

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

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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 locations 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 3620 kg/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 variety (OPV) check. These stable high yielding genotypes can be used for yield and evaluation trial with local check to be released as widely adapted varieties. GGE biplot techniques were used identify specifically adapted genotypes. EUP 32 (No bristle) was specifically adapted to Marigat, EUP 7 (No bristle) to Koibatek.

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

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Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is one of the world's hardest warm season cereal crop and in the tropical and sub-tropical regions of the world. It is ranked second among staple foods in east and central Africa (Mgonja et al., 2006). Like sorghum, 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. 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 especially 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. The eastern provinces are 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 that over 50% of the total millet grain production is pearl millet, 30% proso/golden and fox tail, millet and constitute approximately 11% finger millet. The remaining 8 species are of little

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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 a 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. Non-alcoholic beverages, and snacks can be made 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 high levels of protein (up to 12%) and energy (3600 K cal kg⁻¹). It has a cheap source of protein, grain iron (Fe) and zinc (Zn) (Parthasarathy *et al.*, 2006; ICRISAT, 2007). The crop also forms an excellent feed for livestock both as grain and forage and thus advantageous as a dual purpose crop (Yadav *et al.*, 2011). In addition, pearl millet is easy to grow and suffers less from diseases as compared to 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 rank 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 programs. Genotype by Environment interaction is important when it is significant and causes significant change in genotype ranks in different environments. A significant genotype by environment interaction can seriously impair efforts to select 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 has low efficiency in improving productivity of the crop. Knowledge of degree of association existing between yield as well as its yield components is very important for selection. This assumes greater importance in pearl millet because, grains are formed in panicle and unless association between plant characters and yield are established, it may not be possible to identify yield components 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 tool used to study the kind of variation present in a selected population (Toker, 2004) and multivariate polymorphism (Mallikarjuna *et al.*, 2003). The 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 in millet using data that was pooled across three environments indicated that, only four principal components were significant (Hair *et al.* (1998). According to Hair *et al.* (1998) eigen values greater than 1 are considered significant and component loadings greater than ± 0.3 are 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 four

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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). An ideal cultivar is one that constantly yields well in its area of initial selection as well as other new sites (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.

Materials and Methods

Experimental Sites

The study area (Marigat and Koibatek) are characterized as hot to warm semi-arid lowlands in which major crops are finger millet and sorghum. The experiment was conducted at two locations, (Marigat and Koibatek) in Baringo County during the 2011/12 cropping season. These locations are found within altitudinal ranges of 1500-1890m.a.s.l and are in the range of environments suitable for pearl millet growth. Since these locations are different in soil type, altitude, mean annual temperature and rainfall, they were considered as an individual environment. Description of the study locations is given in Table1

Experimental Materials (genotypes)

Thirty six genotypes of pearl millet obtained from ICRISAT Nairobi were used in this study. The description of the genotypes included in the experiment is given in table 2.

Experimental design and trial management

The experiment was conducted in a randomized complete block design (RCBD) with two replications. The experiments were planted at different times due to difference in the strating of the rainfall seasons in the two locations; Marigat, was planted in March while Koibatek was planted in May.

Seeds of each genotype were planted at a rate of 40 kg /ha in a plot consisting of four rows each 2m long and 0.75m inter-row and 0.20m intra-row spacing. Thinning was done four weeks after planting plants to obtain a uniform plant density. At Marigat supplementary furrow irrigation was given to allow uniform establishment because of low rainfall.

Data Collection

Five plants from two middle rows were 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), 1000 seed weight (weight of 1000 seeds) and yield per plot and per hectare.

Statistical Analysis

Analysis of Variance (ANOVA)

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All data collected were subjected to ANOVA using GENSTAT release 14.0 and treatment means were separated using LSD at $P \leq 0.05$ 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 ANOVA:

$$y_{ijkl} = \mu + \rho_i + \tau_j + \tau\rho_{ij} + \varepsilon_{ijkl} \quad (\text{Montgomery, 2005})$$

Where

y_{ijkl} = The individual observation in each Plot;

μ = Overall mean

ρ_i = Complete effect of the block;

τ_j = the estimate of j^{th} treatment (hybrid) effect.

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

General Mathematical Model for ANOVA across Environments:

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

Where:

y_{ijkl} = 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 j^{th} block effect in i^{th} environment;

$\tau\rho_{ik}$ = estimate of the k^{th} hybrid or variety.

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

Stability Analysis

ANOVA was carried to assess the stability of genotypes across the two environments. Environment and replication were considered random, while genotype effects were fixed. The F-test was used to check the significance of the pearl millet hybrid and the environmental effects, as well as the genotype x environment (G X E) interactions. Genotype x genotype x environment (GGE) biplot analysis (Yan et al., 2000) was done to determine stability and pattern of response of genotypes in the test site using the first two principal components (PC1 and PC2) that were derived from subjecting environment to singular value decomposition.

Results and Discussion

Analysis of Variance (ANOVA)

Analysis of variance for data of individual environment and combined environments. Data for total number of tiller (number of tillers), number of reproductive tillers (NRT), grain yield (GY),

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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 (Tables 3 and 4). The results showed that there was significant difference amongst the cultivars for grain yield (GY).

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The mean grain yields at individual locations (Tables 3 & 4) ranged from 3600 kg/ha at Marigat to 800 kg/ha at Koibatek. This is likely 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. These genotypes were recommended for further evaluation and possible release since they had double the yields than the current OPVs commercial checks (KAT PM2) which had a mean yield of 2800kgs/ha. The findings of this study showed that pearl millet hybrids had high potential for commercial production in Kenyas ASALs than the OPVs.

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Effects of GXE in both sites combined

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Combined analysis of variance for both sites for grain yield showed that the effects of locations and genotypes were significant for all the measured traits (Table 5). The combined mean showed effects of locations and genotypes were significant for all 8 traits (Table 3 & 4). Mean performance over locations for genotypes for all measured traits is presented in Table 5. The significant effect of locations is due to 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 among the cultivars. Genotypes were significantly different in mean number of tillers (no. 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 where environment effects had had highly significant on all test traits among the genotypes evaluated. Mean performance over locations for genotypes for grain yield, and other traits is presented in Table 5 respectively. 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 and showed wide adaption across locations in grain yield. In general, vegetative tillers and reproductive tillers were medium for yield attributing traits. The tallest genotype with highest grain yield, lowest vegetative tiller and reproductive tillers EUP 32 while the shortest genotype was EUP 4.

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Stability 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 of considerable importance for yield trials, especially when significant genotype x environment is detected. Therefore, GGE biplot analysis was used to determine stability and the best genotypes in various locations.

GGE biplot analysis of grain yield response and stability

Ideal genotype should have both high performance and high stability hence genotypes EUP 34, 14, 20, 27 and EUP 21 were ranked as the 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.

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Additive Main Effects.

The additive main effects based on GGE is shown in Fig 2. The findings showed that the first and second interaction principal component axes (PCA 1 and PCA 2), were significant and explained 50.43 % and 49.57% of the total genotype by environment interaction. Distribution of genotype points in the GGE biplot at figure 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 and genotype EUP 7 had high interaction in Koibatek. The polygon view of the GGE biplot (Figure 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, in Koibatek the highest yielding genotypes was EUP 7.

Conclusion and Recommendation

The findings of this study showed that pearl millet hybrids have high potential for commercial production in Kenya than the OPVs. Genotypes EUP 32 and EUP 35 were the highest yielding across all sites followed by EUP 35 and could be recommended for further multi-location evaluation and release. 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. The results on stability and wide adaptation showed that 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 in varied agro-ecologies and recommended for release as commercial hybrid varieties in ASALs of Kenya.

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

Location	Altitude	Rainfall (mm)	Mean temperature(°c)	Soil type
Marigat	1500	500mm	10 – 28°c	Heavy loam to sand
Koibatek	1890	800mm	23 – 37 °c	Light loam soils

Source: National Meteorological Department (KALRO Perkerra)

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

Genotype Entry	Source	Remarks	PHENOLOGYPhenology???
EUP 1	INCRIS	Hybrid	Moderately resistant to drought
EUP 2	INCRIS	Hybrid	Moderately resistant to drought
EUP 3	INCRIS	Hybrid	Moderately resistant to drought
EUP 4	INCRIS	Hybrid	Moderately resistant to drought
EUP 5	INCRIS	Hybrid	Moderately resistant to drought
EUP 6	INCRIS	Hybrid	Moderately resistant to drought
EUP 7	INCRIS	Hybrid	Moderately resistant to drought
EUP 8	INCRIS	Hybrid	Moderately resistant to drought
EUP 9	INCRIS	Hybrid	Moderately resistant to drought
EUP 10	INCRIS	Hybrid	Moderately resistant to drought
EUP 11	INCRIS	Hybrid	Moderately resistant to drought
EUP 12	INCRIS	Hybrid	Moderately resistant to drought
EUP 13	INCRIS	Hybrid	Moderately resistant to drought
EUP 14	INCRIS	Hybrid	Moderately resistant to drought
EUP 15	INCRIS	Hybrid	Moderately resistant to drought
EUP 16	INCRIS	Hybrid	Moderately resistant to drought
EUP 17	INCRIS	Hybrid	Moderately resistant to drought
EUP 18	INCRIS	Hybrid	Moderately resistant to drought
EUP 19	INCRIS	Hybrid	Moderately resistant to drought
EUP 20	INCRIS	Hybrid	Moderately resistant to drought
EUP 21	INCRIS	Hybrid	Moderately resistant to drought
EUP 23	INCRIS	Hybrid	Moderately resistant to drought
EUP 23	INCRIS	Hybrid	Moderately resistant to drought
EUP 24	INCRIS	Hybrid	Moderately resistant to drought
EUP 25	INCRIS	Hybrid	Moderately resistant to drought
EUP 26	INCRIS	Hybrid	Moderately resistant to drought
EUP 27	INCRIS	Hybrid	Moderately resistant to drought
EUP 28	INCRIS	Hybrid	Moderately resistant to drought
EUP 29	INCRIS	Hybrid	Moderately resistant to drought
EUP 30	INCRIS	Hybrid	Moderately resistant to drought
EUP 3	INCRIS	Hybrid	Moderately resistant to drought
EUP 32	INCRIS	Hybrid	Moderately resistant to drought
EUP 33	INCRIS	Hybrid	Moderately resistant to drought
EUP 34	INCRIS	Hybrid	Moderately resistant to drought
EUP 35	INCRIS	Hybrid	Moderately resistant to drought
KAT PM 1	KALRO OPV	Commercial Ch	Highly resistant to drought

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Comment [RX2]: Drought tolerance is not phenology. Phenology is about flowering and maturity.

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Table 3: Yield related traits of thirty six 35 pearl millet hybrids and an OPV evaluated at Marigat, Kenya 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)	1000 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
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

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Table 4: Yield related traits of thirty six five pearl millet hybrids and an OPV evaluated at Koibatek, Kenya 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

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Table 5: Means of thirty six five pearl millet genotypes hybrids along with an OPV tested for grain yield performance across two location in Kenya??

Genotypes	Season I	Season II	means
EUP 1	3.44abc	3.93abc	3.69abcd
EUP 2	3.21abc	3.71abc	3.46abcd
EUP 3	3.56abc	4.00abc	3.78bcd
EUP 4	1.57a	1.99a	1.78a
EUP 5	3.13abc	3.59abc	3.36abc
EUP 6	3.97abc	4.18abc	4.08bcd
EUP 7	3.90abc	4.17abc	4.04bcd
EUP 8	3.07abc	3.36abc	3.22abc
EUP 9	3.72abc	4.00abc	3.86bcd
EUP 10	3.82abc	4.30abc	4.06bcd
EUP 11	2.63ab	3.02ab	2.83abc
EUP 12	3.87abc	4.25ab	4.06bcd
EUP 13	3.09abc	3.63abc	3.36abc
EUP 14	2.96abc	3.93abc	3.45abcd
EUP 15	3.90abc	4.30abc	4.10bcd
EUP 16	3.13abc	3.02ab	3.08abc
EUP 17	3.90abc	4.25abc	4.08bcd
EUP 18	3.57abc	3.63abc	3.60abcd
EUP 19	4.37abc	4.85abc	4.61cd
EUP 20	3.19abc	3.63abc	3.41abc
EUP 21	3.13abc	3.52abc	3.33abc
EUP 22	2.60ab	3.02ab	2.81abc
EUP 23	3.92abc	4.47abc	4.20bcd
EUP 24	2.33ab	2.57ab	2.54ab
EUP 25	3.08abc	3.61abc	3.34abc
EUP 26	3.84abc	4.27abc	4.06bcd
EUP 27	3.01abc	3.47abc	3.24abc
EUP 28	3.71abc	3.96abc	3.84bcd
EUP 29	3.43abc	3.83abc	3.63abcd
EUP 30	2.95abc	3.28abc	3.12abc
EUP 31	2.96abc	3.40abc	3.18abc
EUP 32	6.18c	6.40c	6.29e
EUP 33	2.75ab	3.05ab	2.90abc
EUP 34	3.46abc	3.85abc	3.66abcd
EUP 35	5.14bc	5.51bc	5.33de
KAT PM2	3.41abc	2.34ab	2.88abc
Grand Mean	3.44	3.79	3.62
C.V%	38.5	35.4	33.6
Genotype	ns	ns	**

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Figure Legends

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

Figure 2: Biplot for PCA 1 vs PCA 2 scores of different genotypes.

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Comment [RX4]: Genotype base?

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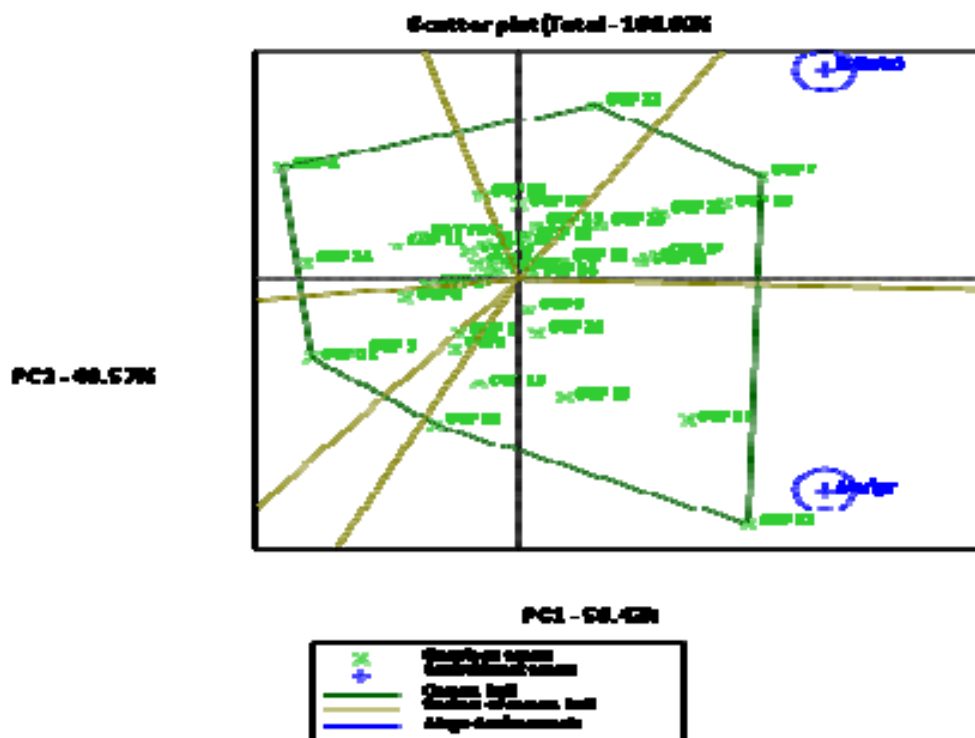
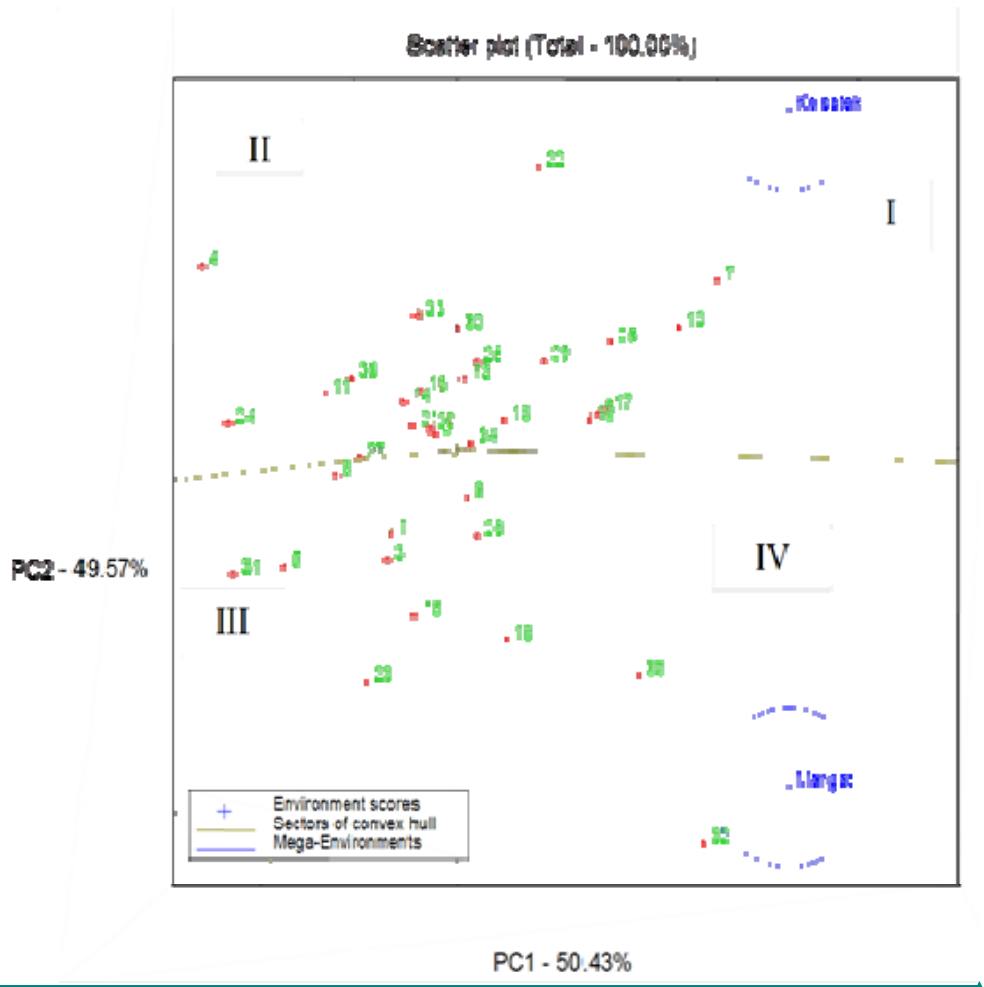


Figure 1

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Figure 2