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Agronomic performance, genetic variation and heritability of yield and related traits in rice genotypes under upland conditions

Al-Imran D.[1*], Musila R. N.[2], Kamau W. J.[1]

[1*1]Department of Plant Sciences, Kenyatta University, P. O. Box, 43844–00100
Nairobi, Kenya.
[2]Rice and Maize breeder, Kenya Agricultural and Livestock Research Organization,
P.O Box, 2981–0300, Kerugoya, Kenya.

[1*]Corresponding Author's Email: alimrandianga@gmail.com

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ABSTRACT

Although rice production potential under rain fed ecology doubles that of irrigated lowland in Kenya, there has been little advancement in identifying suitable varieties adapted to upland rice ecology. This study was carried out to appraise the agronomic performance, heritability, grain yield components, genetic variability, and correlations for grain yield and identity of suitable varieties for the upland ecology. Eight rice genotypes were evaluated in a randomized complete block design alongside three replicates under upland conditions. Collection of data included days to 50% flowering, height of the plant, productive tillers^{-1}, panicle length, grain length, panicle weight, grains panicle^{-1}, spikelet fertility, grain yield weight of one thousand grains, grain breadth and breadth/length ratio of the grain. Data analysis involved Analysis of variance, broad sense heritability estimates determination and principal component analysis. Genotype's variation was significant for all traits measured. The first three principal components accounted for 94.67% of the sum variation among 12 traits under study. The outcome of heritability estimates and the PCA indicated that the characters 50% flowering days, weight of a thousand grains, spikelet fertility, length of the panicle, grain breadth, length of the grain and breadth/length ratio, accounted for most of variance in the variables observed and showed average to high broad sense heritability. Therefore, for these traits, early generation selection was effective in identifying superior genotypes following hybridization. From the eight cultivars used in the study, NERICA 10 and NERICA 2 varieties had better indicators for coastal lowlands of Kenya.

Keywords: Phenotypic, Genotypic, Variation, Upland, Rice.

INTRODUCTION

Amongst staple food crops in Kenya, rice is the third most important after maize and wheat (FAO, 2020). The annual rice consumption exceeds production by about 70% creating a deficit which is met through imports. Since 2008, the import bill tripled to about US$ 260 million per annum (FAO, 2020). In spite of this, there exists a vast potential for production of rice in the country with about 500,000 hectares of land able to support irrigated rice production and a further 1,000,000 hectares able to support rain fed rice production (MoA, 2009). This rain fed production ecology offers great potential and needs to be utilised to reduce production-consumption gap. However, little headway has been made in identifying suitable rice lines adapted to upland rice ecology. Farmers have no option than to cultivate low yielding traditional and old improved varieties (Musila *et al.*, 2018). Therefore, developing high yielding and early maturing cultivars would be the best option for bettering sustainable upland rice production in Kenya.

A breeding program success is determined by knowledge of characters that present genetic variability in any given population of genotypes (Acquaah, 2012). Principal component analysis (PCA) is one of the most important methods in genetic variability analysis. The PCA, elaborates clearly the extend of genetic variation in the genotypes and determines key characters with higher contribution to the total variability. Since variations routinely occur in crop species for quantitative traits, the PCA aims at identifying the variables that account for most of the variance in the observed variables (Maji Shaibu, 2012). It is a tool that can be relied upon in guiding parents' identification process for hybridization and breeding strategies in various breeding programs (Mvuyekure *et al*., 2018). Exploitation of genotypic variability depends upon heritability of individual trait. Estimates of heritability gives the plant breeder indication on procedures used in selection that can be used to come up with genotypes that are superior.

In rice studies, heritability estimates for yield and other components of yield mostly have been done based on a broader sense. A good number of studies have shown moderate to high broad sense heritability for grain yield (Verulkar *et al*., 2010; Bernier *et al*., 2009; Venuprasad *et al*., 2007). On yield components, under upland rice ecology, heritability estimates for days to 50% maturity, height of the plant, number of grains per panicle, days to 50% heading, weight of the panicle, and length of the panicle have mostly been medium to high. However, heritability estimates have been low for tiller numbers per plant and a thousand grain weight (Akinwale *et al*., 2011; Verulkar *et al*., 2010; Efisue *et al*., 2009). In studies that have recorded low heritability estimates for grain yield, use of secondary characteristics for indirectly selecting higher yield has been used. The contribution of a secondary character to the yield of the grain can easily be established using correlation coefficients. At the start of the previous decade, Kenya Agricultural and Livestock Research Organization (KALRO) Mtwapa started a rice breeding programme to come up with farmer preferred rice cultivars that are high yielding for upland ecology and irrigated ecology in the Kenyan coastal lowlands (Musila, 2015). Selected interspecific and *Oryza sativa* L. pure lines grown in other parts of the country were introduced as candidates of hybridization to improve the local germplasm. Of the introduced germplasm, eight varieties including five NERICA varieties were selected for evaluation under upland ecology. Therefore, objectives of this study were to 1) establish the agronomic performance, genetic variability, heritability and correlations for grain yield and yield components, 2) Identify suitable varieties for the upland rice ecology.

Materials and methods

Study area

Study sites were on-station at (KALRO)-Mtwapa for two seasons and on-farm in Kilifi South sub-county for one season. KALRO-Mtwapa is located in Kilifi County, along Mombasa-Malindi Road and lies on latitude 3°50'S and longitude 39°44'E with 15 m elevation above sea level (masl). On-farm site in Kilifi South sub county of Kilifi County lies on latitude 3°67'S and longitude 39°80'E with a 20masl elevation. Both sites are located in coastal lowlands 3, (CL3), categorized as the coastal lowland's sugarcane zone. The sites annual mean temperatures range between 22°C and 26°C. The area means annual rainfall ranges from 1000 to 1200 mm with long rains that are reliable falling between March to August and the short rains that are variable falling between October and December (Jaetzold and Schmidt, 1983).

Germplasm, experimental design and management

The germplasm used in this study were NERICA 1, NERICA 10, NERICA 2, *Dourado precoce,* NERICA 4, NERICA 11, Komboka and Mandevu. All germplasm were sourced from KALRO except Mandevu that was sourced from farmers. The experimental design used was randomized complete block with three replicates. The plots sizes were 2 m^2 with between and within row spacing of 20 cm resulting in 50 plants per plot.

Seeds were planted in plastic containers (30cm width and 50cm height) in October of 2018 and later transplanted to the field after 12 days. Two seedlings per hill were transplanted and later thinned to one seedling. Overall field management involved application of basal fertilizers; calcium ammonium nitrate (CAN) as a source of N and diammonium phosphate (DAP) as a source of P. The P was applied during planting at the rate of 60 kg P ha^{-1} which is the recommended rate. The N was applied by top dressing at the rate of 120 kg N ha^{-1} in three splits of 40 kg ha^{-1} 21 days after transplanting, at tillering stage and panicle initiation stage. Fertiliser application was done by hand. Foliar feed as a source of micronutrients was applied by spraying once during the tillering stage. Rice stem borer pests were controlled by spraying a synthetic pyrethroid. Weed's control was mainly by hand picking while harvesting was done manually.

Measurements

Data on days to 50% flowering (from sowing to when 50% of the plants start flowering) was recorded. At harvest the following parameters were recorded; height of the plant (cm) by measuring from soil surface to the tallest panicle tip (awns were excluded), productive tillers per plant, length of the panicle (cm), weight of the panicle (g), number of grains $panicle^{-1}$, fertility of spikelet's (%) calculated by determining percentage of total number of filled spikelets $panicle^{-1}$ over total number of spikelets $panicle^{-1}$, weight of one thousand grains (g), length of grain (mm), breadth of the grain (mm), grain breadth/length ratio. Yield of grains was determined by weighing the unshelled grains harvested on whole plot basis. This was followed by conversion to tons' ha^{-1} at 14% moisture content. Data collection adhered to standard evaluation systems for rice (SES) (IRRI,1996). From the middle of the row of each plot 10 plants were randomly selected and used for data collection.

Statistical analysis

Analysis of variance (ANOVA) was performed to determine the effects of genotype environment interaction (GEI), environment and genotype on yield of the grain and other yield components using GenStat statistical package version 14 (Payne *et al*., 2011). Separation of the genotype means was done using the least significant differences (LSD) test. Roles played by each character under study in overall variability was identified through the Principal Component Analysis (PCA), which establishes important traits with a greater significance to the total variability. The PCA was conducted on the means recorded on 12 phenotypic characters from the 3 sites of the trial.

The genetic variances for the various traits were determined as:

Genetic variance (Vg) = (genotypic mean squares – error mean squares)/number of replicates;

Phenotypic variance (Vp) as the total sum of the genotype's variance and variance of the environmental (Vp = Vg + Ve). (1)

The genotypic coefficient of variation (CVG) = (√vg/grand mean) *100; (2)

Phenotype coefficient of variation (CVP) = (√vp/grand mean) *100; (3)

Broad-sense heritability $(h_b^2): \frac{\hat{\sigma}^2 genotypic}{\hat{\sigma}^2 phenotypic}$. (4)

Where (h_b^2) is broad sense heritability

$\hat{\sigma}^2 genotypic$ is genotypic variance

$\hat{\sigma}^2 phenotypic$ is phenotypic variance

Phenotypic correlation coefficients were calculated using Pearson's linear correlation protocols as stipulated by Steel and Torie (1984).

RESULTS

Performance of rice genotypes

Genotypes mean squares were highly significant ($p < 0.01$) for all characters under study indicating varied performance for rice genotypes in every environment (Table 1). The environment and environment x genotype were significant in all traits except non-significant environment effects for weight of a thousand grains and height of the plant, and environment and genotype effects for thousand grain weight, length of the panicle and number of tillersplant[1]. The average yield of the grains across environments was 2.52 t ha^{-1} ranging from 1.62 t ha^{-1} to 3.22 t ha^{-1} (Table 2). Best performing varieties across environments were NERICA 10 (3.22 t ha^{-1}) and NERICA 2 (2.94 t ha^{-1}). NERICA 10 also showed a significantly higher grains per panicle (185) and heavy weight of the panicle (5.01 g) compared to the other varieties.

Table 1: Analysis of variance for grain yield and other yield related traits for 8 rice genotypes grown under upland conditions in coastal lowlands of Kenya.

Source of Variation	DF	Gwgt†	SF	Tgwt	DFL	PH	PT	PL	PW	GPP	GB	GL	GR
Environment	2	20.40**	371.38**	4.61	1364.93**	106.14	13.86*	30.71**	3.08**	4436.60*	3.36**	1.31**	6.58**
Rep (Site)	6	0.24	20.34	9	11.32	37.67	1.44	1.08	0.15	423.6	0.03	0.03	0.03
Genotypes	7	2.30**	686.41**	111.55**	2026.18**	690.07**	14.83**	18.92**	3.04**	2555.60**	0.79**	0.84**	1.94**
Genotypes x environment	14	0.41*	118.56**	1.3	131.77**	37.13*	2.73	3.73**	1.56**	1076.10*	0.11**	0.14	0.29**
Error	42	0.21	13.29	7.2	5.51	14.53	1.62	1.21	0.38	483.6	0.02	0.11	0.03
CV		18.1	4.1	9.1	2.9	4.9	16.9	4.6	15.6	14.2	6	3.6	4.6

*: $P < 0.05$ and **: $P < 0.01$

† DFL, 50% days to flowering; Gwgt, Grain yield weight; GPP, Grains per panicle; GB; Grain breadth; GL, length of the grain; GR. Grain length breadth ratio; PH, Height of the plant; PT, Productive tillers; PL, length of the panicle; PW, Weight of the grain; Tgwt, Weight of a thousand grain; SF, Spikelet fertility.

Table 2: Average of measured traits for 8 rice genotypes grown under upland conditions in coastal lowlands of Kenya.

	Variety	Gwgt	SF	Tgwt	DFL	PH	PT	PL	PW	GPP	GB	GL	GR
		t/ha	%	G	Days	Cm	#	Cm	G	#	mm	mm	Ratio
1	NERICA 1	2.36a	92.66c	32.00c	74.00a	71.77a	7.00a	23.16a	4.05a	161b	2.52c	9.40c	3.81a
2	NERICA 2	2.94c	92.19c	28.33b	71.00a	71.16a	8.00a	22.94a	3.54a	147a	2.48b	9.24b	3.80a
3	NERICA 4	2.75b	90.82b	28.83b	75.00b	77.13b	7.00a	23.96a	3.89a	154a	2.42b	9.24b	3.87a
4	NERICA 10	3.22c	91.61b	27.72b	76.00b	77.13b	7.00a	24.09a	5.01b	185b	2.44b	9.06b	3.82a
5	NERICA 11	2.13a	88.00b	31.33c	80.00c	76.72b	6.00a	23.3a	4.33a	167b	2.62c	9.50c	3.74a
6	Komboka	2.76b	92.47c	23.33a	92.00d	71.18a	10.00b	23.65a	3.30a	157a	2.19d	8.91a	4.13a
7	*Dourado precoce*	2.36b	91.44b	35.17d	74.00a	85.84c	6.00a	22.44a	4.01a	137a	2.71c	9.85c	3.71a
8	*Mandevu*	1.62a	66.97a	28.00b	116.00e	96.47d	9.00b	27.17b	3.25a	132a	1.77a	9.01b	5.10a
	Mean	2.52	88.27	29.34	82.00	78.43	7.00	23.84	3.92	155	2.39	9.28	4.00a
	LSD (0.05)	0.43	3.47	2.55	2.00	3.63	1.00	1.05	0.58	21	0.14	0.32	0.18a
	Se	0.15	1.22	0.89	0.78	1.27	0.42	0.37	0.20	7	0.05	0.11	0.06a

† DFL, 50% days to flowering; Gwgt, Grain yield weight; GPP, Grains per panicle; GB; Grain breadth; GL; length of the grain; GR. Grain ratio length breadth ratio; PH, Height of the plant; PT, Productive tillers; PL, Length of the panicle; PW, Weight of the panicle; Tgwt, Weight of a thousand grain; SF, Spikelet fertility, Se, Standard error, LSD, least significant difference; t/ha, tons per hectare; #, number; G, grams

Table 3: Correlation matrix of 12 characters used in characterizing the 8 rice genotypes grown under upland conditions in coastal lowlands of Kenya.

	Gwgt	SF	Twgt	DFL	PH	PT	PL	PW	GPP	GB	GL	GR
Grain yield weight												
Spikelet fertility	0.46***											
A thousand grain weight	-0.05	0.07										
Days to 50% flowering	-0.38**	-0.44***	-0.46***									
Plant height	0.15	-0.05	0.05	0.09								
No of productive tillers	0.06	0.12	-0.16	0.11	-0.14							
Panicle length	0.19	0.26*	0.00	-0.01	0.28*	0.36**						
Panicle width	0.09	0.21	0.15	-0.16	0.07	-0.12	0.32**					
Grains panicle-1	0.11	0.29*	0.12	-0.27*	-0.14	0.10	0.38*	0.61***				
Grain breadth	0.57***	0.54***	0.43***	-0.60***	0.28*	0.01	0.10	0.14	0.19			
Grain length	0.16	0.28*	0.62***	-0.47***	0.21	0.00	0.27*	0.23	0.22	0.64***		
Grain length/breath ratio	-0.65***	-0.51***	-0.27*	0.58***	-0.27*	0.00	-0.01	-0.07	-0.11	-0.93***	-0.37**	
	Gwgt	SF	Twgt	DFL	PH	PT	PL	PW	GPP	GB	GL	GR

* $P < 0.05$ and ** $P < 0.01$: *** $P < 0.001$

† DFL, 50% days to flowering; Gwgt, weight of grain yield; GPP, Grains per panicle; GB; Grain breadth; GL, Grain length; GR. Grain ratio; PH, Plant height; PT, Productive tillers; PL, length of the panicle; PW, weight of the panicle; Twgt, Weight of a thousand grains; SF, Spikelet fertility.

Table 4: Estimates of genotypic and phenotypic variability, genotypic (GCV) and phenotypic (PCV) Coefficients of variation and heritability in broad sense (h^2B) in 8 rice genotypes.

Traits	Variance components		Coefficient of variation		Heritability broad sense
	Phenotypic	Genotypic	Phenotypic	Genotypic	(%)
Grain yield weight	0.37	0.21	24.17	18.21	56.79
Spikelet fertility	104.09	63.09	11.56	9.00	60.61
A thousand grain weight	13.48	12.25	12.51	11.93	90.86
50% days to flowering	255.03	210.49	19.43	17.65	82.54
Height of the plant	86.54	72.55	11.86	10.86	83.83
No of productive tillers	2.43	1.34	21.02	15.63	55.26
Length of the plant	3.07	1.69	7.34	5.45	55.06
Weight of the panicle	0.73	0.16	21.72	10.34	22.64
Grains panicle $^{-1}$	576.82	164.39	15.50	8.28	28.50
Grain breadth	0.11	0.08	14.14	11.49	65.96
Grain length	0.14	0.08	4.00	3.00	56.06
Grain length/breath ratio	0.28	0.18	13.33	10.72	64.60

Phenotypic correlation

The Pearson coefficients of correlation for characters among the eight genotypes are shown in Table 3. Among the variables under study, the most highly significant correlation related to grain width and length/Breadth ratio (r = -0.98***). The traits weight of the grain, fertility of spikelet's, weight of a thousand grains presented most significant and positive correlation with width of the grain and negatively correlated with length/breadth ratio. Days to 50% flowering days presented significantly negative correlation with grain yield of -38**, with a spikelet fertility of -0.44***, weight of a thousand grains was -0.46***, grain breadth of the grain at -0.60***, and a 3.22 t ha^{-1} to length of the grain giving a value of -0.47***. However, 50% days to flowering correlated positively with length/breadth ratio (0.58***). The relation between weight of the grain and fertility of spikelets (0.46***) and between grains panicle^{-1} and weight of panicle (0.61***) was positive and highly significant. From these correlations it can be deduced that earliness was associated with increased yield of the grain, reduced spikelet sterility and wider and/or longer heavier grains.

Genetic Variability

The genotypic coefficient of variation (GCV) was less than phenotypic coefficient of variation (PCV) for all traits studied (Table 4). The GCV was highest for yield of the grains (18.21) followed by 50% days to flowering (17.65) and lowest for length of the grain (3.00). Generally broad sense heritability varied from 23% for a thousand grain weight to 91% for weight of the panicle. Based on the categories of broad sense heritability estimates, where low is taken to be less than 40%, medium ranges between 40-59%, moderately high varied between 60-79% and very high is above 80% (Singh, 2001), the estimates were very high for weight of one thousand grains (91%), 50% days to flowering (83%) and height of the plant (84%). Moderately high estimates were recorded for fertility of the spikelet, width of the grains and grain ratio. The traits, yield of the grains, number of tillers per plant and length of the panicle and length of the grain showed medium estimates. Days to flowering had high GCV (17.65) with very high heritability estimates (82.54%) whereas grain yield had high GCV (18.21) with moderate broad sense heritability estimates (56.75%

Principal component analysis

From the latent roots, which are the eigenvalues of the correlation matrix, the total variance of the twelve standardised variables was 12. The first, second and third principal component contributed a variance of 6.93, 3.09, and 1.34 respectively. The variance of first, second and third principal component as a percentage of the total variance was 57.8%, 25.7% and 11.2% respectively. The variance contributed by first and second principal components was 83.5% that according to Guci *et al.* (2005) can be termed adequate in accounting for variation in this data. According to Raji (2002) traits having coefficients above 0.30 were considered as having an effect large enough to contribute significantly to variation. However, in in this study, this criterion applied to PC1 to avoid redundancy in PC2 and PC3. The first principal component had great positive association with fertility of the spikelet's (0.34) and grain breadth (0.37). In contrast the variables contributing most negatively were 50% flowering days (-0.37), length of the panicle (-0.35) and length/breadth ratio (-0.38). The second principal component had large positive association with weight of a thousand grains (0.50) and length of the grains (0.45). The third principal component showed large positive association with weight of the panicle (0.65) and grains panicle^{-1} (0.53).

Plotting PC1 against PC2 resulted in clustering the 8 genotypes into 4 clusters (Figure 1).

Quadrant 1 was made up of *Mandevu* characterised long slender paddy grains, low yields and long duration. Quadrant 11 was made up of *Dourado precoce*, NERICA 1 and NERICA 11 and were characterized by heavy grains with wider and longer grains. Quadrant III was made up of *Komboka* characterized by high tillering ability, medium duration and low yields. The fourth quadrant was made up of NERICA 10, NERICA 2 and NERICA 4 a group mostly characterised by high yielding short duration with reduced spikelet sterility.

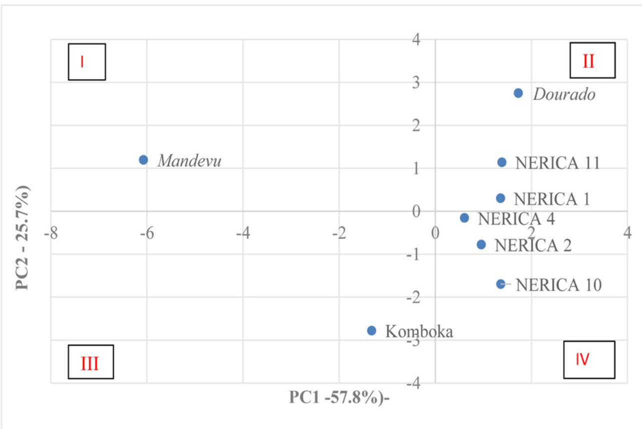

Figure 1: Biplots analysis of relationship groups between entries based on PC1 and PC2

DISCUSSIONS

In this study, significant differences among genotypes with regard to 12 quantitative traits were found. The local variety *Mandevu* performed poorly with a grain yield of 1.62 t ha^{-1} due to low spikelet fertility (67%) indicating that it is not suitable for upland ecology. On grain physical characteristics grain length varied between 8.91 to 9.50 mm with a mean of 9.28 mm indicating that all the varieties belonged to the extra-long paddy type. The mean length to breadth ratio was 4.00 mm ranging from 3.71 to 5.10 mm indicating that the varieties under study belonged to the slender sub-type. These results are in agreement with other studies that have also reported variation among genotypes evaluated under upland conditions (Ndebeh *et al.*, 2018; Atera *et al.*, 2011). For instance, performance differences in grain yield and yield components were reported among 9 NERICA rice varieties evaluated for 2 seasons in coastal lowlands of Kenya (Kega *et al.*, 2006) and among 4 NERICA varieties and a local variety- *Dourado precoce* evaluated for 3 seasons in Western Kenya (Atera *et al.*, 2011). Assessment of genetic variability showed that weight of a thousand grains, 50% days to flowering, height of the plant, fertility of the spikelet, width of the grain and breadth/length ratio had high broad sense heritability estimates. This is an indication that these characteristics were controlled by additive gene action thus their transmissibility from the parental plants to offspring was high. Therefore, use of simple selection procedures may be enough while selecting for more superior genotypes. Yield of the grains, productive tillers^{-1}, length of panicle and grain showed medium broad sense heritability estimates indicating that these characters were controlled by additive and non-additive gene action and partly under environmental influence. Similar to this study high heritability estimates among rice genotypes evaluated under upland conditions have also been reported for weight of a thousand grains (Osman *et al.*, 2012), height of the plant (Abebe *et al.*, 2017; Osman *et al.*, 2012; Akinwale *et al.*, 2011;) and days to 50% flowering (Osman *et al.*, 2012) and moderate broad sense heritability estimates were reported for yield of the grains (Abebe *et al.*, 2017) and length of the panicle (Akinwale *et al.*, 2011). However, contrary to this study low heritability estimates were reported for weight of a thousand grain weight (Osman *et al.*, 2012) and high heritability for grain yield (Osman *et al.*, 2012; Akinwale *et al.*, 2011), productive tillers^{-1} and length of the panicle (Osman *et al.*, 2012). These results show important information that can be used in upland rice breeding program breeding program in Kenya. The results showed that indeed there was useful genetic variation among the quantitative traits measured. This hinted on the selection procedures which may apply following hybridization of selected parents.

Principal component analysis showed that cumulative variance of 83.5% by the initial three principal components strongly correlated with 9 traits. This is an indication that the identified traits greatly influenced the genetic variation of the genotypes under study. Other studies have also shown that, initial three principal components and associated traits are more important in showing variation patterns among the different genotypes (Sanni *et al.*, 2012). Of the nine traits, seven showed moderate to high broad sense heritability estimates. These were 50% days to flowering weight of a thousand grains, spikelet fertility, length of the panicle, breadth of the grain, length of the grain and breadth/length ratio. Findings from other authors corroborate with the present study where by characters like days to 50% flowering, weight of a thousand grains, grain breadth and length are found to be strongly associated with the first three components (Mvuyekure *et al*., 2018; Sanni *et al*., 2012; Guci *et al*., 2005). From the results identified traits showed moderate to high broad sense heritability estimates. This implies that following hybridization early generation selection will be effective in identifying superior genotypes.

The biplot analysis produced IV clusters of the 8 genotypes. One of the clusters (quadrant IV) consisting of NERICA 2, 4 and 10 was characterized by high yield, low spikelet sterility, low tillering ability, shorter panicle length and wider and extra-long paddy grains. This cluster also had the best yielding varieties across environments that is NERICA 10 (3.22 t ha^{-1}) and NERICA 2 (2.94 t ha^{-1}). Elsewhere, NERICA 4 and NERICA 2 were reported to be potential suitable varieties for upscaling in coastal lowlands of Kenya (Kega and Maingu, 2006). Although Komboka was found to be unsuitable for the upland ecology, through hybridization it can be used to improve the tillering ability of the NERICA varieties in quadrant IV. The local variety *Mandevu* in quadrant I took longer to mature and showed low yields due to low spikelet fertility (67%) indicating that it was not suitable for upland ecology. However, *Mandevu* can be hybridized with NERICA 2, 4 and 10 to produce high yielding progenies with long panicle length, slender and extra-long paddy types with a grain shape more than 5, rice traits that farmers prefer in the coastal lowland of Kenya (Musila *et al*., 2018). The dimension of the paddy grain plays a great role in the determining grain standards and throughout the processing cycle. Shape of the grain is considered as a vital agronomic character as it has direct or indirect effect to quality traits and grain yield (Zheng, 2007).

CONCLUSIONS

The eight genotypes under study indicated considerable variability for most traits. Principal components analysis educed seven most polymorphic characters mostly responsible for genetic variability and that showed moderate to high broad sense heritability estimates. These characters included were: days to 50% flowering, spikelet fertility, a thousand grain weight, grain size and shape. Therefore, these characters must be accorded great emphasis during parents' selection in hybridization process for development of improved rice varieties for the upland rice ecology. This study recommends that the varieties NERICA 10 and NERICA 2 should be promoted for cultivation in the upland ecology of coastal lowlands of coastal Kenya as they are high yielding and short durational.

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