UNDER PEER REVIEW

Evaluation of Genotype x Environment Interaction and Stability of grain yield and related yield components in Pearl Millet (*Pennisetum glaucum* (L.) R.Br.) genotypes

Abstract

Thirty six pearl millet genotypes were evaluated in randomized complete block design with two replications during 2011/2012 at two locations to study the magnitude of genotype by environment interaction for yield and yield related traits and identify the most stable high yielding genotypes. ANOVA of data at individual location revealed significant differences among genotypes at Marigat and Koibatek for all yield components.Combined mean analysis of variance showed that the Genotype and location main effects and the genotype by environment interaction were highly significant ($P \leq 0.01$) for grain yield and other traits, indicating differential response of genotypes across testing locations and the need for stability analysis. Marigat was the most suitable environment and gave highest mean grain yield of 3620kg/ha. The lowest yield (870 Kg/ha) was observed at Koibatek. Genotypes EUP 32, EUP 35, EUP 19 and EUP 10 produced high mean yield of 3530, 3080, 2690 and 2590kg/ha respectively. The lowest grain 1290kg/ha was obtained from genotype EUP 4. Eight stability parameters were used to identify stable pearl millet genotypes for wide growing conditions. Based on the parameters of stability, three stable (widely adapted) and high yielding genotypes (EUP 34,EUP 18, and EUP 9 were identified. They also out yield the standard open pollinated check. GGE biplot techniques was used identify specifically adapted genotypes. EUP 32 (No bristle) was specifically adapted to Marigat, EUP 7 (No bristle) to Koibatek. Analysis of principal component showed that the first and second principal component explained 50.43 % and 49.57% of the total genotype by environment interaction. These stable high yielding genotypes can be evaluated further for possible release as commercial checks.

Keywords: *Genotype by environment interaction, Stability, Pearl millet, Yield*

Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is one of the world's hardiest warm season cereal crop and in the tropical and sub-tropical regions of the world. It is ranks the second among stable foods in east and central Africa Mgonja *et al*., (2006). Pearl millet is a crop of hot and dry climates, and can be grown in areas where rainfall is not sufficient (250-600 mm) for other cereal crop. Like sorghum. In Kenya the total area under pearl millets is about 93,310 ha, producing about 68,800 tons per annum with productivity of 200-800 Kg ha^{-1} against yield potential of 1500-3000 Kg ha^{-1}. Pearl millet is, however, important in south eastern Kenya comprising mainly Tharaka, Mbeere, Mwingi, Kitui, Makueni and also drier areas of the Rift Valley mainly in Baringo, Elgeyo Marakwet and West Pokot. Eastern province is the main producer of millet, producing over 60% of the total millet while Rift valley produces less than 10% Omamo *et al*., (2006).

Several types of millet exist in production in different parts of the world. Statistics indicate over 50% of the total millet grain production is pearl millet, 30% proso/golden and fox tail millet and 11% finger millet. The remaining 8 species are of little economic importance and account for only 10% of the world millet production (EPZ, 2005). The widespread impression that pearl millet grain is essentially an animal feed, unpalatable to all but the desperately hungry, is wrong. The grain is actually a superior foodstuff, containing at high protein and a good balance of amino acids. It has more oil than maize and is a "high-energy" cereal. Pearl millet is also a versatile foodstuff since it has neither the tannins nor the other compounds that reduce digestibility in sorghum. It can make non-alcoholic beverages, and snacks and grain from certain cultivars is roasted whole and consumed directly. Moreover amongst all cereals (maize, sorghum, finger millet etc) pearl millet is the most nutritious with

UNDER PEER REVIEW

high levels of protein (up to 12%) and energy (3600 K cal kg^{-1}). It has a balanced amino acid profile making it a cheap source of grain iron (Fe) and zinc (Zn) (Parthasarathy *et al*., 2006; ICRISAT, 2007). The crop also forms an excellent feed to livestock both as grain and forage and thus advantageous as a dual purpose (Yadav *et al*., 2011). Pearl millet is easy to grow and suffers less from diseases than sorghum, maize, or other grains.

Yield performance in crops, the observed phenotype, is a function of genotype, environment and genotype by environment interaction. Genotype by environment interaction is commonly observed as differential position of cultivar performances among locations. Genotype by environment interaction is evaluated when different genotypes respond differently to diverse environments. Scientist have long been aware of the various outcomes of Genotype by environment interaction in breeding program. Genotype by Environment interaction is important only when it is significant and causes significant change in genotypes ranks in different environments. A significant genotype by environment interaction can seriously impair efforts to selecting superior genotypes for crop introductions and cultivar development programs (Yan and Racjan, 2002). Yield is a dependent character resulting from interplay of various related traits. It is influenced by the growing environment and its heritability is low. As a result, direct selection for yield is less efficient in improving productivity of the crop. The knowledge of degree of association existing between yield and its attributes and further among yield components is very important for selection. This assumes greater importance in pearl millet because, the grain are formed in panicle and unless association between plant characters and yield are established, it may not be possible to effect proper selection of plants prior to harvest. For successful selection it is necessary to study the nature of association of characters with other relevant traits. Path coefficient analysis provides better means for selection by resolving the correlation coefficients of yield and its components into direct and indirect effects. Principal components analysis is a multivariate analysis used to study the kind of variation present in a selected population (Toker, 2004) and multivariate polymorphism (Mallikarjuna *et al.,* 2003). First principal component and the second principal component normally accounts for the first and second highest amount of variance and so on (Broschat, 1979). Principal component analysis across the trials when data was pooled across the environments indicated that, only four principal components were significant. According to Hair et al. (1998) Eigen value greater than 1 are considered significant and component loadings greater than ± 0.3 were deemed meaningful. As a result, only the first four principal components were used for the study and traits with loadings greater than ±0.3 were taken to represent the corresponding principal axis. Similar results were obtained by Kiprotich *et al* (2015) when they analyzed 60 pearl millet genotypes for their biochemical composition. In this study 4 PCAs accounted for a total variation of 81% with PCA 1 accounting for 27.7% and PCA 2 accounting for 19.1%. PCA 3 accounted for 18.5 and the 4th PCA accounting for 15.6%. These results were similar to Wedajo (2014) who found out four principal components with the first PC closely associated with days to maturity, days to 50% flowering and days to 50% maturity when he evaluated 16 pearl millet genotypes. The results indicate that; number of reproductive tillers and plant height and panicle characteristics are important traits to be considered in breeding for grain yield.

Furthermore, the importance of evaluating many potential genotypes in different environments (Location and seasons) before selecting desirable ones for release and commercial cultivation has been recognized by breeders (Gupta 1991). A desirable cultivar is one that does not only yield well in its area of initial selection, (Yahaya*et al.*, 2006). The objectives of the study were to determine genotype by environment interaction for yield and yield traits in selected pearl millet genotypes and their yield stability across varied agro-zones.

UNDER PEER REVIEW

Materials and Methods

Experimental Sites

The experiment was conducted at two locations, (Marigat and Koibatek) in Baringo county during 2011/12 cropping season. These locations are found within altitudinal ranges of 1890m.a.s.l and are in the range of environments suitable for pearl millet growth. The study area (Marigat and Koibatek) are characterized as hot to warm semi-arid lowlands. Since these locations are different in soil type, altitude, mean annual temperature andrainfall, they were considered as an individual environment. Description of the study locations is given in Table1

Table1: Description of the experimental locations and their overall agro-climatic conditions.

Location	Altitude	Rainfall (mm)	Mean temperature(^{o}c)	Soil type
Marigat	1500	500mm	10 – 28°c	Loam to sand
Koibatek	1890	800mm	23 – 37 ^{o}c	Loam to sand

Source: National Meteorological Department (KALRO Perkerra)

Experimental Materials (genotypes)

Thirty six genotypes of pearl millet obtained from ICRISSAT Nairobi were used in this study.

The description of the genotypes included in the experiment is given in table 2.

Table2. List and descriptions of pearl millet genotypes studied at two locations in 2011/12

Genotypes	Source	Remarks	Phenology
EUP 1	INCRISAT	Hybrid	Moderate resistant to drought
EUP 2	INCRISAT	Hybrid	moderate resistant to drought
EUP 3	INCRISAT	Hybrid	moderate resistant to drought
EUP 4	INCRISAT	Hybrid	moderate resistant to drought
EUP 5	INCRISAT	Hybrid	moderate resistant to drought
EUP 6	INCRISAT	Hybrid	moderate resistant to drought
EUP 7	INCRISAT	Hybrid	moderate resistant to drought
EUP 8	INCRISAT	Hybrid	moderate resistant to drought
EUP 9	INCRISAT	Hybrid	moderate resistant to drought
EUP 10	INCRISAT	Hybrid	moderate resistant to drought
EUP 11	INCRISAT	Hybrid	moderate resistant to drought
EUP 12	INCRISAT	Hybrid	moderate resistant to drought
EUP 13	INCRISAT	Hybrid	moderate resistant to drought
EUP 14	INCRISAT	Hybrid	moderate resistant to drought
EUP 15	INCRISAT	Hybrid	moderate resistant to drought
EUP 16	INCRISAT	Hybrid	moderate resistant to drought
EUP 17	INCRISAT	Hybrid	moderate resistant to drought
EUP 18	INCRISAT	Hybrid	moderate resistant to drought
EUP 19	INCRISAT	Hybrid	moderate resistant to drought
EUP 20	INCRISAT	Hybrid	moderate resistant to drought
EUP 21	INCRISAT	Hybrid	moderate resistant to drought
EUP 23	INCRISAT	Hybrid	moderate resistant to drought
EUP 23	INCRISAT	Hybrid	moderate resistant to drought
EUP 24	INCRISAT	Hybrid	moderate resistant to drought
EUP 25	INCRISAT	Hybrid	moderate resistant to drought
EUP 26	INCRISAT	Hybrid	moderate resistant to drought
EUP 27	INCRISAT	Hybrid	moderate resistant to drought
EUP 28	INCRISAT	Hybrid	moderate resistant to drought
EUP 29	INCRISAT	Hybrid	moderate resistant to drought
EUP 30	INCRISAT	Hybrid	moderate resistant to drought
EUP 31	INCRISAT	Hybrid	moderate resistant to drought
EUP 32	INCRISAT	Hybrid	moderate resistant to drought
EUP 33	INCRISAT	Hybrid	moderate resistant to drought
EUP 34	INCRISAT	Hybrid	moderate resistant to drought
EUP 35	INCRISAT	Hybrid	moderate resistant to drought
KAT PM 2	KALRO	Commercial Check	high resistant to drought

Experimental Design and Trial Management

The Randomized Complete Block Design (RCBD) with two replications was used to conduct the experiments. The experiments were planted at different times due to difference in the planting time for the test locations; Marigat, were planted in March while Koibatek were planted in May.

UNDER PEER REVIEW

Seeds of each genotype were planted at a rate of 40 kg /ha in a plot consisting of four rows each 2m long and 2m width with 0.5m inter-row spacing resulting a plot size of $4m^2$. Thinning was done four weeks after planting plants to obtain a uniform plant density. At Marigatsupplementary furrow irrigation was given because of low rainfall,

Data Collection

Five plants from two middlerows was used for data collection and harvested at maturity. Individual plant data as well as plot data were collected on different traits of pearl millet genotypes. Data recorded on individual plant were plant height (cm), total number of tillers per plant, number of productive tillers per plant, panicle length (cm) and weight of grain per head (g). Five plants' average was used for statistical analysis. Data collected on plot include 1000 seed weight (weight of 1000 seeds in gram drawn randomly from the bulk seeds of each plot).

Statistical Analysis

Analysis of Variance (ANOVA)

Randomized Complete Block Design Analysis of variance was done for all data of each location separately after checking for homogeneity of experimental error. The following model was used for ANOVA of data of individual location.

General Mathematical Model for Individual Site

$$y_{ijk} = \mu + \rho_i + \tau_j + \tau\rho_{ij} + \varepsilon_{ijkl}$$

Where

$y_{ijk} =$ The individual observation in each Plot;

μ = Overall mean

ρ_i = Complete effect of the block;

τ_j = the estimate of jth treatment (hybrid) effect.

ε_{ijkl} = Overall error effect to the ij observation.

General Mathematical Model for ANOVA across Environments:

$$y_{ijk} = \mu + \alpha_i + \rho(\alpha)_j + \tau\rho_{ik} + \varepsilon_{ijkl}$$ (Montgomery, 2005)

Where:

$y_{ijk} =$ The individual observation in each Plot;

μ =Overall mean for each variable,

α_i= estimate of the environmental effect;

$\rho(\alpha)_j$= estimate of the jth block effect in i^{th} environment;

$\tau\rho_{ik}$= estimate of the kth hybrid or variety.

ε_{ijkl}= Overall error effect in relation to ijkl observation.

UNDER PEER REVIEW

Stability Analysis

Stability Analysis was considered on each individual genotype. Environment and replication were considered random, while genotypes effects were fixed, F- test was used to check the significance of the pearl millet hybrid and the environmental effects, as well as the genotype-by- environment (G X E) interactions. GGE biplot analysis was done to determine stability and pattern of response of genotypes in the test siteusing the first two principal components (PC1 and PC2) that were derived from subjecting environment to singular value decomposition.

Results and Discussion

Performance of test genotypes in each location

All data collected was subjected to Analysis of variance for individual environment and combined environments. These included total number of tiller (number of tillers), number of reproductive tillers (NRT), grain yield (GY), plant height(PH), panicle length (PL) and grain per head (GH). ANOVA data for both individual as well as combined analysis for grain yield, and other eight traits were discussed separately below (Table3 and 4) The results showed that there was significant difference amongst the at all location for grain yield (GY).

The mean grain yields at individual locations (Table 3 & 4) ranged from 3600 kg/ha to 800 kg/ha at Marigat and Koibatek, respectively. Marigat gave highest grain yield of 3600kg/ha. This is because these two locations are not similar in mean annual rainfall and temperatures (Table 1). Despite the high rainfall, Koibatek gave lowest yield of 800kg/ha. These may be due to high monthly total rainfall and low temperatures which affected flowering stage of the crop. Genotypes EUP 32 and EUP 35 gave highest yield at Marigat, respectively. These genotypes were recommended for further evaluation and possible release since they had double the yields than the current OPVs commercial checks KAT PM2 (2800kgs/ha). The findings of this study showed that pearl millet hybrids has high potential for commercial production in Kenya than the OPVs.

Table 3: Yield related traits of thirty six pearl millet hybrids evaluated at Marigat in 2012/2013 short and long rains.

Entry	No. Reproductive tillers	No. Vegetative tillers	Plant. Height(cm)	Panicle Length (cm)	Panicle weight (g)	Panicle diameter (cm)	Seed weight(g)	Yield t ha^{-1}
KAT PM2	5.8	10.1	185.4	21.1	34.2	5.7	10.4	2.8
EUP 1	6.7	13.7	189.7	22.4	36.0	5.9	13.6	3.6
EUP 2	6.7	10.8	188.6	22.4	35.8	5.9	12.9	3.4
EUP3	6.8	13.3	178.0	22.8	36.0	5.9	13.7	3.7
EUP 4	5.2	9.8	177.3	19.9	32.3	5.3	8.8	1.7
EUP 5	6.5	13.4	185.1	22.2	35.5	5.9	12.9	3.3
EUP 6	7.2	14.5	206.1	22.8	36.9	6.2	14.5	4.0
EUP 7	6.9	14.6	205.2	22.0	36.5	6.1	13.8	4.0
EUP 8	6.0	11.0	181.8	21.3	35.0	5.7	11.4	3.2
EUP 9	6.9	14.3	185.5	23.0	36.4	6.1	13.8	3.8
EUP 10	7.0	13.4	206.4	22.5	36.7	6.2	14.2	4.0
EUP 11	5.7	11.6	184.4	21.0	34.1	5.7	10.1	2.8
EUP 12	7.0	14.4	206.6	23.1	36.7	6.2	14.2	4.0
EUP 13	6.4	12.9	203.6	22.2	35.5	5.9	12.9	3.3
EUP 14	5.8	13.6	187.5	21.4	34.9	5.7	11.4	3.2
EUP 15	7.4	14.7	183.7	24.1	37.1	6.2	14.7	4.1
EUP 16	6.1	13.3	189.4	21.7	35.1	5.7	11.7	3.2
EUP 17	7.3	14.6	207.4	23.8	36.9	6.2	14.6	4.0
EUP 18	6.6	13.9	188.6	22.4	35.7	5.9	12.9	3.7
EUP 19	7.5	14.3	208.8	24.3	37.5	6.3	15.4	4.6
EUP 20	6.4	13.6	187.1	22.4	35.3	5.9	12.7	3.4
EUP 21	6.3	14.4	187.9	22.2	35.3	5.9	12.4	3.3
EUP 22	5.7	11.9	183.5	20.9	33.9	5.4	9.0	2.8
EUP 23	7.4	13.2	208.1	24.2	37.2	6.3	15.2	4.1
EUP 24	5.6	9.8	182.2	20.8	33.4	5.3	9.0	2.5
EUP 25	6.2	14.3	185.1	22.2	35.2	5.8	12.3	3.3

UNDER PEER REVIEW

EUP 26	7.0	14.1	206.2	23.1	36.6	6.1	13.9	4.0
EUP 27	6.1	14.1	198.9	21.9	35.1	5.8	12.4	3.2
EUP 28	6.9	14.1	199.6	21.5	36.1	6.0	13.8	3.8
EUP 29	6.8	14.1	198.6	22.9	36.0	5.9	13.7	3.6
EUP 30	5.7	14.1	188.1	21.2	34.5	5.7	11.0	3.1
EUP 31	5.7	11.1	183.6	21.3	34.6	5.7	11.9	3.1
EUP 32	7.8	15.2	209.4	25.4	37.7	6.1	17.2	6.2
EUP 33	5.7	10.1	186.3	21.2	34.4	5.7	10.9	2.9
EUP 34	6.6	13.6	189.4	22.3	35.6	5.9	12.9	3.6
EUP 35	7.7	14.9	209.1	24.5	37.5	6.3	16.4	5.3
G. Mean	**6.5**	**13.2**	**194.3**	**22.4**	**36.0**	**6.01**	**12.9**	**3.6**
C.V (%)	**37.1**	**25.2**	**11.6**	**11.7**	**22.4**	**21.8**	**28.1**	**24.4**

Table 4: Yield related traits of thirty six pearl millet hybrids evaluated at Koibatek in 2012/2013.

Genotypes	Vegetative tillers (No)	Reproductive tillers (No)	Plant height (cm)	Panicle Length (cm)	Panicle weight (g)	Panicle diameter (cm)	1000 seed weight (g)	Yield tha^{-1}
KAT PM2	13.9	10.3	180.7	17.6	10.8	2.5	9.2	0.8
EUP 1	15.0	9.6	138.3	16.7	9.4	2.3	8.2	0.7
EUP 2	12.9	11.0	174.8	18.1	11.2	2.6	9.8	0.8
EUP3	12.9	9.5	139.3	16.6	9.4	2.3	8.2	0.7
EUP 4	11.9	10.0	171.4	16.9	10.5	2.5	9.2	0.8
EUP 5	14.7	8.6	139.0	16.1	8.8	2.1	7.7	0.6
EUP 6	11.7	11.7	176.4	19.0	13.2	2.7	11.3	0.9
EUP 7	13.3	13.8	193.0	21.5	14.9	3.0	13.5	1.1
EUP 8	13.9	9.7	138.9	16.7	9.5	2.4	8.5	0.7
EUP 9	14.9	10.5	180.6	17.8	10.9	2.6	9.5	0.8
EUP 10	14.2	12.9	191.1	20.0	14.4	2.9	13.2	1.1
EUP 11	11.7	10.1	172.0	17.0	10.6	2.5	9.2	0.8
EUP 12	10.7	11.7	176.7	18.9	13.2	2.7	11.3	0.9
EUP 13	11.6	10.1	174.4	18.5	12.7	2.7	10.7	0.9
EUP 14	12.1	10.1	180.9	18.1	11.4	2.6	10.0	0.8
EUP 15	11.0	10.6	138.0	16.5	8.9	2.3	7.8	0.7
EUP 16	10.5	11.1	181.7	18.1	11.4	2.7	10.1	0.8
EUP 17	11.9	12.2	188.0	19.7	13.8	2.8	11.7	1.0
EUP 18	15.6	11.1	173.6	18.3	12.3	2.7	10.6	0.9
EUP 19	13.2	9.8	139.1	16.3	9.6	2.4	8.7	0.7
EUP 20	12.9	10.9	174.1	17.9	11.1	2.6	9.7	0.8
EUP 21	13.6	10.9	170.0	17.9	11.1	2.6	9.6	0.8
EUP 22	12.0	13.5	190.5	20.2	14.8	2.9	13.3	1.1
EUP 23	12.0	7.8	137.5	15.3	8.8	2.0	7.6	0.6
EUP 24	13.3	9.5	138.5	16.1	9.1	2.2	8.0	0.7
EUP 25	11.5	11.3	175.4	18.8	12.9	2.7	10.8	0.9
EUP 26	13.6	10.2	173.0	17.2	10.7	2.5	9.2	0.8
EUP 27	12.4	9.9	140.1	16.9	10.5	2.5	9.2	0.7
EUP 28	12.5	12.8	188.2	20.0	13.9	2.9	12.5	1.0
EUP 29	11.5	11.9	176.8	19.2	13.5	2.7	11.7	0.9
EUP 30	11.3	11.5	175.7	18.9	13.1	2.7	11.0	0.9
EUP 31	11.5	7.2	125.5	15.1	8.1	1.9	17.0	0.6
EUP 32	18.6	9.8	139.2	16.8	10.1	2.5	8.9	0.7
EUP 33	11.8	11.2	173.4	18.6	12.9	2.7	10.7	0.9
EUP 34	11.1	11.1	182.6	18.3	12.1	2.7	10.5	0.8
EUP 35	12.4	11.8	182.3	17.8	10.9	2.6	9.5	0.8
Grand mean	**12.8**	**10.6**	**166.4**	**17.9**	**11.0**	**2.5**	**9.9**	**0.8**
C.V (%)	**27.2**	**18.6**	**13.0**	**15.4**	**14.6**	**18.1**	**16.6**	**19.5**

UNDER PEER REVIEW

Effects of GXE in both sites combined

Combined analysis of variance for both sites for grain yield showed that the effects of locations and genotypes were significant for seeds all the measured traits (Table 5). Mean performance over locations for genotypes for all measured traits is presented in Table 5. The significant effect of locations is due to their variation in rainfall amount and seasonal distribution, temperature and soil type (Table 1).Therefore environments played a significant role in the expression of these traits. Genotypes were significantly different in mean number of tillers, number of reproductive tillers (NRT), grain yield(GY) , plant height(PH), panicle length (PL) and grain per plot (GH).

This result is in agreement with the findings of Yahaya (2005) and Mohammed (2005) in pearl millet in which effects due to environment and genotypes were very highly significant for all traits. The poorest genotypes across location were EUP 4 and EUP, respectively. Genotypes EUP 9 best adapted to Marigat and EUP 34 best adapted to Koibatek. EUP 32 gave high yield across locations. They showed wide adaption across locations in grain yield. In general, tillers and reproductive tillers were medium for yield attributing traits. The tallest genotype with highest grain yield, lowest vegetative tiller and reproductive tillers was EUP 32 while the shortest genotype was EUP 4. Other yield traits significantly varied as shown in Table 3 and 4.

Table 5:Mean for yield related traits of thirty six pearl millet hybrids evaluated at both sites combined at Koibatek and Marigat in 2012/2013.

Entry	No. Reproductive tillers	No. Vegetative tillers	Plant. Height(cm)	Panicle Length (cm)	Panicle weight (g)	Panicle diameter (cm)	1000 seed weight(g)	Yield t ha-1
KAT PM2	9.85	10.2	183.05	31.9	4.1	4.1	9.8	1.8
EUP 1	10.85	11.65	164	31.8	4.1	4.1	10.9	2.15
EUP 2	9.8	10.9	181.7	33.6	4.25	4.25	11.35	2.1
EUP3	9.85	11.4	158.65	32.2	4.1	4.1	10.95	2.2
EUP 4	8.55	9.9	174.35	30.4	3.9	3.9	9	1.25
EUP 5	10.6	11	162.05	31	4	4	10.3	1.95
EUP 6	9.45	13.1	191.25	36	4.45	4.45	12.9	2.45
EUP 7	10.1	14.2	199.1	36.9	4.55	4.55	13.65	2.55
EUP 8	9.95	10.35	160.35	30.8	4.05	4.05	9.95	1.95
EUP 9	10.9	12.4	183.05	33.9	4.35	4.35	11.65	2.3
EUP 10	10.6	13.15	198.75	36.9	4.55	4.55	13.7	2.55
EUP 11	8.7	10.85	178.2	31.6	4.1	4.1	9.65	1.8
EUP 12	8.85	13.05	191.65	36.3	4.45	4.45	12.75	2.45
EUP 13	9	11.5	189	34.9	4.3	4.3	11.8	2.1
EUP 14	8.95	11.85	184.2	32.8	4.15	4.15	10.7	2
EUP 15	9.2	12.65	160.85	33	4.25	4.25	11.25	2.4
EUP 16	8.3	12.2	185.55	33.1	4.2	4.2	10.9	2
EUP 17	9.6	13.4	197.7	37.6	4.5	4.5	13.15	2.5
EUP 18	11.1	12.5	181.1	34.7	4.3	4.3	11.75	2.3
EUP 19	10.35	12.05	173.95	33.9	4.35	4.35	12.05	2.65
EUP 20	9.65	12.25	180.6	33.5	4.25	4.25	11.2	2.1
EUP 21	9.95	12.65	178.95	33.3	4.25	4.25	11	2.05
EUP 22	8.85	12.7	187	35.7	4.15	4.15	11.15	1.95
EUP 23	9.7	10.5	172.8	33	4.15	4.15	11.4	2.35
EUP 24	9.45	9.65	160.35	29.9	3.75	3.75	8.5	1.6

UNDER PEER REVIEW

EUP 25	8.85	12.8	180.25	35.1	4.25	4.25	11.55	2.1
EUP 26	10.3	12.15	189.6	33.8	4.3	4.3	11.55	2.4
EUP 27	9.25	12	169.5	32.4	4.15	4.15	10.8	1.95
EUP 28	9.7	13.45	193.9	35.4	4.45	4.45	13.15	2.4
EUP 29	9.15	13	187.7	36.4	4.3	4.3	12.7	2.25
EUP 30	8.5	12.8	181.9	34.3	4.2	4.2	11	2
EUP 31	8.6	9.15	154.55	29.4	3.8	3.8	14.45	1.85
EUP 32	13.2	12.5	174.3	35.5	4.3	4.3	13.05	3.45
EUP 33	8.75	10.65	179.85	34.1	4.2	4.2	10.8	1.9
EUP 34	8.85	12.35	186	34.4	4.3	4.3	11.7	2.2
EUP 35	10.05	13.35	195.7	35.4	4.45	4.45	12.95	3.05
G. Mean	9.65	11.9	180.35	33.4	4.255	4.255	11.4	2.2
C.V (%)	32.15	21.9	12.3	26.3	19.95	19.95	22.35	21.95
GXE	**	*	*	**	**	*	**	**

Key: * , ** significant at 1 and 5% level of significance

Stability and GGE biplot analysis for Grain Yield

Genotype by environment interaction continues to be challenging issue among plant breeders, geneticists, and agronomist who conduct crop performance trials across different environments. For release of a variety for wider and variable environments, stability of performance had considerable importance for yield trials, especially when significant genotype x environment is detected. Therefore, GGE biplot was used to determine stability and the best genotypes in various locations. Ideal genotype should have both high performance and high stability hence genotypes EUP 34, 14, 20, 27 and EUP 21 was almost qualifying to be best genotypes. Similar findings were reported by Badu-Apraku *et al.,* (2011). The line which passes through the origin and is perpendicular to the average environment axis with arrows represents the stability of genotypes. Either direction away from the biplot origin on this axis indicates greater genotype by environment interaction and reduced stability (Yan, 2002). Thus, EUP 32 and EUP 7 are especially suitable for production at Marigat and Koibatek respectively.

The additive main effects was shown by results from GGE analysis (Fig 2). The findings showed that the first and second interaction principal component axis (PCA 1 and PCA 2), were significant and explained 50.43 % and 49.57% of the total genotype by environment interaction. This showed that the two PCAs accounted for 100% of the genotype by environment interaction. Distribution of genotype points in the GGE biplot (Fig 1) revealed that the genotypes, EUP 34, and EUP 9 were scattered close to the origin, indicating minimal interaction of these genotypes with locations. The remaining genotypes scattered away from the origin in the biplot indicating that the genotypes were more sensitive to environmental interactive forces. Interaction of genotypes with specific environmental conditions was judged by projection of genotype points on to environment. Accordingly EUP 32 and 35 had high interaction in Marigat, genotype EUP 7 had high interaction in Koibatek. The polygon view of the GGE biplot (Fig 2) indicates the best genotype(s) in each environment and groups of environments (Hunt, 2002). The highest yielding genotype in location Marigat was EUP 32 while in Koibatek the highest yielding genotypes was EUP 7. These varieties were stable across the two environments and are recommended for production by farmers.

UNDER PEER REVIEW

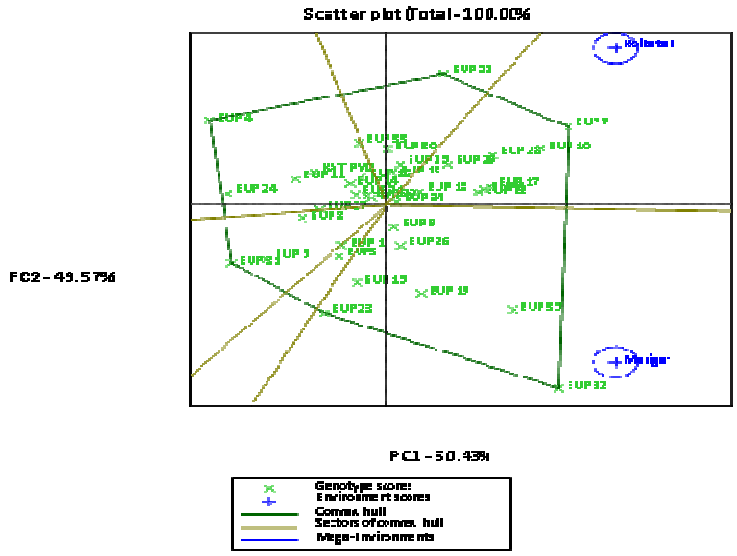

Fig 1: The best genotypes base on genotype by environment interaction.

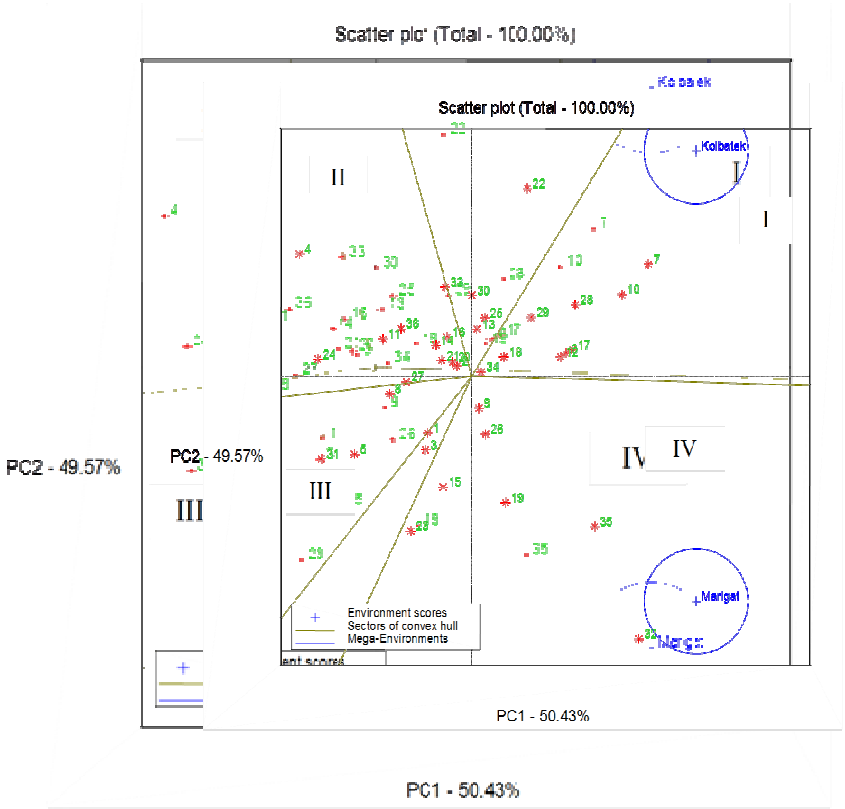

Fig 2. Biplot for PCA 1 vs PCA 2 scores of different genotypes.

Conclusion and Recommendation

The findings of this study showed that pearl millet hybrids has high potential for commercial production in Kenya than the OPVs. Genotypes EUP 32 and EUP 35 were highest yielding across all sites. Analysis of principal component showed that the first and second principal component explained 50.43 % and 49.57% of the total genotype by environment interaction.

UNDER PEER REVIEW

Results on stability and wide adaptation and yield genotypes EUP 34,EUP 18, and EUP 9 were the best performing since they out yield the standard OPV check. These stable high yielding genotypes can be evaluated further and recommended for release as commercial hybrid varieties.

References

FAO, (Food and Agriculture Organization of the United Nation), (2008). Production Year book. Rome, Italy.

Gupta SC, Ndoye AT (1991). Yield stability analysis of promising pearl millet genotypes in Senegal. Maydica.36:83-86.

Hussien, Mohammed Ali., Asmund Bjornstand, A.H. Aastveit, and Trygve Berg.2000.SASGxESTAB-A SAS program for computing genotype by environment stability statistics. Awassa, Ethiopia.84p.

ICRISAT (2009). International Crops Research Institute for the Semi-arid Tropics, *Annual repor*t Nairobi, Kenya.

Mgonja, M.A., Shiferwaw B. K., and Mitaru, B., (2006) An assessment of sorghum and millet sub sector in ECA. Towards better integration and exploitation of productivity enhancement and market opportunities. *In Proceedings of ECARSAM stakeholders workshop,* Daresalaam, Tanzania, November 20-22, 2006

Mgonja et al, 2002.Pearl millet is important drought tolerant crop in tropical and sub-tropicalSelection criteria in pearl millet. *Crop Improvement, 20 (1).pp.21-26. ISSN 0256 - 0933.*

Omamo et al, 2006. Pearl millet is cereal crop in the drier parts of semi-arid tropics. eddy, K.N., S.A. Rao and M.H. Mengesha. 1996. Diversity in pearl millet germplasm from Central African Republic.*Genet.Res. Crop Evol. 43(4): 303-308Outlook Agric., 18:46-53.*

Kiprotich, F., Kimurto P., Ombui P., Towett, B., Jeptanui, L., Ojulong H., and Lagat, N.,(2015).Multivariate analysis of nutritional diversity of selected macro and micro nutrients in pearl millet (*Pennisetum glaucum*) varieties. African Journal of Food Science. V9.

Yadav, O.P. 1996. Pearl millet breeding: achievements and challenges, Plant Breed. Abst.,66:157-163.

Yan W.,L.A. Hint,Q.sheng and Z.szlavnics,2000.Cultivar evaluation and Mega-environment investigation based on the GGE biplot .crop science,40:597-605.

Yan, W. and L.A. Hunt.2002.Biplot Analysis of multi-environment trial data.In: kang, M.S.(ed) Quantitative Genetics, Genomics and Plant breeding. CAB International.Pp.289-303.

Yan, W., and Racjan, I. 2002.Biplot analysis of test sites and trait relations of soybean in Ontario.*Crop Sci.Vol.*42 .Pp.11-20.