1512-5 (980 g kg^{-1}) and HKBL 1385-13 (965 g kg^{-1}) produced acceptable maltable grain of more than 90% at the Mau Narok site. Whereas the test variety KHBL 1512-5 produced higher maltable grain than the control variety Nguzo (963 g kg^{-1}) test variety HKBL 1385-13 was similar to the control at this site. At the university of Eldoret site, the two test varieties, HKBL 1512-5 (982 g kg^{-1}) and HKBL 1385-13 (988 g kg^{-1}) were similar and both were superior to the control variety Nguzo (876 g kg^{-1}) which produced lower maltable grain than is acceptable by maltisters (Table 4). The test varieties were, therefore, not site specific with respect to maltable grain in this study. These results agree with (Mackenzie *et al.,* 2005; McClelland *et al.,* 2009; Akar *et al.,* 2004) who found significant differences in maltable grain among varieties and across some locations. The results also agree with findings of (Fox *et al.,* 2006) who found that genetic effect on grain size was greater than environmental effect, even when the environment suffered from terminal moisture stress, with a heritability value of 89-98% for plump grains (2.3 mm sieve).

Although significant differences were observed among varieties in this study, the two test varieties produced acceptable maltable grain of more than 90%. On this basis, the two test varieties were comparable and therefore, choice of variety for either of the sites on this basis could be combined with a consideration of other yield and malting quality components. This result is consistent with (Glen *et al.,* 2006) who reported that, although varietal differences exist for maltable grains, most of them attained retention values in the range of 88 to 96%, indicating that selecting barley genotypes can be based on those genotypes that maintain large and stable grain size across a range of environments. Bentayehu (2013) also reported low grain size variation across locations and that some genotypes were more stable. Grain nitrogen concentration is one of the most important malting qualities of barley.

At the Mau Narok site, the two test varieties; HKBL 1512-5 (2.33%) and HKBL 1385-13 (2.21%), not only had superior grain nitrogen concentration, but the concentration exceeded the upper limit acceptable to maltisters in Kenya which is 2.2%. However, at the university of Eldoret site, both test varieties HKBL 1512-5 (1.97%) and HKBL 1385-13 (1.87%), were significantly different from each other but similar to the control variety Nguzo (1.91%), (Table 4). The two test varieties accumulated grain nitrogen concentration within the acceptable malt-grade range of 1.7 – 2.2 %. On this basis alone, both test varieties HKBL 1512-5 (2.33%) and HKBL 1385-13 (2.21%) were found to be unsuitable for the more fertile Mau Narok site, whereas, both were suitable for the university of Eldoret site. Mackenzie, (2005) reported modest grain protein differences among varieties and across 71% of the locations. He further reported acceptable grain protein content at 50-60 % of the sites tested. Molina-cane, *et al.*, (2001) reported a consistent 2% difference in grain protein content between varieties across sites. Low grain nitrogen concentration lowers enzymatic activity during steeping whereas high grain N-content leads to fizzing in the final product, beer. Therefore, varietal selection for malting quality at either of the sites can be based more on the grain nitrogen concentration than on the maltable grain. However, this criterion should be combined with other yield components to maximize both grain yield and grain quality.

Conclusions

1. HKBL 1385-13 out yielded both Nguzo and the HKBL 1512-5 at both sites
2. HKBL 1512-5 had consistently superior 1000-kernel weight and proportion of maltable grain, but with poor agronomic traits for yield components of productive tillers plant^{-1}, spike length, number of grains spike^{-1} and overall grain yield at all sites
3. Proportion of maltable grain for all test varieties was above the lower limit for all the two test varieties at either of the sites
4. At the U.o.E site all varieties accumulated grain N-concentration within the acceptable range for malting, whereas, at the Mau Narok site, both HKBL 1512-5 and HKBL 1385-13 accumulated grain N-concentration above the upper limit

Recommendations

1. HKBL 1385-13 is suitable for the university of Eldoret site based on its high grain yield resulting from high tillering. However, its selection for the Mau Narok site should consider other agronomic practices that will lower its grain nitrogen concentration e.g. higher seed rates or lower nitrogen fertilizer application rates.
2 HKBL 1512-5 is more suitable for crop improvement of other malt barley varieties since it has superior traits of 1000-kernel weight and proportion of maltable grain but poor traits for grain yield components.

References

Akar, T., M. Avci, F. Ducunceli (2004). *Barley : Post-harvest operations.* The central research institute for field crops, Ulns, Ankara, Turkey. http://www.fao.org/.../user../**Post_Harvest_-_BARLEY.**pdf. Accessed on 16/6/2012

Australian Govt. (2008).The biology of Hordeum vulgare L. (Barley).Office of the Gene Technology Regulator.Available at http://www.ogtr.gov.au.

Aynewa Y., T. Dessalegn, and W. Bayu (2013).Participatory Evaluation of Malt Barley and other Agronomic Traits at Northern Ethiopia.Wudpecker Journal of Agricultural Research VOL. 2(8), PP 218 -222

Bentayehu M. (2013). Study on malting barley genotypes under diverse agro ecologies of north western Ethiopia. African journal of plant science 7(11), pp 548-557.

Bleidere M., (2008).Genetic and environmental effect on the grain quality of spring barley.Latvian journal of agronomy 11:33-39

Bulman P., D. E. Mather and D. L. Smith (1993).Genetic improvement of spring barley cultivars in Eastern Canada.Euphytica 71:35-48

EPZA (Export Processing Zone Authority) (2005). *The Kenyan beer industry.* Nairobi, Kenya. Available at http;//www.epzakenya.com/UserFiles/Beer.pdf.

FAO (Food and Agriculture Organization), (2003), Explore on-farm: On-Farm Trials for Adapting and Adopting Good Agricultural Practices.Food and Agricultural organization of the United Nations, Viale delle Terme di Caracalla, Rome, Italy.

Fettell, N.A., D.B. Moody, N. Long and Flood, (1999).Determinants of Grain Size in malting barley.In ''9th Australian Barley Technical Symposium''. Melbourne, Victoria. (Eds. D. B. Moody, R. G. Flood) (The Regional Institute Ltd).

Glen P. F., A. Kelly, D. Poulson, A. Inkerman, and R. Henry (2006).Selecting for increased barley grain size Journal of cereal science, Vol. 43 (2) pp. 198-208.Online at http://dx.org/10.106/j./jcs 2005 08 004. Accessed 21-08-2013.

Gomez, K. A., and A. A. Gomez (1976).Statistical procedures for agricultural research, with emphasis on rice.International Rice Research Institute; Los Banos, Phillippines.

ISTA (International Rules for Seed Testing), Rules (1996).International Seed Testing Association (ISTA). Seed Science and Technology 24 (supplement). Zurich, Switzerland.

Jaetzold, R. and H. Schmidt, (1982).Farm management handbook of Kenya, vol. IIIB.Nairobi, Kenya.

Jalal A. A. and H. A. Ahmad (2012). Genetic Variation, Heritability, Phenotypic and Genotypic Correlation Studies for Yield and Yield Components in Promising Barley Genotypes. Journal of Agricultural Science, Vol. 4, No. 3; pp 193-210

Jung-cang Q., C. Jin-xin, W. Jun-mei, W. Fei –bo, C. Lian-pu and Z. Guo-ping (2005). Protein and hordein fraction content in barley seeds as affected by sowing date and their relations to malting quality. Journal of Zhejiang university science b. 6(11): 1069-1075

Junmei W., Guoping Z., Jinxin C., Quiqnan S. and Feibo W. (2003).Genotypic and environmental variation in barley beta-amylase activity and its relation to protein content.Food Chemistry 83(2): pp163-165

Kavitha G., G. S. Dhindsa, S. Singh and J. Singh (2009).Stability Analysis of Yield and its Components in Malt Barley (Hordeum vulgare L.) Genotypes; Journal of Crop Improvement 36 (1): 29 – 34.

Krizanova K.; Z. AlZbeta, H. Michaela, S. Lodovlt, G. Sona, M. Daniela, G. Jozef and H. Jana (2010).Grain yield and malting quality of new spring barley genotypes.Agriculture/pol'nohospodarstvo, 56(3):90-94

McClelland, K.P., B. Green, D. Campell, Dr. B. Rossnagel, J. Foster, Dr. N. Kendall (2009).Malting Barley.Available online at;
http: www.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdexx98

Mckenzie R., H., A.B. Middleton and E. Brener (2005). Fertilization, Seeding rate and Seeding date of Malting Barley Yield and Quality in Southern Alberta. Canadian Journal of Plant Science 85 (3): 603-614. Online at; http://pubs/ac/doi/abs/10.4141.

Molina-Cane, J. P. Polo, E. Romera, J. L. Arans, J. Zarco and J. S. Swaston (2001). Relationship between Barley Hordines and Malting Quality in Mutant of cv. Triumph 1; Genotype by Environment Interaction on Hordein Content (abs). *Journal of Cereal Science* 34 (30): 285-294.

Nanak C., S. R. Vishwakarma, O. P. Verma and M. Kumar (2008).Worth of Genetic Parameters to Sort out New Elite Barley Lines over Heterogeneous Environments. Barley genetics newsletter 38:10-13

Newton, A.C., A.J. Flavell, T.S. George, P. Leat, B. Mullholland, L. Ramsay, C. R. Giha, J. Russell, B.J. Stefferson, J.S. Swanston, W.T.B. Thomas , R. Waugh, P.J. White, I.J. Bingham (2011).Crops that feed the world 4. Barley: a resilient crop? Strengths and weaknesses in the context of food security. Food Security 3:141-178.

O'Donovan, J .T., T. K. Tarkington, M .J. Edney, G. W. Clayton, R. H. Mackenzie, P. E. Justkiw, G. P. Lafond, C. A. Grant, S. Brandt, K. N. Harker, E. N. Johnson and W. E. May (2011). Seeding Rate, Nitrogen Rate And Cultivar Effects On Malting Barley Production. Agronomy Journal 103 (3); 709-716 (doi: 10.2134/agronj2010.0490).

Okalebo, J.R., K.W. Gathua and P.L. Woomer (2002).Laboratory methods of soil and plant analysis: A Working Manual, 2ndedition.TSBF-CIAT and SACRED AFRICA, Nairobi Kenya.

Panda, S. C. (2005) *Agronomy AGRIBIOS, INDIA*

Rao W. M., A. Qayyyum, S. Liaqat, A. Hamza, M.M. Yousaf, B. Ahmad, J. Shah, M. Hussain, A. N. Ahsan, S. H. Qurashi and E. Noor (2012).Variability, Heritability and Genetic Advance for Some Yield and Yield Related Traits in Barley (Hordeum vulgare L.) Genotypes in Arid Conditions; Journal of Food, Agriculture and Environment Vol. 10 (3&4): pp. 626 – 629).

Shengguan C., G. Yu, X. Chen, Y. Huang, X. Jiang, G. Zhang and X. Jin (2013).Grain protein content variation and its association analysis in barley.BMC Plant Biology 13:35 (doi: 10.1186/1471-2229-13-35).

Soudabeh A., D. Hassanpanah, N. Mohebalipour, and M. Ghasemi (2013).Evaluation of Genetic Diversity Genotypes of Barley Using Agronomic and Morphological Traits.International Journal of Agronomy and Plant Production Vol. 4 (2): 350-354

Sukram P., S. Tejveer and B. Ramesh (2010). Estimation of Genetic Parameters in Barley (Hordeum vulgare L.); Journal of Crop Improvement (Abs.) 37 (1): pp. 52 – 56

Tambussi E. A., S. Nogues, P. Ferrio, J. Voltas and J.L. Araus (2005). Does Yield Potential Improve Barley Performance in Mediterranean Conditions? A Case Study; Field Crops Research, 91: pp149 – 160

Tamm, U., (2003).The variation of agronomic characteristics of European malting barley varieties.Agronomy Research 1:99-103

Zadock J. C., T. T. Chang and C. F. Konzak (1974). A decimal code for the growth stages of cereals. Weed Res., 14:415-421.

Appendix

Table 1: Rainfall Amount in mm during the growth Phase at Mau Narok and U. o. E

Mau Narok (August, 2011 – January, 2012)		U. o. E (May – September, 2012)	
Month	Amount (mm)	Month	Amount (mm)
August 2011	97	May	231.2
September	73	June	140.6
October	83	July	137.8
November	100	August	110.3
December	61	September	99.5
January, 2012	30	October	0
Total	**444**		**719.4**

Table 2: Extractable Soil Nutrients at Mau Narok and U. o E Experimental Sites

Site	Site history	Core depth	pH(H_2O)	P(ppm)	Total N(%)	% OC
Chepkoilel	Stubble	0 – 15 cm	4.75	8.62	0.13	1.93
Mau Narok	Stubble	0 – 15 cm	5.40	18.75	1.16	2.14
Chepkoilel	Stubble	15 – 30cm	4.70	7.99	0.13	1.92
Mau Narok	Stubble	15 – 30cm	5.30	15.46	1.01	2.42

Table 3: Comparison of Yield Components among Promising Barley Varieties

Variety	G/Yield (T/Ha^{-1})	P/Stand (plants m^{-2})	P/Tillers (plant^{-2})	G/Spike^{-2} (No.)	1000-grain wt. (g)
	MAU NAROK SITE 2012				
HKBL 1512-5	4.0 c	180 a	4.9 a	25.7 b	52.5 a
NGUZO	4.4 b	147 b	6.6 b	29.4 a	47.6 c
HKBL 1385-13	4.9 a	140 b	6.2 b	29.1 a	49.0 b
Mean	**4.4**	**156**	**5.9**	**28.1**	**49.7**
LSD	0.28	9	0.61	0.48	0.86
CV (%)	13.2	11.7	21.7	3.6	3.6
UNIVERSITY OF ELDORET FARM SITE 2012					
HKBL 1512-5	3.8 b	173 a	2.7 a	24.8 b	49.9 a
NGUZO	3.7 b	203 b	2.9 a	28.9 a	41.8 b
HKBL 1385-13	5.1 a	192 b	5.8 b	28.8 a	49.8 a
LSD	0.22	11	0.5	0.15	0.59
Mean	**4.2**	**189**	**3.8**	**27.5**	**47.2**
CV (%)	11.1	12.0	27.6	3.8	2.6

Table 4: Comparison of Quality Components at Individual Sites

Variety	M/Grain (g/kg)	Grain Nitrogen Concentration (%)
MAU NAROK SITE 2012		
HKBL 1512-5	980 a	2.33 a
NGUZO	962 b	2.08 c
HKBL1385-13	965 b	2.21 b
LSD	3.7	0.043
CV (%)	0.8	3.1
UNIVERSITY OF ELDORET SITE 2012		
HKBL 1512-5	982 a	1.97 a
NGUZO	876 b	1.91 ab
HKBL 1512-5	988 a	1.87 b
LSD	8.9	0.07
CV (%)	2.0	3.9