academicJournals

Vol. 11(17), pp. 1559-1568, 28 April, 2016
DOI: 10.5897/AJAR2016.10895
Article Number: D3EF55458359
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Characterization and evaluation of twenty rice (*Oryza sativa* L.) genotypes under irrigated ecosystems in Malawi and Mozambique

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Received 10 February, 2016; Accepted 17 March, 2016

Field experiments were carried out in Mozambique (Muirrua Rice Research Station) and Malawi (Lifuwo Rice Research Station), during 2010 and 2011 growing season to evaluate twenty rice (*Oryza sativa* L.), genotypes under irrigated ecosystem following randomised complete block design (RCBD) with three (3) replications and 20 treatments. Data on number of days to flowering, number of tillers, number of days to maturity, panicle length, number of grains per panicle, grain length, 1000-grain weight, and grain yield were assessed, and analyzed. Muirrua ecosystem produced the highest mean yield (3.96 t ha^{-1}) followed by Lifuwu ecosystem (3.42 t ha^{-1}). Nine traits, namely number of tillers, 1000-grain weight, panicle length, number of grains per panicle, grain length, number of days to 50% flowering, and number of days to maturity were positively correlated with grain yield. Significant differences (P<0.001) were found in grain length, although 19 genotypes were greater in grain length (>7.5 mm). Faya showed the highest percentage on the whole grain (60%), in comparison with Marista (20.2%).

Key words: Genotypes, ecosystem, environment, characterization, yield.

INTRODUCTION

Rice contains thousands of cultivated varieties belonging to two species, *Oryza sativa* L. grown worldwide and *Oryza glaberrima* grown mainly in West Africa (Khush, 1997). Grown on 154 million hectares worldwide in a wide range of environments (Babu et al., 2012), rice (*O. sativa* L.) is cultivated between 36 ES to 55 ES and grown from sea level to an elevation of 2500 m above the sea level or even higher (Khush and Singh, 1991; Khush, 1997). It constitutes 27% of dietary energy supply and 20% of dietary protein (Kueneman, 2006), and provides food for more than 50% of the world's population (Khush, 2005).

Mozambique is a widespread country naturally endowed with abundant lands appropriate for rice

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production (Agrifood Consulting International, 2005) and has a great diversity of local genotypes of rice, mostly concentrated in the provinces of Zambézia, Sofala and Nampula. However, there is lack of information on their trait characteristics and performance under different agro-ecological conditions including their potential when grown under irrigated environments. The persistence of the rice growers in the preference of their genotypes over the improved ones presents a special challenge for breeders and/or variety developers. Witcombe and Virk (1997) discussed that when choosing some varieties to grow, farmers consider not only the yield but also other traits that may improve their crop, and many breeding programmes do not take into account such traits at the start of breeding varieties. Breeders opt to assess traits like crop yield, plant height, plant type, number of panicles while farms may be interested in grain quality and aroma or other traits which breeders consider in later generations of breeding, often near to release of the varieties. As a result, these varieties do not meet the requirements of farmers (Tripp and Louwaars, 1997) because they show low adoption, or they do not adopt them at all.

In Malawi, rice is the second most important cereal crop after maize, and its production by smallholder farmers in fields is solely less than 1.0 ha on average (Mzengeza, 2010). It is grown under three ecosystems namely irrigated lowlands, rainfed lowlands, and rainfed uplands. Landraces are widespread and popular among farmers which play an important role in local agriculture owing to their genetic diversity (Modi, 2004) that represents wild plant populations as genetic resources (Das and Ashesh, 2014). They possess a large genetic diversity which can be used to complement and broaden the gene pool of advanced genotypes (Ahmed et al., 2012). Landraces play a vital role in the local food security and sustainable development of agriculture (Tang et al., 2009). The major objective in the rice breeding programme is to maintain the desirable traits with an increase in the yield potential of landraces (Kobayashi et al., 2006). Genetic improvement mainly depends on the amount of genetic variability present in the population, and estimation of genetic diversity between different landraces in the crop of interest is the first and foremost process in any plant breeding programme (Charrier et al., 1997).

Based on performance records, varieties and/or crops with reputation for possessing biotic and abiotic resistance can be identified for breeding. Despite this observation, re-creating genotypes with durable resistance and proper agronomic characteristics remains a great challenge in breeding. To improve food security, particularly in Central of Mozambique, where more than 60% of the country's rice is produced, there is need to study and understand farmers' genotypes through characterization and evaluation, as the first step in rice improvement. Genetic material (germplasm) is useful to scientists and plant breeders only when it has been properly characterized and evaluated because it enables scientists to study the diversity of species, search for material caused to direct introduction as cultivars, or provide genetic variability in breeding programs (Perrino et al., 1991).

Since Mozambique depends on imports to meet its rice demand, it is urgent that more productive and stress-tolerant rice varieties be developed. In view of the production constraints and possible benefits of rice, there is a need to develop technologies that are agronomically, ecologically, and economically sustainable with potential of increasing farmers' output. Information on trait characterization and genotypic performance is critical to plant scientists (plant breeders and plant physiologist) and farmers in improvement, production and utilization of rice and it will contribute significantly to improve food security, nutrition, and household cash income in Mozambique and Malawi. The general objective of this research study was to characterize and evaluate twenty rice genotypes under two irrigated ecosystems and two environmental conditions in order to identify traits and genotypes that can be utilized in the genetic improvement of rice or to introduce as cultivars in Mozambique and Malawi, specifically to evaluate yield and yield components of twenty rice genotypes in irrigated ecosystem and determine the correlation between yield and growth parameters of these genotypes.

MATERIALS AND METHODS

Twenty rice genotypes originated from irrigated ecosystems in Mozambique and Malawi were grown in both countries during 2010 and 2011 growing season. 16 genotypes (*Marista, Nassope, Rafik, Djanibwere, Djissa, Gorongosa, Paula, Niwaio, Nene, M'finico, Chibiça, Chencherica, Chupa, Mocuba, Mucandara redondo, Singano*) of the 20 genotypes were sourced from farmers' fields in Mozambique, Zambézia Province, whereas 4 genotypes (*Kilombero, Nunkile, Faya and Mtupatupa*) were from Malawi, Lifuwu Research Station. The work was carried out under field conditions in two sites including Muirrua Rice Research Station and Lifuwu Research Station.

Muirrua Rice Research Station is located in Mozambique, Zambézia Province, and District of Nicoadala about 35 km from Quelimane town, the capital of the Province. The district is in the South part of the Province, between 16° 17' and 17° 32' south latitude and 35° 12' and 37° 35' East longitude. The climate is humid tropical in the strip of the plains, and subtropical in the central plateau and the highlands (PEDD – Nicoadala, 2007). In the humid tropical climate, the relative humidity varies from 90 to 100% in the rainy season and 75 to 90% in subtropical climate. Annual mean temperature varies around 26°C in the plains and plateau, and about 20°C in the highlands (PEDD – Nicoadala, 2007). The climates possess two seasons, namely, hot and rain season from October to April, and the dry and cool season from May to September. Rainfall varies from 1,000 mm in the humid tropical areas to 1,300 mm in the highlands (PEDD – Nicoadala, 2007).

Lifuwu Research Station is situated at the foot of the Lifuwu hill, which is a part of the expansive and seasonally flooded Katete dambo. The station is at an altitude of 500 m above sea level (masl) in approximate latitude 13° 40' South and longitude 34° 35' East. The soil type of the paddy lowland fields is predominantly vertisol, characterized by low nitrogen and phosphorus content, with pH 7 to 8. The annual average rainfall is 1,200 mm. Mean minimum and maximum temperatures are 19 and 29°C, respectively. Between May and August, absolute air temperatures may drop to 16°C, as low as what occurred during the rainfall period between December, 2010 to June, 2011.

Soil analyses of both sites are shown in Appendix 1. The optimum phosphorus availability to rice occurs at pH lower than 6.5. For upland crops, P availability is usually optimum when the soil pH is between 6.0 and 6.5. In acid soils (pH < 6.0), P is associated with iron and aluminium compounds which are available slowly to most plants. When soil pH is higher than 6.5, P is primarily associated with calcium and magnesium (Cassman et al., 1993).

The experiment was laid out in randomized complete block design with three replications and 20 treatments (genotypes). The genotypes were first established in nurseries and transplanted, one plant per hill, 25 days after sowing (DAS) in net plot of 10 m^2 (5 m long and 2 m width). The plots were kept well-watered at all stages of plant growth, supplemented water according to an irrigation scheme. Weed control was done by hand weed and no pesticide was applied. Rainfall data during the period of the trials was collected at both field sites. Minimum and maximum daily temperatures were also collected at both sites. Data collection on Agronomic parameters (days to flowering, number of tillers, plant height, days to maturity, panicle length, number of grains per panicle, grain length, grain shape, 1000-grain weight, and grain yield) were assessed according to the International Rice Research Institute (IRRI, 1996) procedures and analysed using General statistics (GenStat 14th Edition) computer statistical package. Analysis of variance was used to test the source of variation and test their influence on the genotypes under the study. The statistical model used is described as follows:

Model: $Y_{ipqr} = \mu + ß_r + G_i + E_q + S_p + (GS)_{ip} + (GE)_{iq} + (ES)_{ip} + Є_{ripq,}$

Where; Y_{ipqr} is the observed weight of grain yield within the (p^{th}) ecosystem, (i^{th}) genotypes, (q^{th}) environments, and (r^{th}) block; µ. is the population mean; E_q is the effect of the q^{th} ; $B_{r\cdot}$ is the effects of the r^{th}; S_P is the effect of the p^{th}; G_i is the effect of the i^{th}; GE_{qi} the effect of interaction between the q^{th} and the i^{th}; GS_{pi} is the effect of interaction between the p^{th} and i^{th}; $Є_{ripq,}$ is the random error.

Grain shape (Gsh)

The ratio of the brown rice length and brown rice width define the grain shape as suggested by Saleem et al. (2010). The scale used to describe the grain shape in rice as suggested by IRRI (1996) are: for the scale 1, the shape is slender and the ratio is over 3.0; for scale 3, the shape is medium and the ratio is from 2.1 to 3.0; for scale 5, the shape is bold and the ratio is from 1.1 to 2.0; scale 9 is the last, the shape is round and the ratio is less than 1.1. Additive main effect and multiplicative interaction (AMMI) analysis were carried out to understand whether there was interaction between genotypes and environments. The magnitude of the interactions or the differential genotypic responses to environments was analyzed using a model to determine adequate responses of specific genotypes to specific environments, rank the performance and adaptability of the genotypes in two ecosystems and two environments. The following statistical model was used:

$$Y_{ijkr} = M + G_i + E_j + B_k + \sum I_n V_{in} L_{jn} + Є_{ijkr}$$

Where; Y_{ijkr} is the yield of genotype (i) in ecosystem (j) for replicate ®; M: is grand mean; G_i is mean deviation of the genotype; E_j is mean deviation of the environmental mean; B_k is mean deviation of the block; I_n is the singular value for interaction principal component axis or IPCA (n); V_{IN} is the genotype (i) eigenvector value for IPCA axis (n); L_{jn} is the environment (j) eigenvector value for IPCA axis (n); $Є_{ijkr}$ is a random error.

The data were analysed, combined over locations and location-wise. The genotypic means were separated using Duncan's multiple range test at 5% level of probability (Gomez and Gomez, 1984), while site and environmental means were separated by using the least significant difference (LSD) test at 5% and 1% level of probability. The correlation was used to determine the strength of the relationship between grain yield and other measured variables, which these were calculated using Statistical Package for Social Sciences (SPSS) software version 16.

RESULTS AND DISCUSSION

Grain yields, yield components and growth parameters of twenty rice genotypes across the two environments

Means of yield, yield components and growth parameters of the twenty rice genotypes under the irrigated experiment at Lifuwu (Ecosystem 1) are shown in Table 1. Number of tillers per plant, panicle length, number of filled grains per panicle, grain length (paddy length), 1000-grain weight, grain shape (length/width ratio), days to 50% flowering, days to maturity, and leaf length showed significant differences ($p<0.001$) among genotypes. Osman et al. (2012) reported significant genetic variability for some selected yield and yield components except for number of tillers per plant and panicle length.

Genotype *Chencherica* had the highest yield (4.43 t ha^{-1}) while *Djissa* had the highest number of tillers (14). The lowest yield and number of tillers were found in genotypes *Nassope* (2.3 tha^{-1}) and *Kilombero* (6). Morales (1986) suggested that number of grains per panicle and 1000-grain weight might be considered as important criteria for increasing yield per unit area. The highest mean for panicle length, number of grains per panicle, grain length, 1000-grain weight, grain shape, days to 50% flowering, days to physiological maturity, and leaf length were identified in the genotypes *Nassope* (28.82 cm), *Mucandara* (277), *Nene* (11.20 mm), *Marista* (35 g), *Singano* (4.77), *Faya* (105 d), *Chupa* (150 d), and *Nassope* (55.20 cm), respectively. The lowest mean for panicle length, number of grains per panicle, grain length, 1000-grain weight, grain shape, days to 50% flowering, days to physiological maturity, and leaf length were *Paula* (22.03 cm), *Niwaio* (134), *M'finico* (7.03 mm), *Singano* (19 g), *M'finico* (2.07), *Marista* and *Nene* (79 d), *Nene* (110 d), and *Nunkile* (34 cm), respectively. Results of the present study suggest that five component characters, namely, panicle length, number of filled grains per panicle, grain length, weight of 1000 grains, grains

Table 1. Mean grain yield, yield components and growth parameters of twenty rice genotypes grown under irrigated ecosystem at Lifuwu Research Station, Malawi.

Genotypes	T ha^{-1}	NT	PL	Gr/P	GL	TGW	GS	DFL	DM	LL
Marista	2.73	9	25.4	189	9.70	35.0	2.83	79	117	48.0
Nassope	2.30	7	28.8	236	9.37	25.7	2.60	103	141	55.2
Rafik	3.77	9	27	264	9.77	24.0	3.80	104	144	51.3
Kilombero	3.90	6	26	254	10.70	34.7	3.50	93	137	45.8
Pedra	2.80	9	22.2	161	9.23	24.0	3.37	80	120	48.5
Djissa	2.90	14	22.2	207	10.10	25.3	3.83	90	116	47.2
Gorongosa	3.13	9	26	184	9.60	27.0	2.93	102	137	46.1
Paula	3.30	11	22	190	9.97	31.3	3.23	92	118	44.6
Niwaio	2.70	10	22.2	134	8.50	29.3	2.63	84	120	41.3
Nunkile	3.37	11	22.2	202	9.87	24.7	4.13	85	121	34.4
Nene	3.17	7	23.8	190	11.20	34.0	3.27	79	110	41.4
M'finico	3.90	9	26.1	217	7.03	20.3	2.07	104	141	45.2
Chibiça	4.07	11	25.8	201	9.77	25.3	3.17	95	123	40.8
Chencherica	4.43	12	27.5	198	10.73	32.7	4.23	98	131	48.9
Chibiça	4.07	11	25.8	201	9.77	25.3	3.17	95	123	40.8
Chupa	4.27	7	27.9	261	9.43	32.3	3.23	104	150	46.0
Mocuba	3.37	10	24.7	223	10.13	34.0	3.13	102	137	54.7
Mucandara	4.03	9	25.1	277	9.63	33.0	2.87	99	136	54.7
Singano	2.97	12	24.8	174	10.03	19.0	4.77	95	119	45.2
Mtupatupa	3.70	10	28.4	249	8.87	26.0	3.07	99	140	49.0
Mean	3.42	9.68	25.30	210.90	25.25	28.50	3.39	94.75	129.80	46.99
LSD $_{(5\%)}$	0.72	3.70	1.58	31.70	0.8	5.04	0.43	2.25	7.11	7.15
CV	12.80	23.10	8.00	9.10	5.00	10.70	7.60	11.40	3.30	9.20

Tha^{-1}: Tones per hecter, NT: Number of tillers per plant; PL: Panicle length (cm); Gr/P: grain per panicle; GL: grain length (cm); TGW: Thousand grain weight (g); GS: grain shape; DFL: Days to 50% flowering (d); DM: Days to physiological maturity (d); LL: Leaf length (cm).

shape, days to 50% flowering, days to physiological maturity, and leaf length had high significant differences ($p<0.001$) which implies that the genotypes constitute a pool of germplasm with adequate genetic variability. The number of tillers per plant showed significant differences ($p<0.05$). The genotypes with higher magnitude of these component characters could either be selected from the existing gene pool for on-farm evaluation (participatory selection) in order to introduce them as cultivars or utilize in breeding programs for genetic improvement.

Under Muirrua irrigated environment, the analysis of variance for each character revealed that the twenty rice genotypes differed amongst themselves at $p<0.001$ for yield (t ha^{-1}), panicle length, number of grains per panicle, weight of 1000-grains, grain shape (length-width ratio), days to 50% flowering, and days to maturity, indicating the presence of genetic variation among the genotypes for each quantitative character mentioned. The genotype *Chencherica* had the highest yield (5.63 t ha^{-1}), while *Mucandara* (23) and *Nunkile* (23) had the highest number of tillers. The lowest yield and lowest number of tillers were found in genotypes *Mtupatupa* (2.77 t ha^{-1}) and *Nene* (8), respectively. The highest means for panicle length, number of grains per panicle, grain length, 1000-grain weight, grain shape, days to 50% flowering, days to physiological maturity, and leaf length were found in the genotypes *Mocuba* (31.77 cm), *Mucandara* (313), *Chincherica* (11.47 mm), *Mocuba* (35.60 g), *Singano* (5.43), *Chupa* (114 d), *Chupa* (147 d) and *Mocuba* (147 d), and *Niwaio* (62.10 cm), respectively.

The lowest mean for panicle length, number of filled grains per panicle, grain length, 1000-grain weight, grain shape, days to 50% flowering, days to physiological maturity, and leaf length were in *Kilombero* (23.10 cm), *Niwaio* (152), *M'finico* (6.40 mm), *Singano* (23.6 g), *M'finico* (1.93), *Nene* (66 d), *Nene* (105 d) and *Kilombero* (43.66 cm), respectively (Table 2).

Effect of the ecosystem on grain yield, yield components and growth parameters of the twenty rice genotypes across the environments

The results for grain yield showed significant differences

Table 2. Mean grain yield, yield components and growth parameters of twenty rice genotypes grown under irrigated ecosystem at Muirrua Research Station, Mozambique.

Genotypes	T ha^{-1}	N T	P L	Gr/P	G L	TGW	GS	DFL	DM	LL
Marista	3.50	14	25.9	194	9.6	31.2	3.10	91	129	55.1
Nassope	3.10	16	27.5	267	8.8	25.6	3.50	95	132	56.1
Rafik	4.03	9	25.8	289	9.1	24.7	3.60	94	139	49.7
Kilombero	4.73	15	23.1	287	9.2	35.3	3.40	94	135	43.7
Pedra	3.83	11	24.6	172	9.6	25.0	3.50	97	132	50.7
Djissa	2.93	16	23.4	262	9.1	25.7	3.30	102	135	59.5
Gorongosa	4.50	17	23.8	199	11.2	26.7	3.40	99	144	60.7
Paula	3.64	14	24.3	215	10.7	29.6	3.30	109	141	48.7
Niwaio	3.33	14	23.6	152	9.9	28.6	2.90	95	129	62.1
Nunkile	3.53	23	23.1	241	9.8	27.6	4.50	75	108	49.4
Nene	4.40	8	26.3	259	9.9	35.4	2.80	66	105	52.4
M'finico	3.27	20	27.1	245	6.4	27.1	1.90	95	135	48
Chibica	4.45	19	26.5	220	9.3	25.8	3.30	102	134	47
Chencherica	5.63	15	30.5	257	11.5	33.6	4.20	105	142	45.7
Faya	4.37	19	29.6	257	10	32.5	3.40	97	133	54.7
Chupa	4.70	15	29.7	295	8.8	27.0	3.20	114	147	52.3
Mocuba	5.40	19	31.8	280	10.4	35.6	3.00	104	147	61.3
Mucandara	2.93	23	29.7	313	9.8	35.1	2.90	110	142	59.3
Singano	4.43	19	26.9	197	10.5	23.6	5.40	106	135	51.6
Mtupatupa	2.77	21	29.6	300	9.9	29.9	3.40	102	137	54.0
Mean	3.96	16.00	26.65	245.00	9.70	29.30	3.40	96.00	134.00	53.10
LSD (5%)	0.95	7.52	4.397	54.03	2.51	6.03	1.03	4.09	0.97	10.46
CV	14.60	27.70	10.00	13.30	15.70	12.50	18.20	3.00	0.40	11.90

Tha^{-1}: Tones per hectare, NT: Number of tillers per plant; PL: Panicle length (cm); Gr/P: grain per panicle; GL: grain length (cm); TGW: Thousand grain weight (g); GS: grain shape; DFL: Days to 50% flowering (d); DM: Days to physiological maturity (d); LL: Leaf length (cm).

Table 3. Analysis of variance for grain yield (t ha^{-1}) of twenty rice genotypes across the two sites and two environments (Lifuwu irrigated and Muirrua irrigated).

Source of variation	Degree of freedom	Sum square	Mean square	F-value
Total	239	383.4	-	-
Block	2	0.06	0.03	-
Ecosystem (S)	1	42	42.00***	137
Environment	1	193.98	64.66***	210.87
Genotype (G)	19	45.71	2.41***	7.84
S×G interaction	19	24.09	1.27***	4.13
G×E interaction	57	35.24	0.62***	2.02
Error	138	42.32	0.31	

*, ** and *** mean significant at 0.05, 0.01 and 0.001 probability levels, respectively.

in the interaction between ecosystems and genotypes (S×G), environments and genotypes (G×E), environments (E), genotypes (G) (p<0.001), and blocks (B) (p<0.05), showing high genetic variability among the twenty genotypes in the environment and site interactions (Table 3). The ecosystems (Lifuwo and Muirrua) and the environments (Lifuwu irrigated and Muirrua irrigated), affected genotypes performance differently and ranked individual genotypes (Table 4).

It is probably that soil and climate features (rainfall, temperature and relative humidity) affected the performance of the twenty genotypes across two

Table 4. Mean grain yield (t ha^{-1}) ranking of the twenty rice genotypes in each ecosystem across the two environments.

Lifuwu ecosystem		Muirrua ecosystem	
Irrigated		Irrigated	
Chincherica	4.40	Chincherica	5.93
Chupa	4.26	Mocuba	5.25
Chibica	4.09	Chupa	4.75
Mucandar	4.01	Nene	4.63
Kilombero	3.94	Faya	4.37
M'finico	3.91	Kilombero	4.37
Rafik	3.75	Singano	4.33
Mtupatupa	3.65	Rafik	4.17
Faya	3.60	Gorongosa	4.06
Mocuba	3.36	Chibica	3.94
Nunkile	3.36	Marista	3.8
Paula	3.31	Nunkile	3.55
Gorongosa	3.18	Niwaio	3.55
Nene	3.14	Paula	3.52
Singano	2.98	Pedra	3.32
Pedra	2.86	Djissa	3.31
Djissa	2.86	Mtupatupa	3.19
Marista	2.70	M'finico	3.15
Niwaio	2.68	Mucandara	3.12
Nassope	2.32	Nassope	2.90

environments. According to Hossain et al*.* (2013), fluctuations in the temperature and relative humidity can affect rice yield and their component in a considerable manner. Ahmed et al. (2008) reported that extremely low and high temperatures can affect rice production at all growth stages. The relative yield in the irrigated environment can be attributed to supplemented water from the irrigation scheme. Poehlman and Sleper (1995) reported that rice production systems differ widely in cropping intensity and yield, ranging from single-crop rainfed lowland and upland rice with small yields (1 to 3 t ha-^{1}) to triple-crop irrigated systems with an annual grain production of up to 15 to 18 t ha^{-1}. Kush (1997) reported that irrigated rice is the most productive crop system, which covers 75% of the global rice production. In this study, the yield was (3.69 t ha-^{1}) indicating significance in the irrigated system. Muirrua site yielded more with a mean of 3.22 t ha-^{1} while Lifuwu had a mean of 2.39 t ha-1. Atlin et al. (2006) concluded that development of rice varieties would produce acceptable yields under both water limited and favourable environments, while Annicchiarico and Perenzin (1994) and Eberhart and Russell (1966) advised that in situations with unpredictable site to site fluctuations of the environmental parameter, selections of a stable genotype, though not necessarily with the highest yielding, offered the best solution.

The performance of the twenty genotypes could have been influenced by availability of the nutrients depending on environmental factors such as pH, organic matter, and moisture. According to Andriesse et al. (1993), the availability of soil nutrients, however, changes with the moisture regimes of soils. The deficiency of nitrogen is the most common constraint on rice production. Uncertainty exists in abiotic factors affecting soil nitrogen supply in rice production and it has been commonly believed that total soil nitrogen can give adequate information about nitrogen release (Cassman et al., 1993).

Both sites did not meet the requirements of nutrients for rice production, in terms of amount and availability. For example, pH in Muirrua was 5.25 while it was 8.38 in Lifuwu. In terms of locations, it can be stated that geographical factors (latitude, longitude and altitude) may also have played some important roles on performance of the genotypes since most of rice genotypes in high-yielding regions are planted outside the Tropic of Cancer and Tropic of Capricornia. According to Andriesse et al. (1993), latitude is not responsible for high yield alone, although it is possible that latitude may have an effect on yield through resultant differences in temperature, solar radiation and day length.

The study revealed that the number of tillers in Lifuwu irrigated ecosystem was 12 while in Muirrua irrigated ecosystem, it was 14. The high tillering capacity is considered as a desirable trait in rice production, since number of tillers per plant is closely related to the number of panicles per plant. There were no significant differences ($p<0.001$) for panicle length in both ecosystems, Lifuwu and Muirrua, with 26 cm in Lifuwu and 25.92 cm in Muirrua. The mean numbers of filled grains per panicle were 234 for Lifuwu and 222 for Muirrua, with the grain length (paddy length) of 9.59 mm in Lifuwu irrigated and 9.78 mm in Muirrua irrigated.

Relationships between yield, yield components and growth parameters

Correlation analysis for yield, yield components and growth parameters showed that the number of tillers per hill (0.19), panicle length (0.15), the number of grains per panicle (0.07), grain length (0.37), weight of 1000-grains (0.27), grain shape (0.26), days to 50% flowering, and days to maturity are positively correlated with yield. Two traits, 1000-grain weight and grain shape, showed significant correlations at ($p<0.05$), while grain length showed significant correlations ($p<0.01$) (Table 5).

Rice grain yield has been reported to be positively correlated with plant height, panicle length and panicle weight (Samonte et al., 1998; Reddy et al., 1997), the number of grains per panicle and 1000-grain weight

Table 5. Correlation coefficients among grain yield, yield components and growth parameters of twenty rice genotypes at Muirrua irrigated ecosystem.

Parameter	1	2	3	4	5	6	7	8	9	10
Yield	1	0.19	0.15	0.07	0.37**	0.27*	0.26*	0.05	0.19	-0.15
No. tillers		1	0.21	0.14	0.07	0.12	0.14	0.16	0.09	0.03
Panicle length			1	0.36**	0.17	0.25	-0.1	0.31*	0.33**	-0.03
Grains/panicle				1	-0.03	0.26*	-0.06	0.08	0.18	0.03
Grain length					1	0.15	0.68**	0.06	0.07	0.19
1000-grain weight						1	-0.22	-0.12	-0.05	-0.33
Grain shape							1	0.03	-0.08	-0.06
Days to 50% flowering								1	0.89**	0.06
Days to maturity									1	0.11
Leaf length										1

*, ** show that the correlation is significant at 0.05 and 0.01 levels, respectively.

Table 6. Correlation coefficients among grain yield and yield components and growth parameters of twenty rice genotypes at Lifuwu irrigated ecosystem.

Parameter	1	2	3	4	5	6	7	8	9	10
Yield	1	0.14	0.33*	0.42**	0.02	0.16	0.01	0.41**	0.42**	0.06
No. tillers		1	-0.2	-0.34*	0.07	-0.02	0.27*	0.08	-0.23	-0.16
Panicle length			1	0.55**	-0.09	0.05	-0.02	0.66**	0.69**	0.40**
Grains/panicle				1	0.01	0.12	-0.01	0.56**	0.60**	0.42**
Grain length					1	0.31*	0.68*	-0.16	-0.32	-0.08
1000-grain weight						1	-0.23	-0.08	0.02	0.14
Grain shape							1	-0.02	-0.23	-0.14
50% flowering								1	0.83**	0.41**
Days to maturity									1	0.40**
Leaf length										1

*, ** show that the correlation is significant at 0.05 and 0.01 levels respectively.

(Samonte et al., 1998; Geetha et al., 1994), number of days to 50% flowering and number of days to maturity (Geetha et al., 1994). The grain length was highly and positively correlated with grain shape (0.68), while days to 50% flowering were highly correlated with days to physiological maturity.

In Lifuwu irrigated ecosystem, yield showed positive correlation with all nine evaluated traits. Bansal et al. (2000) reported that yield per plant was positively correlated with the number of productive tillers and 1000-grain weight, while Feil (1992) observed positive correlations between grain yield per plant and yield components including total spikelets per panicle, fertile florets per panicle and 1000-grain weight. Significant positive correlations were detected with panicle length (0.33), filled grains per panicle (0.42), days to physiological maturity (0.42) and days to 50% flowering (0.41). The 50% days to flowering showed high correlation with days to physiological maturity (0.83). Effective number of grains per panicle revealed significant positive correlation with days to 50% flowering (0.66) and days to physiological maturity (0.60). Significant positive correlations were found in days to 50% flowering (0.66) and days to maturity (0.69), correlated with panicle length (Table 6).

GENERAL CONCLUSION AND RECOMMENDATIONS

The results, obtained in this study, indicated that the twenty rice genotypes performed significantly different. These results showed that there was genetic variability in the material studied. The yield performance of the genotypes was consistent across the two irrigated sites of Muirrua and Lifuwu, probably suggesting stability of the genotypes. The ecosystems (Muirrua and Lifuwu) and the environments (Muirrua irrigated and Lifuwu irrigated) played an important role in phenotypic expression of grain yield, yield components and growth parameters (number of tillers per plant, number of filled grains per panicle, 1000-grain weight, days to physiological maturity, panicle length, grain shape, and days to 50% flowering).

The correlation analysis of the study revealed that the number of tillers per plant, panicle length, number of filled grains per panicle, weight of 1000-grains, grain length, and days to maturity were the most important yield components. Therefore, the results suggested that the number of filled grains per panicle, grain length, the number of tillers per hill, and weight of 1000-grain weight are important yield traits which selection based on them would be effective under irrigated ecosystems.

The genotypes *Chencherica*, *Mucandara redondo, Nene, Paula, Kilombero, Mocuba, Nunkile, Pdtra* and *Faya* presented five most important traits that can be probably preferred by farmers both in Mozambique and Malawi, namely yield potential, milling yield percentage, long grains, aroma, and not unsticky grains when cooked. These genotypes could be recommended and introduced to farmers as cultivars; although they need to be more improved in the case of some undesirable traits, for example shattering in *Chencherica.* The genotypes contain adequate genetic variability, which can be used to complement and broaden the gene pool in advanced genotypes. Breeders should therefore use the genotypes in their crop improvement programs not only to incorporate the desirable traits that are present in the genotypes, but also to change some undesirable traits.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

We want give special thanks and gratitude to Alliance for Green Revolution in Africa (AGRA) for funding for this research. Special gratitude is going to the breeding division of Lifuwu Research Station and Mr. Innocent Machira, for the support rendered in the field and laboratory. Special gratitude is also going to Muirrua Research Station and Mrs José Muderafa Magia, Mr. Mouzinho Emílio and Mr. Belmiro Silveira, for the support rendered in the field during the collection of data. To the Department of Crop and Soil Sciences (DCSS) staff members of Univesrity of Malawi.

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Appendix

Appendix 1. Soil characteristics of two environments (Lifuwu irrigated and Muirrua irrigated).

Parameter	Ecosystem			
	Lifuwo Irrigated		Muirrua Irrigated	
Deep (cm)	0-15	15-30	0-15	15-30
pH	4.90	4.20	8.50	8.70
P (mg/kg^{-1})	65.20	52.30	166.90	137.30
Ca (mg/kg)	9.60	8.90	651.90	597.80
Mg (mg/kg)	657.80	781.60	113.90	108.00
K (mg/kg)	18.40	19.00	24.10	21.70
Fe (mg/kg)	23.10	12.30	6.70	6.00
Cu (mg/kg)	0.14	0.10	0.10	0.50
Zn (mg/kg)	0.07	0.07	0.10	0.10
O.M (%)	3.20	3.10	4.70	4.60
N (%)	0.15	0.16	0.20	0.20
Sand (%)	27.20	27.70	31.00	29.00
Silt (%)	16.20	17.50	17.00	19.00
Clay (%)	56.50	55.60	52.00	52.00
Texture class	clay	clay	clay	clay