Agronomic Performance of Zinc-Rich Rice Genotypes in the Valley of Les Cayes

Ludger Jean Simon[1*], Eugene Levael[2], Arsene Similien[1], Ruth Aminada Edme[1], Pierre Duclona[1], Jean Maude Louizias[1],

[1]College of Agriculture and Environmental Sciences, American University of the Caribbean, Les Cayes, Haiti

[2]International Center for Tropical Agriculture, Port-au-Prince, Haiti

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***Abstract.* Consumption of zinc-rich rice could help to reduce the prevalence of stunting in children under five in Haiti. A field experiment was conducted at Poteau, commune of Torbeck, Haiti, to evaluate 29 zinc-rich rice genotypes for their agronomic performance. A 6x6 lattice design was utilized in three replications. The cultivars IR64 and M8 were used as control treatments. Rice seedlings were transplanted at one plant per hill, spaced 25 cm x 25 cm, translating to 160,000 plants per hectare. The complete fertilizer 20-20-10 NPK was applied 4 days after transplanting, at the rate of 50 kg ha^{-1} N, 50 ha^{-1} P_2O_5 and 25 ha^{-1} K_2O. At 25 and 44 days after planting, urea (46-0-0) was applied at the rate of 30 kg ha^{-1} N in each application. Local practices were followed for water and weed management. The experimental plots were harvested when at least 50% of the grains reach physiologic maturity. The variables measured were severity of leaf blight, date of panicle initiation, plant height, number of tillers per plant, date of harvest, and grain yield. The results of the experiment show that there was no significant yield difference between IR64, M8, and the 10 best yield performers among the zinc-rich rice genotypes, with an average yield of 4.8 tons per hectare. Grain yield increased linearly with date of panicle initiation and with number of tillers per plant.**

Introduction

Rice (*Oryza sativa* L.) is after corn (*Zea mays* L.) the second most important cereal crop grown in Haiti. The national production oscillates between 132,000 and 186,087 metric tons for an area harvested oscillating between 47,121 and 61,279 hectares (FAO, 2022). Rice imports in Haiti for the market year 2023/2024 are forecast at 435,000 metric tons (Cledo, 2023).

Zinc is an essential trace element required for maintaining intestinal cells, bone growth, and immune function. Children who are living in low-income settings are often undernourished and zinc deficient (Gibson and Ferguson, 1999). About one-fifth of the world's population is at high risk of zinc deficiency (Lindenmayer et al., 2014). Zinc deficiency can cause stunting and worsen diarrhea and pneumonia, the most common causes of death among children in developing countries. Almost half a million children die every year from infections that could have been easily overcome if they had enough zinc (HarvestPlus, 2015). Deficiencies may arise from the insufficient intake of foods containing zinc or insufficient absorption.

The International Center for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI) started HarvestPlus as a joint program, with the goal of tackling hidden hunger caused by a lack of vital minerals and vitamins in the diet through biofortification. The 15 Research Centers of the Consultative Group on International Agricultural Research (CGIAR) and partners have developed and released biofortified crops, such as Zinc Rice that will eventually provide up to 50% or more of daily need for the target nutrient

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*Corresponding author: jsludger@gmail.com

(Rijsberman, 2014). Led by the International Rice Research Institute (IRRI), the goal of the HarvestPlus Zinc Rice program is to provide 80% of daily zinc needs through fully biofortified rice (HarvestPlus, 2015). Consumption of zinc-rich rice could help to reduce the prevalence of stunting in children under five in Haiti and elsewhere.

The American University of the Caribbean (AUC) has received from CIAT for field testing 29 rice lines selected for their high content in zinc along with the cultivar IR64 to be used as control. This experiment was an initial screening of the introduced genotypes. The most promising genotypes will be selected for Genotype-by-Environment (G x E) testing to verify that yield is stable across sites and planting seasons.

The research objective is to introduce, through adaptive research, sustainable production of high-yielding and zinc-rich rice cultivars in the Valley of Les Cayes.

Materials and methods

Experimental site

The experiment was conducted on producer field in the locality of Poteau, Commune of Torbeck. The geographic coordinates of the experimental site were 18.7089º N latitude, 73.810059º W longitude, and 12 m altitude. The location is classified as Af by Köppen and Geiger. The average temperature is 26.7ºC and the average annual rainfall is 2120 mm (Climate data, 2016). Total rainfall during the experiment was 574.2 mm (Figure 1). Soil texture was classed as clay (13.4% sand, 40.2% silt, and 46.4% clay), of pH 8.0, low in N, low in P, and moderate in K.

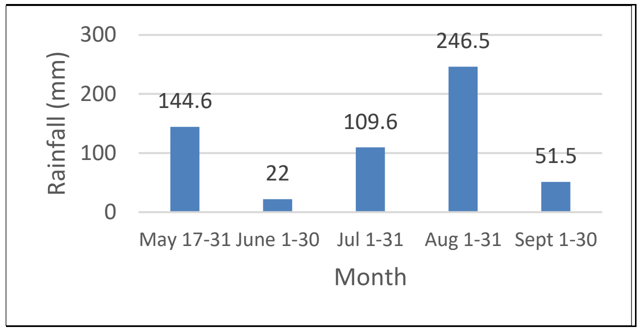

Figure 1. Rainfall during the experiment

Experimental design

A 6x6 Lattice design was utilized in three replications for this experiment. Each replication consisted of six incomplete blocks containing six entries each. There was a total of 108 experimental units for a total of 29 zinc-rich lines. The cultivar IR64 was used as CIAT check, and the cultivar M8 (Entry 30) as local check. 'IR64' was represented once in each incomplete block (Figure 2). The area of the experimental unit was 16 m^2 (4m x 4 m), with a spacing of 40 cm between experimental units within one replication. The area of one replication was 676 m^2 (26 m x 26 m), and the total area of the experiment 2080 m^2 (80 m x 26 m).

Cultural practices

Rice seedlings were produced in nursery established on 17 May 2016 and field transplanted on 11 June 2016. The area of the nursery bed was 1m x 1m for each experimental unit and received an application of 20-20-10 NPK at the time of sowing, supplying 50 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5 and 25 kg ha^{-1} K_2O. The seeds were pre-germinated for three days before sowing (14-17 May).

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*Corresponding author: jsludger@gmail.com

		COLS					
REP	ROWS	1	2	3	4	5	6
1	1	5	4	IR64	10	6	27
	2	22	20	14	28	25	IR64
	3	9	IR64	2	15	8	1
	4	3	12	13	18	IR64	29
	5	IR64	17	23	16	11	7
	6	30	24	21	IR64	26	19
2	1	10	21	IR64	20	8	11
	2	24	13	22	4	16	IR64
	3	17	IR64	27	1	3	25
	4	7	30	5	12	IR64	2
	5	IR64	28	6	15	26	18
	6	9	23	29	IR64	19	14
3	1	23	22	IR64	21	5	18
	2	3	6	11	14	2	IR64
	3	29	IR64	15	27	24	7
	4	17	30	20	9	IR64	13
	5	IR64	16	28	19	10	1
	6	25	8	4	IR64	26	12

Figure 2. Plot layout

Rice seedlings were transplanted at one plant per hill and hill spacing of 25 cm x 25 cm, translating to a density of 160,000 plants per hectare. The number of plants per experimental unit was 256.

Complete fertilizer 20-20-10 NPK was applied 4 days after transplanting (DAT), at the rate of 50 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5 and 25 kg ha^{-1} K_2O (thus 0.4 kg of 20-20-10 NPK per experimental unit). At 25 DAT and 44 DAT, urea (46-0-0) was applied at the rate of 30 kg ha^{-1} N, thus 104.4 g urea per experimental unit in each application. Local farmer practices were followed for water management.

Weed control was done manually on 25 June (14 DAT) and 15 July (34 DAT). Dominant weed species were *Heteranthera reniformis*, *Fimbristylis littoralis*, *Ammannia coccinea*, and *Ludwigia octovalvis*.

The insecticide Karate (Lambda Cyhalothrine) was used on 13 August to control the rice stink bug (*Oebalus ypsilongriseus*), Pentatomidae family of the order Hemiptera.

The experimental plots were harvested when at least 50% of the grains reached physiologic maturity. Each experimental unit was harvested separately, weighted and tested for moisture content in the field, and put in separate bags for further drying to reduce moisture content to the level of 14% or lower. The first harvest date was 3 September (84 DAT) and the last harvest date 1 October (112 DAT).

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Measured variables

The variables measured were: (1) Severity of leaf blast, using a scale of 1-9, where 1 refers to absence of the disease and 9 plants dying or completely died (Rohrmoser, 1985); (2) Date of panicle initiation, when the panicles are visible on at least 50% of the plants; (3) Plant height at panicle initiation, measured from soil level to the top of the plant; (4) Number of tillers per plant at panicle initiation, by counting the number of tillers for a sample of 5 plants and then calculating the average; (5) Date of harvest, recorded in number of days after planting; (6) Grain yield (kg/ha), calculated from the weight of grains harvested from an area of 2 m^2 for each experimental unit.

Statistical analysis

Generalized Linear Mixed Models (GLMM) and DGC (Di Rienzo, Guzmán y Casanoves) mean comparison test were performed at 5% alpha level. The InfoStat statistical software (Balzarini et.al, 2008) was utilized to perform the statistical analysis.

Results and Discussions

Table 1 depicts the mean comparisons of the different rice genotypes for the variables measured.

Leaf blast caused by the fungus *Pyricularia oryzae* Cav was more severe for genotypes 1, 14, 18, and 23 (p-value < 0.0001). Leaf blast is one of the most serious constraints for rice production at the global level (Persaud et al., 2021). Rice plants grown under high blast disease levels showed reduced plant height and grain yields compared to those grown under low disease levels (Koutroubas et al., 2009). The main effect of leaf blast on yield components was a reduction in the number of spikelets per panicle (Bastiaans, 1993).

Panicle initiation date was earlier for genotypes 10, 11, 12, 16, 26, and 28; and later for genotype 6 and M8 (p-value < 0.0001). The genotypes with the highest number of tillers per plant were IR64, 6, 17, 22, 25, 28, 29, and M8 (p-value < 0.0001). The plants were the tallest for genotype 27 (p-value <0.0001). Crop cycle from transplanting to harvest was the longest for genotype 28 and intermediate for genotypes 6, 20, 23, 24, M8, and IR64 (p-value < 0.0001). Ashfaq et al. (2012) found no correlation between heading date, tillers per plant, plant height, or maturity date and plant yield. Other authors (Martinez-Eixarch et al., 2015; Tefera et al., 2019) found a direct association between rice grain yield and tillers per plant.

The genotypes with highest yields were IR 64, 3, 4, 6, 7, 8, 19, 20, 23, 25, 29, and M8. Genotype 26 depicted the lowest yield (p-value < 0.0001). None of the genotypes that expressed early panicle initiation were among the highest yielding materials. Figure 3 and Figure 4 show linear relations of grain yield with date of panicle initiation and of grain yield with number of tillers per plant, indicating a tendency of higher yields for rice cultivars with late panicle initiation and high number of tillers per plant.

Conclusion

Ten of the zinc-rich rice genotypes had equal yield as IR64 and M8. Like IR64 and M8, these genotypes also had low leaf blast infection and high or intermediate number of tillers per plant. Leaf blast is a common disease of rice in Haiti, therefore resistance to this disease should be a key criteria for rice genotype selection.

Further genotype-by-environment experiments are necessary to verify that yields of the 10 best performers are stable across sites and cropping seasons.

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Table 1. Mean comparisons for the variables measured

Genotype	Disease severity (1-9)	Panicle initiation (DAT)	Tillers per plant	Plant height (cm)	Harvest date (DAT)	Yield (kg/ha)
IR64	1.56 b	66.61 b	21 a	86.54 d	95.28 b	4968.41 a
1	3.26 a	54.05 c	12.31 b	103.3 b	85.06 c	2546.67 b
2	2.49 b	56.24 c	10.63 c	108.22 b	84.23 c	3113.49 b
3	1.99 b	59.34 c	13.61 b	80.2 d	88.42 c	4050.49 a
4	2.19 b	57.66 c	14.32 b	83.24 d	90.41 c	4112.59 a
5	2.46 b	60.38 c	14.11 b	79.69 d	88.13 c	3428.66 b
6	1.81 b	72.24 a	19.42 a	95.33 c	97.46 b	4697.96 a
7	2.43 b	58.39 c	12.85 b	96.28 c	89.44 c	4428.19 a
8	0.72 b	59.81 c	11.79 b	97.65 c	83.71 c	4319.1 a
9	1.43 b	55.82 c	8.33 c	108.19 b	86.36 c	2012.16 c
10	2.9 b	48.39 d	9.2 c	90.26 c	83.98 c	1575.5 c
11	2.12 b	49.66 d	10.13 c	96.41 c	83.99 c	1809.58 c
12	2.21 b	51.68 d	7.35 c	92.44 c	84.77 c	2130.05 c
13	1.03 b	55.28 c	6.31 c	111.15 b	88.8 c	1793.75 c
14	3.95 a	58.84 c	10.62 c	90.81 c	84.01 c	1884.18 c
15	2.2 b	55.21 c	10.25 c	109.06 b	84.52 c	2764.92 b
16	2.3 b	48.49 d	10.07 c	90.44 c	84.41 c	2469.06 b
17	1.02 b	65.04 b	20.55 a	82.22 d	93.07 c	3823.97 b
18	4.0 a	59.62 c	9.85 c	98.54 c	89.78 c	3476.27 b
19	1.59 b	59.12 c	13.87 b	95.8 c	91.75 c	4641.7 a
20	2.61 b	66.17 b	14.18 b	92.33 c	97.71 b	4380.58 a
21	2.75 b	62.57 b	15.06 b	77.01 d	90.35 c	3620.07 b
22	1.27 b	64.63 b	17.52 a	78.26 d	92.15 c	3578.38 b
23	3.52 a	65.99 b	13.12 b	90.81 c	97.2 b	4696.34 a
24	2.69 b	64.02 b	11.97 b	91.18 c	95.11 b	3681.02 b
25	2.67 b	56.43 c	16.68 a	83.76 d	83.97 c	4115.71 a
26	2.06 b	47.89 d	10.11 c	77.84 d	86.7 c	460.63 d
27	1.74 b	63.26 b	7.42 c	146.07 a	84.13 c	2976.29 b
28	1.89 b	51.24 d	18.75 a	83.17 d	112.04 a	2182.02 c
29	0.87 b	58.66 c	17.67 a	73.73 d	90.97 c	4300.63 a
M8	2.17 b	71.54 a	22.95 a	113.49 b	97.71 b	4198.36 a
P-values	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Means with a common letter are not significantly different (p > 0.05)

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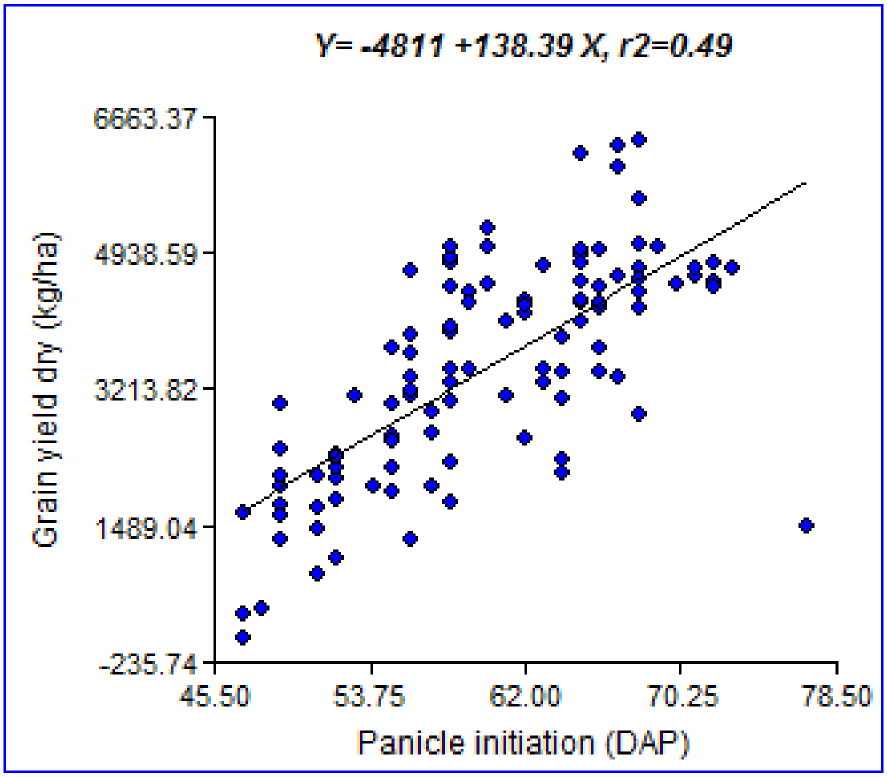

Figure 3: Grain yield as affected by date of panicle initiation

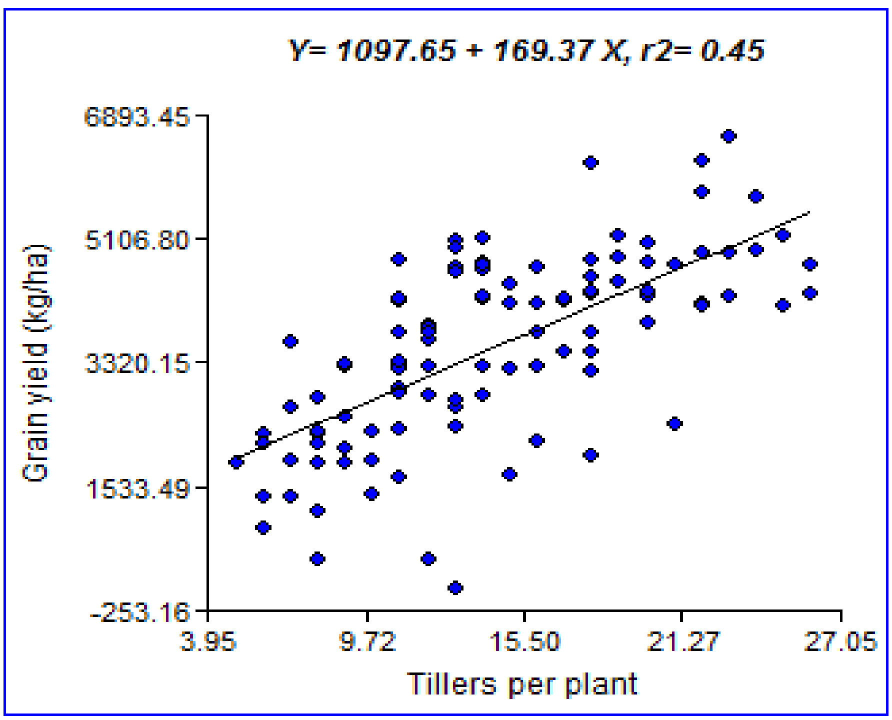

Figure 4. Grain yield as affected by number of tillers per plant

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*Corresponding author: jsludger@gmail.com

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