Journal of Agriculture Sustainability and Environment ISSN:2997-271X
https://doi.org/10.56556/jase.v1i1.775

RESEARCH ARTICLE

Phenotypic characterization of two lowland Rice Genotypes Cultivated with Organic Fertilizer

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Received: 03 January, 2022, Accepted: 25 February, 2022, Published: 28 February, 2022

Abstract

Rice farming in Liberia has long grappled with subpar yields, ranging from 0.5 to 1.5 tonnes per hectare (t/ha), attributed to outdated agronomic practices and the utilization of inferior inbred rice varieties. To alleviate the potential catastrophes and challenges of a changing climate and to improve rice production, we conducted a field experiment to determine the impact of organic fertilizer on the yield and growth attributes of two lowland rice genotypes (Nerica-L19 and the traditional landrace Bold Grain). The experimental layout was Randomized Complete Block Design (RCBD) in split plot arrangement with the main plots being organic fertilizer at a rate of 2.5 t/ha. Results revealed that there were significant differences between the landrace bold grain and the improved genotypes for all traits measured except for panicle length, seed length and stem diameter. Pearson coefficients of correlation analysis showed that days to 50 % flowering correlated significantly with plant height, number of tillers and number of panicles per plant. Nerica-19 exhibited the highest grain yield along with growth traits, suggesting its potential for smallholder farmers and warranting further evaluation across various environments.

Keywords: Genotype; landrace; phenotype; agronomic trait; organic fertilizer

Introduction

In Liberia, rice is the first most important cereal crop after maize, and its production by smallholder farmers in fields is solely less than 1.0 ha on average (MOA, 2020). 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 that represents wild plant populations as genetic resources (Das and Ashesh, 2014). Landrace rice varieties 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 the South-eastern region of Liberia, where more than 20% 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 Liberia 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 Liberia.

New Rice for Africa (NERICA) was developed by the West Africa Rice Development Authority (WARDA), 2006 through the successful crossing of African rice, Oryza *glaberrima* L, and Asian rice, Oryza *sativa* L, to produce inter-specific progeny which combine the best traits of both parents. This improved genotype (NERICA-L19) is a new type of lowland rice cultivar identified as promising and suitable for cultivation that perfectly adapts to the rain-fed lowland ecology in Liberia. On the other hand, Bold grain is a landrace variety in Liberia cultivated on both ecologies, which was identified by Central Agricultural Research Institute (CARI) scientists in 1983 through varietal selection. Majority of farmers have inadequate information on its cultivation techniques. The name of the variety was characterized by the morphology shape of the grains.

The existing rice varieties in Liberia are of long duration with poor gains yield which do not fit well into the farming systems practiced by farmers. There has been a paradigm shift towards producing more short duration with high yielding rice varieties to reduce hidden hunger and widespread malnutrition. Extensive research and adoption of higher yielding varieties will enable Liberian farmers to achieve sustained self-sufficiency in food which is paramount to domestic food security (MOA, 2020). Several studies have shown that rice cultivars perform differently across different agro-ecological zones. Some promising rice genotypes showed highly significant yield differences among rice genotypes due to environmental interaction (Mosavi, 2013; Ali et al., 2020; Xuan et al., 2020). Hence, local and improved hybrid rice varieties have to be evaluated across different environments to identify superior genotypes that can be adopted by farmers to improve rice production. Therefore, the aimed of this study was to evaluate yield and agronomic performance of two lowland rice genotypes (Nerica-L19) and landrace (Bold Grain) cultivated with organic fertilizer. The study hypothesized that the application of organic fertilizer would positively influence the yield of both Nerica-L19 and Bold Grain rice genotypes.

Material And Methods

The Study Area

The study was conducted at the research field of the College of Agriculture and Food Science, William V.S. Tubman University in Harper, Maryland County, Liberia. The experimental field is located at latitude 07°69'N and longitude 4°39’W at an elevation of 76 meters above sea level within the tropical forest agro-ecological zone (Figure 1).

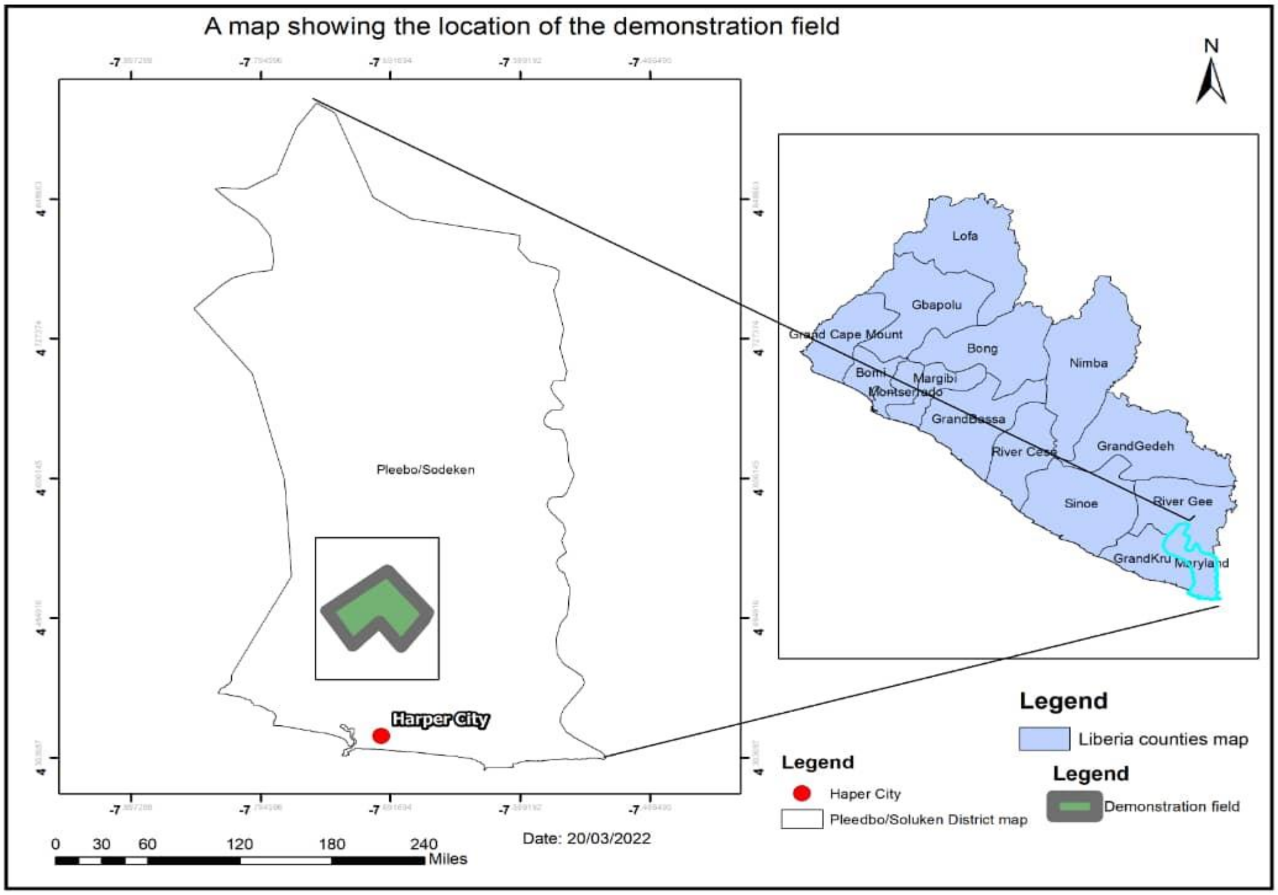

Figure 1: A Map showing the location of the demonstration field

Experimental design and field layout

The field was cleared and manually ploughed to provide a fine tilth for cultivation. Improved rice genotypes (Nerica-L19) and local genotype (Bold Grain) were obtained from the Central Agriculture Research Institute (CARI) for the study. The experimental layout was Randomized Complete Block Design (RCBD) in split plot arrangement with the main plots being organic fertilizer at a rate of 2.5 t/ha. The field was measured 26 m × 20 m with each plot demarcated with a 30 cm walk way and a plot size of 4 m × 4 m. The seedlings were raised in on a wet bed nursery with seed rate of 0.02kg of pre-germinated seeds randomly broadcasted on a 1m width by 14m length. After 14days, transplanting was done in straight row measured 0.3m by 0.3m on 26 November, 2021. Weeding of the field was carried out manually using hoe to control broad based weeds. At harvest, the lower, middle and upper portion of each plot was harvested and the grain weight (grain yield was reported at 14% moisture) represent the plot after drying (Saito *et al*., 2005). Ten selected rice hills were sampled from inside the harvested area for measurement of plant height, panicle number and length, number of tillers, stem diameter and dry weight of grains and averaged. Harvesting commenced at mid-February and proceeded to early March in 2022.

Data Collection

Data were collected on days to 50 % flowering (FPFl); plant height (PH); number of tillers per plant (#tillers); number of panicle per plant (#panicles); 1000 grain weight per plant (GW, 10 plants); seed length (SL) and stem diameter (SD). Except for days to flowering, all other data were collected at harvest. Harvesting was recorded within hundred days after transplanting when 50% of the crop had reached physiological maturity; plant height was recorded in centimeter (cm), follow by seed length and stem diameter were measured in millimeter (mm). While grain weight was recorded in grand (g) using a calibrated scale. Plant height (PH) was recorded from the plant base to the topmost part with a tape measurement. Stem diameter (SD) was recorded using a pair of vernier calipers while seed length was recorded using a vernire calipers.

Statistical analysis

Analysis of Variance (ANOVA) was performed to determine level of significance among the genotypes (LSD) ($P \leq 0.05$) using the R-Software Package (ver.9.2). The Pearson coefficients of correlation analysis among the traits were calculated to determine degree of associations among these traits.

Results and Discussion

Findings of the study revealed that both genotypes showed significant differences ($P \leq 0.05$) for plant height, 50% days to flowering, grain weight, number of tillers and panicle length per plant (Table 1). Moreover, there were significant differences ($P \leq 0.05$) for number of seed length and seed diameter for Bold grain (Table 1). Nerica L19 recorded the highest grain weight (1276g) while Bold grain recorded the least of 1082.5g. Improved variety recorded higher ($P \leq 0.05$) grain weights than the landrace. This may be attributed to the lateness of Bold grain in flowering and fruiting therefore coincided with terminal drought causing less assimilate to be translocated for grain formation. Most of the grains for landrace Bold grain were not fully filled, resulting in lower weight of grains. Good performance of the Nerica L19 genotype under nutrient-rich and rain-fed growing conditions has also been reported in the Philippines (Babu *et al*., 2012). Nerica L19 recorded similar yield, possibly due to adaptation to extreme environments as they might have exploited their early maturity periods by increasing the greater portion of photo-assimilates into grain production. This might have accounted for grains to be fully filled and recorded heavier weights than Bold grain. Thus, our findings revealed that genotypes selected tolerance with seasonal change performed well under moist conditions in the tropical forest agro-ecological zone of Liberia (Saito *et al*., 2005).

Additionally, Bold grain recorded the tallest plant height of 131.35, while Nerica L 19 registered the shortest plant height (103.55 cm) (Table 1). Majority of rice farmers in Liberia preferred tall plants to lessen their burden of cutting the panicles with a knife during harvesting. However, extremely tall rice varieties have a propensity to lodge, particularly, under stormy conditions; hence high yielding, relatively medium height and improved rice cultivars or their interspecific hybrids are recommended (Soares *et al*., 2014). Days to 50% flowering as indicator of earliness for rice revealed significant differences ($P \leq 0.05$) for the two genotypes studied. Nerica L 19 recorded the shortest maturity date ($n = 70$) while Bold grain recorded the longest maturity date of $n = 75$ (Table 1). There was no significant difference ($P \leq 0.05$) for number of tillers for both the local and improved genotypes studied. The numbers of panicles for both genotypes studied were significantly different; while the panicle lengths for both genotypes were not significantly different from each other ($P \leq 0.05$). Bold grain recorded the longest panicle length (25.3mm) while Nerica L 19 recorded the shortest panicle length of 25.0 mm (Table 2). The increase in some of these agronomic characters could be ascribed to the fact that plant height and number of tillers affect panicle traits and those plants with moderate heights could utilize energy from the sun for improved photosynthesis (Malik *et al.* 2005).

Table 1: Phenotypic response of Nerica–L19 and Bold grain genotypes evaluated

Genotype	PH (cm)	FPFl	#Tillers	#Panicle	GW (g)	PL (mm)	SL (mm)	SD (mm)
NERICA–L19	107.4^{c}	71.8^{c}	11b	9b	1276b	25.0ab	9.0ab	2.4ab
Bold Grain	131.3a	113.8b	8c	6c	1082.5c	25.3ab	8.9b	2.3a
CV %	4.3	0.9	14.9	15.8	3.98	5.25	1.9	11.2
SE	2.47	0.36	0.78	0.72	24.73	0.65	0.08	0.13
LoS	**	**	*	*	*	*	*	ns

Means with the same letters within the same column are not significantly different. LoS = level of significance, ns = not significant; PH = Plant Height; FPFl = days to 50% flowering; # Tiller = Number of Tillers; # Panicle = Number of Panicle; GW = Grain weight, PL = Panicle length; SL = Seed length and SD = Stem diameter at the base

Pearson correlation coefficients among both traits of rice genotype evaluated

There was positive correlation between plant height and days to 50% flowering; number of panicles per plant and number of tillers per plant for both genotypes whereas a negative correlation was observed between number of tillers per plant and number of panicles per plant; plant height and number of tillers per plant; plant height and number of panicles per plant; panicle and days to 50% flowering respectively.

The significant negative correlation observed with plant height and number of tillers (*r* = -0.968) and number panicles (*r* = -0.843) in (Table 2). This study corroborated earlier findings by Kato *et al* (2007) reported that rice genotypes with higher plant heights are usually larger in overall plant size, intercept more sunlight and use water faster through transpiration, leading to lower plant water status, higher dead leaf scores, and more spikelet sterility. Number of tillers (*r* = -0.857) and number panicles *(r* = -0.976) correlated significantly with days to 50% flowering respectively. These correlation indices estimated are very good since leaf and panicle water potential are highly associated with panicle exertion and anther dehiscence were reported in this study by Babu *et al*.(2012). The benefits of earlier flowering over later flowering in terms of higher spikelet fertility, higher harvest index, and higher grain yield have been reported by Guimarães *et al.* (2013) in (Table 2).

Additionally, the number of panicles had significant correlation with number of tillers per plant(*r* =0.947), while number of grain per plant recorded significant positive (*r* =0.707) and negative correlations with panicle length (*r* = -0.783) respectively (Table 3). It was observed that seed length (*r* = 0.846) was positively correlated with stem diameter but negatively correlated with grain weight (*r* = -0.802) (Table 3). Soares *et al.* (2014) also noted that agronomic traits in rice have a certain degree of associations with each other and particularly traits such as plant height, tillering, panicles, and early maturation. Most of these agronomic traits are controlled by multiple genes each of which is positively or negatively effective in the performance of the crop. A similar observation was made by Malik *et al*. (2005) who reported that tillering is a major component in agronomic performance of rice as it correlates well with panicle number as well as the grains weight (yield). The result of the correlation analysis revealed that most productive genotypes under the rain-fed conditions were those with the highest number of panicles and tillers per plant, and well-formed grains. In this study corroborated earlier findings by Lafitte *et al*. (2002). Despite the observed variations in all these traits, all the genotypes had the normal range of values for all the traits studied in agreement with Smith *et al* (2003), except for number of seeds per panicle and days to 50 % flowering. Rice genotypes with such photosynthetic potential are noted for high yield as a result of effective utilization of sunlight for efficient photosynthetic process.

Conclusion

Nerica 19 was the most productive genotypes recorded comparably significant grain weight than Bold grain with chicken manure application. The genotype Nerica 19 had higher plant height, earlier flowering period, higher grain weight, more panicles and tillers per plant than the landrace cultivar (Bold grain). The correlation analyses 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. 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 Bold grain Landrace. The Nerica L-19 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.

Declaration

Acknowledgment: I would like to express my sincere gratitude to the members of the research team who contributed to the successful completion of this study.

Funding: N/A

Conflict of interest: The authors have not declared any conflict of interests.

Authors' contribution: The authors confirm sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Data availability: All authors take public responsibility for the content of the work submitted for review.

Appendices

Appendix.1

Table 2: Pearson correlation coefficients of NERICA-L19 traits genotypes evaluated

Trait	FPFl	PH	Tiller	Panicle	PL	GP	SL	SD	GW
FPFI		0.879**	-0.857**	-0.976**	-0.056	-0.370	-0.260	-0.369	0.031
PH			-0.968**	-0.843**	-0.340	-0.427	0.040	-0.090	-0.287
Tiller				0.720**	-0.677*	0.850**	-0.283	-0.195	0.368
Panicle					0.285	0.697	0.039	0.123	0.076
PL						-0.675	-0.426	-0.451	0.202
GP							0.142	-0.226	0.269
SL								0.967**	-0.987**
SD									-0.865**
GW									

* Pearson correlation is significant at 0.05 levels (2tailed).
** Pearson correlation is significant at 0.01 levels (2 tailed).
PH = Plant Height; FPFl = Days to 50% flowering; # Tiller = Number of Tillers; # Panicle = Number of Panicle; GW = Grain weight, PL = Panicle length; GP = Number of grains per plant; SL = Seed length and SD = Stem diameter at the base

Appendix. 2

Table 3: Pearson correlation coefficients of Bold Grain traits genotypes evaluated

Trait	FPFl	PH	Tiller	Panicle	PL	GP	SL	SD	GW
FPFI		0.770**	-0.793**	-0.858**	-0.047	-0.481	-0.260	-0.369	0.042
PH			-0.914**	-0.889**	-0.410	-0.427	0.040	-0.090	-0.277
Tiller				0.947**	-0.783*	0.707**	-0.283	-0.195	0.418
Panicle					0.375	0.697*	0.039	0.123	0.066
PL						-0.675	-0.426	-0.451	0.309
GP							0.142	-0.226	0.249
								0.846**	-0.802**

SL	
SD	-0.892**
GW	

* Pearson correlation is significant at 0.05 levels (2tailed).
** Pearson correlation is significant at 0.01 levels (2 tailed).
PH = Plant Height; FPFl = Days to 50% flowering; # Tiller = Number of Tillers; # Panicle = Number of Panicle; GW = Grain weight, PL = Panicle length; GP = Number of grains per plant; SL = Seed length and SD = Stem diameter at the base

References

Ali, I., He, L., Ullah, S., Quan, Z., Wei, S., Iqbal, A., ... & Ligeng, J. (2020). Biochar addition coupled with nitrogen fertilization impacts on soil quality, crop productivity, and nitrogen uptake under double-cropping system. Food and Energy Security, 9(3), e208.

Xuan, Y., Yi, Y., Liang, H. E., Wei, S., Chen, N., Jiang, L., ... & Li, T. (2020). Amylose content and RVA profile characteristics of noodle rice under different conditions. Agronomy journal, 112(1), 117-129.

Babu RV, Shreya K, Dangi KS and US Shankar Correlation and path analysis studies in popular hybrid rice in India. Int. J. Sci. Res, 2012: 2-7.

Charrier A, Jacquot M, Hamon S, Nicolas D (1997). L'amélioration des plantes tropicales. Quae.

Das T, Ashesh KD (2014). Inventory of the traditional rice varieties in farming system of southern Assam: A case study. Indian J. Tradit. Knowl. 13(1):157-163.

Guimarães CM, Stone LF, Rangel PHN and AC de L. Silva Tolerance of upland rice genotypes to water deficit', Revista Bras de Eng. Agr. Amb. 2013; 17 (8): 805–810.

Kato Y, Kamoshita A and J Yamagishi Evaluating the resistance of six rice cultivars to drought: root restriction and the use of raised beds. Plant & Soil. 2007;300:149-161

Kobayashi A, Ebana K, Fukuoka S, Nagamine T (2006). Microsatellite markers revealed the genetic diversity of an old Japanese rice landrace 'Echizen'. Genet. Resour. Crop Evol. 53(3):499-506.

Lafitte HR, Courtois B and M Arraudeau Genetic improvement of rice in aerobic systems: progress from yield to genes, Field Crops Res. 2002; 75: 171–191

Malik RK, Gupta RK, Singh CM, Yadav A, Brar SS, Thakur TC, Singh SS, Singh AK, Singh R and RK Sinha Accelerating the Adoption of Resource Conserving Technologies in Rice-Wheat Systems of the Indo-Gangetic Plains, Hisar: CCS Haryana Agricultural University, 2005.

Ministry of Agriculture Quarterly Report Ministry of Agriculture, Government of Liberia, Monrovia: Government of Liberia, 2020: 21-35

Mosavi, A. A., Jelodar, N. B. and Kazemitabar, K. (2013). Environmental responses and stability analysis for grain yield of some rice genotypes. World Applied Sciences Journal, (21), 105-108

Perrino NQ, Attere F, Zedan H (1991). Crop Genetic Resources of Africa. Volume II. Proceedings of an International Conference on Crop Genetic Resources of Africa. 17-20 October 1988. Ibadan, Nigeria.

Saito K, Linquist B, Atlin GN, Phanthaboon K, Shiraiwa T and T Horie Response of traditional and improved upland rice cultivars to N and P fertilizer in northern Laos, Field Crops Res. 2006; 96: 216–223. http://dx.doi:10.1016/j.fcr.2005.07.003.

Smith CW and RH Dilday Origin, history, technology, and production of rice, 1st ed., Hoboken, Ed., New Jersey: John Wiley & Sons, 2003.

Soares ER, Fernandes R, da Silva Londero L, dos Santos DL, Corrêa SS, Corrêa ES, dos Santos RC, Gomes AP, Gomes AP, Galon L, Pires FF and R da Silva Gonçalves Agronomic Performance of Cultivars of Upland Rice in the Southern of the Region of Rondônia, Brazil, Agr Sci. 2014; 5: 513-518.

Tang G, Qin J, Dolnikowski GG, Russell RM, Grusak MA (2009). Golden Rice is an effective source of vitamin A. Am. J. Clin. Nutr. 89:1776-1783.

West Africa Rice Development Authority Development Strategy (2006)