Research Article

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Journal of Plant Sciences and Agricultural Research

2024
Vol.8 No.1:128

On-Farm Evaluation of New Rice (*Oryza sativa*) Genotype (FG12-259) for Commercial Cultivation in Guyana

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Received date: March 02, 2024, Manuscript No. IPJPSAR-24-18698; **Editor assigned date:** March 04, 2024, PreQC No. IPJPSAR-24-18698 (PQ); **Reviewed date:** March 19, 2024, QC No. IPJPSAR-24-18698; **Revised date:** March 26, 2024, Manuscript No. IPJPSAR-24-18698 (R); **Published date:** April 02, 2024, DOI: 10.36648/ipjpsar.8.1.128

Citation: Persaud M, Mc Gowan D, Gobind N, Henry M, Baharally V, et al. (2024) On-Farm Evaluation o f New Rice (*Oryza sativa*) Genotype (FG12-259) for Commercial Cultivation in Guyana. J Plant Sci Agri Res Vol.8 No.1: 128.

Abstract

Aim: To evaluate the performance of a candidate rice (*Oryza sativa*) variety, FG12-259 during On-Farm trials.

Background: The ability of a variety to adapt and perform well under varying environs is key to its acceptability by farmers. Hence, this study was conducted to examine the adaptability of the rice genotype FG12-259 within the various rice growing regions of Guyana.

Methodology and Findings: New rice genotype FG12-259, a candidate variety, was evaluated alongside local varieties GRDB FL 10 and GRDB FL 15 for its yield potential and lodging tolerance in varying environments. Trials were conducted within the fields of Twenty-Four (24) and Twenty-Nine (29) farmers during the 1st and 2nd cropping season of 2020 respectively. During the first season plot sizes were 100 m^2 and managed primarily by the research team whereas during the second season plot sizes ranged from 0.6-2.4 ha and were managed primarily by farmers under the supervision of the research team. Data was collected at the maturity stage of the crop.

When examined regionally, candidate variety FG12-259 was observed to have yielded significantly greater than or on par with that of the local varieties. During the first cropping season FG12-259 yielded on average 7795.0 kg ha^{-1} with 0.2% lodging as compared to GRDB FL 10 with 7835.9 kg ha^{-1} and GRDB FL 15, 7679.4 kg ha^{-1} which lodged at 15.5% and 2.2% respectively. In the second cropping season, FG12-259 produced on average 7528.6 kg ha^{-1}, GRDB FL 10, 6794.5 kg ha^{-1} and GRDB FL 15, 7163.4 kg ha^{-1} with lodging incidence of 1.3%, 4.4% and 0% respectively.

An overall 8% (566.9 kg ha^{-1}/3.53 bags ac^{-1}) yield advantage of the candidate variety over local varieties GRDB FL 10 and GRDB FL 15 was recorded.

Conclusion: Based on the results obtained and the general acceptance of FG12-259 by farmers, it was recommended to be released as a commercial variety (GRDB FL 16) for cultivation across the country.

Keywords: Breeding; Genotype; Variety; Stability; Adaptability; Farmer

Introduction

Rice is a remarkably diverse crop both in the way it is grown and how it is utilized. It is considered one of the most important food crops, feeding more than half of the world's population, ranking second in production after wheat and growing on all continents except Antarctica [1].

In Guyana, rice is grown seasonally on approx. 100,000 hectares of lands with national average yield of around 6 tonnes ha^{-1}. To satisfy the needs of farmers and the growing demands for this staple worldwide, an organized breeding program was conceived by the Guyana Rice Development Board (GRDB). This program focuses on increasing the yield, stability, quality and nutrition of rice while also providing a crop suitable to many growing conditions and farmers' needs.

Yield, a highly complex quantitative characteristic, is controlled by numerous genes, and its manifestation is influenced by genotype and environment, as well as their interaction [2]. In multilocational trials, this interaction within varying environments may complicate the selection process as the performance of genotypes may be inconsistent across environments. The ability of a genotype to maintain its status within a changing environment is an important consideration for yield improvement [3].

Lodging is an important character to be considered during the development of high yielding varieties as it can cause significant losses in both grain and quality and presents extreme problems during harvesting [4]. Varieties that lodge very easily are not considered desirable by farmers in Guyana, lodging of up to 100% is not uncommon in fields for varieties that lodged during rainy conditions at harvesting.

Breeders often evaluate various genotypes in diverse environmental conditions before a newly developed variety is released for commercial utilization. One of the most common approaches in identifying crop varieties acceptable to farmers is to expose one or a few promising, newly developed strains to diverse farming environments in order to evaluate and predict their performance. Varietal performance in farmers' fields is predicted in terms of adaptability, which implies the ability to perform well over diverse environments. On farm adaptability evaluation is the link between research station varietal development and the actual acceptance of those varieties by farmers [5]. Testing varieties in farmers' fields is usually done at two levels, introductory and adaptive [6]. Multilocation experiments are important to obtain genotypes that are adapted to a specific location or tend to be stable under various environmental conditions [7]. Therefore, emphasis should be given to identifying genotypes that perform consistently well across environments.

In fulfilling its mandate, the Plant Breeding team of GRDB sought to develop a high yielding rice variety, acceptable to farmers and the export market. The breeding line FG 12-259 was first evaluated alongside other advanced strains and commercial varieties in several multi location yield trials across the country and was thereafter identified as the most suitable candidate for possible varietal release. A varietal release however is not guaranteed without farmers acceptance, as such, on-farm introductory and adaptability trials were conducted in 2020, in the fields of several farmers during the two rice growing seasons in Guyana (November-April and May-October, referred to as Spring and Autumn crop respectively).

Materials and Methods

On-farm trials were conducted in the five major rice growing regions of Guyana. These regions encompass forested highlands, low coastal plains, hilly sands and clays as well as intermediate savannahs. The climatic conditions of these regions care, haracterized by high temperature and humidity as well as heavy rainfall, which varies seasonally. Region #5 being the largest rice growing region had the largest number of participating farmers.

During the Spring crop, Twenty-Four (24) farmers participated in the introductory evaluation of candidate variety FG12-259. Plot sizes of 100 m^2 were mechanically prepared, cultivated and managed by the research team with little assistance from farmers. Fertilizer was applied at a rate of 100 kg N ha^{-1}+30 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} and standard husbandry practices (roguing, pest and disease control) were followed.

In the Autumn crop, Twenty-Nine (29) farmers participated in the adaptability evaluation, plot sizes ranged from 0.6-2.4 ha, these trials were managed primarily by farmers under supervision of the research team.

During both seasons, the candidate variety FG12-259 was evaluated against commercial varieties GRDB FL 10 (one of the highest yielding varieties with a tendency to lodge heavily) and/or GRDB FL 15 (a recently released high yielding variety with minimum lodging tendency).

The variables observed were lodging incidence (%) and grain yield (kg ha^{-1}). The variance of data was analysed using Analysis of Variance (ANOVA) with Statistix 8 software, and mean values for traits were compared according to Least Significant Difference (LSD) statistical test.

Other agronomic characters as well as milling and cooking qualities of FG12-259 were examined during evaluations conducted in the various rice growing regions prior to the strain being selected for on farm evaluation **(Table 1)**.

Results

Yield

Average grain yield (Kg ha-1) as per region **(Table 2)**.

Table 1: Number of farmers participating in in farm trials, 1st and 2nd Crop 2020.

1st crop 2020		2nd crop 2020	
Region#	**No of farmers**	**Region#**	**No of farmers**
Two	4	Two	5
Three	3	Three	4
Four	2	Four	3
Five	10	Five	12
Six	5	Six	5
Total	24	Total	29

Table 2: Average grain yield of strains evaluated in on farm trials, 1st and 2nd crop 2020.

Average grain yield (Kg ha^{-1}) as per region						
Region#	1st crop 2020			2nd crop 2020		
	GRDB FL 10	GRDB FL 15	FG12-259	GRDB FL 10	GRDB FL 15	FG12-259
Two	8254.6a	8194.8a	8398.4a	6866.0b	7480.7a	7638.4a
Three	6663.1b	6384.3b	6812.8b	5915.9c	7236.8a	7737.5a
Four	8820.9a	7953.2ab	7942.4ab	6759.9b	-	7304.0a
Five	7529.8ab	7528.8ab	7723.4ab	7153.1ab	6779.1b	7486.1a
Six	7911.1ab	8335.8a	8099.1a	7277.4a	-	7477.2a
Mean	7835.9	7679.4	7795.2	6794.5	7163.4	7528.6
CV	19.23	23.17	19.51	8.28	8.26	18.49

Note: *Numbers in one column followed by the same letter show no significant difference based on the LSD test at 5%; CV: Coefficient of Variance. a: Variety GRDB FL 10; b: Variety GRDB FL 15.

Grain yield: Data collected during the first season of evaluation revealed that the average grain yield of each of the tested entries across the five regions were 7835.9 kg ha^{-1}, 7679.4 kg ha^{-1} and 7795.2 kg ha^{-1} for varieties GRDB FL 10, GRDB FL 15 and FG12-259 respectively. All entries were observed to have yielded exceptionally well in region #2 while yielding lowest in region #3.

Strain FG12-259 and GRDB FL 15 recorded statistically higher yields in both regions #2 and #6 when compared to other regions while GRDB FL 10 recorded statistically higher yields in regions #2 and #4. The candidate variety was also observed to have yielded greater (though not significantly) that both check varieties in regions # 3 and 5.

Overall, it was observed that 75% (18) of the farmers who cultivated GRDB 10 during the irst season produced >7000 Kg ha^{-1} while 71% (17) of the farmers were able to produce >7000 Kg ha^{-1} of GRDB 15 and FG12-259.

It must be noted that of the 18 farmers producing >7000 Kg ha^{-1} of GRDB 10, 8 (33%) produced within the 7000-7999 Kg ha^{-1} range while 5 (21%) and 4 (17%) of the farmers produced between 8000-8999 Kg ha^{-1} and 9000-9999 Kg ha^{-1} respectively and a single farmer (4%) produced >10000 Kg ha^{-1}.

In the case of GRDB 15, two farmers (8%) were able to produce >10000 Kg ha^{-1} and five farmers (21%) each produced within the ranges of 7000-7999 Kg ha^{-1}, 8000-8999 Kg ha^{-1} and 9000-9999 Kg ha^{-1}. Six farmers (25%) cultivating FG12-259 were able to obtain yields ranging 7000-7999 Kg ha^{-1}, four farmers (17%) between 8000-8999 Kg ha^{-1} and another six farmers (25%) between 9000-9999 Kg ha^{-1} while an individual farmer (4%) produce yields exceeding 10000 Kg ha^{-1} **(Figure 1).**

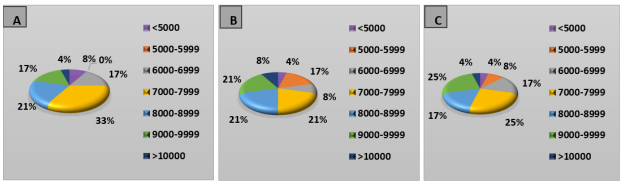

Figure 1: Grain yield ranges of on farmers trials during first crop 2020 of A: Variety GRDB FL 10; B: Variety GRDB FL 15 and C: Candidate variety FG12-259.

In the second crop, the overall average grain yield among the evaluated strains were observed to be lower compared to that of the first crop with GRDBFL 10, GRDB FL 15 and FG12-259 producing an average grain yield of 6794.5 kg ha^{-1}, 7163.4 kg ha^{-1} and 7528.6 kg ha^{-1} respectively. The candidate variety was noted to have produced higher yield than both check varieties in all five rice growing regions. No significant difference was observed across the five regions for yields of the candidate variety, underscoring that even though the crop was managed primarily by farmers whose site-specific cultivation techniques likely varied, the yields obtained were generally high and statistically identical.

None of the farmers were able to produced yields above 10,000 Kg ha^{-1} during the second crop, however, 17% (5) of the farmers cultivating FG12-259 produced yields ranging from 9000-9999 Kg ha^{-1} while only a single farmer cultivating GRDB 10 was able to attain yields within this range. Seven farmers (24%) produced yields ranging 8000-8999 Kg ha^{-1} while another eight (28%) produced yields in the range of 7000-7999 Kg ha^{-1} while cultivating FG12-259. Four of the farmers (17%) cultivating GRDB 10 produced yields ranging 8000-8999 Kg ha^{-1} and seven farmers (31%) produce ranged from 7000-7999 Kg ha^{-1}. Only ive farmers cultivated GRDB 15 during this season, three of which

produced yields ranging 6000-6999 Kg ha^{-1} while two produced yields ranging 8000-8999 Kg ha^{-1} **(Figure 2)**.

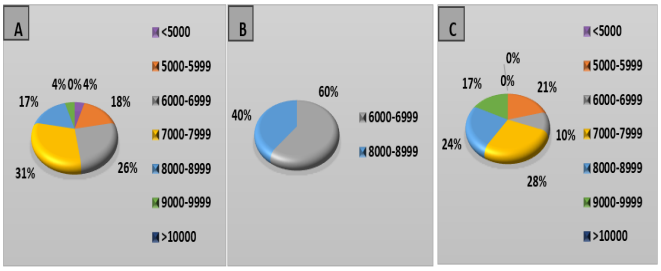

Figure 2: Yield ranges of on farmers trials during second crop 2020 of A: Variety GRDB FL 10; B: Variety GRDB FL 15 and C: Candidate variety FG12-259.

A yield difference of 566.9 kg/ha^{-1} (3.53 bags/ac) was observed between the candidate variety and the two high yielding check varieties (GRDB 10 and GRDB 15) which represent an 8% yield advantage.

Lodging

Average lodging (%)/Region **(Table 3)**.

Lodging: Incidence of lodging was recorded in all but one region over the two seasons of evaluation. Greater incidence of lodging was recorded from GRDB FL 10 as compared to GRDB FL 15 and FG12-259, primarily in regions five and six during the first crop where GRDB FL 10 recorded 29% and 37% lodging respectively and averaging 15.5% across the five regions. In the second crop GRDB FL 10 also recorded the highest average lodging incidence (4.4%) across the five regions. Lodging of the FG12-259 and GRDB FL 15 was minimal during both seasons of evaluation **(Figure 3)**.

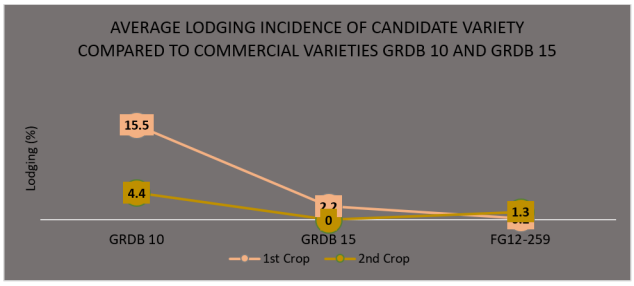

Figure 3: Average lodging (%) of candidate variety (FG12-259) compared to check varieties GRDB 10 and GRDB 15.

Discussion

The inal evaluation for adaptability of a rice variety in a rice testing program involves on-farm multi-locational yield trials with farmer participatory approach. Although many lines are included in preliminary yield tests, only the better performers are selected for further screening in on-farm trials.

The grain yield results of this trial revealed that the candidate variety (FG12-259) exhibited high grain yield performance at the various locations across Guyana during the periods of assessment. This indicates stability in the performance of this genotype over different environments for two traits (yield and lodging) of economic importance to Guyanese farmers. Persaud et al. [8], 2022 reported consistently high stable grain yield performance of breeding lines FG12-259 under six environments in Guyana. The ability of a variety to perform well under diverse conditions indicates the presence of high adaptability traits. Plants which can tolerate environmental stress have the ability to adapt morphologically and physiologically [9]. The varying yields of plants are in luenced by internal factors which includes

Table 3: Average lodging (%) of genotypes evaluated in the on farm trial, 1st and 2nd crop 2020.

Average lodging (%)/Region						
Region	1st crop 2020			2nd crop 2020		
	GRDB FL 10	GRDB FL 15	FG12-259	GRDB FL 10	GRDB FL 15	FG12-259
Two	0	0	0	0	0	0
Three	1.7	0	0	18.8	0	6.3
Four	5	0	0	0	0	0
Five	29	10	0	0.4	0	0
Six	37	1	1	3	0	0
Mean	15.5	2.2	0.2	4.4	0	1.3
CV	118.17	199.17	223.61	182.98	0	223.61
SD	17.18	4.38	0.45	8.12	0	2.81

genetics and external traits, which include environmental factors such as climate, soil and biotic factors [10]. In 2020 Khairullah et al. [11] noted that local varieties (landraces) have an advantage that they are more resistant to biotic or abiotic stress, but generally have long maturity, greater height and poor grain yield. Hence, being able to identify breeding lines which are able to resist/tolerate environmental stresses (comparable to local varieties) while producing higher yields is seen as a tour de force.

Lodging (the bending of stems of grain crops), a critical parameter in yield evaluations was observed to be minimal to non-existent in the candidate variety, FG12-259. A crop free from lodging may ultimately result in higher yields providing that all other essential requirements are met [12]. In an experiment conducted at IRRI, Setter et al. [13] subjected three different rice cultivars to artificial lodging stress, and determined that 75% lodging significantly reduced the plant height and similarly affected the yield. Lodging not only reduces grain size and number but also reduces the amount of crop that can be harvested by the combine harvester. Lodging also often contributes to uneven maturity, high moisture content and loss of grain quality due to sprouting and possible moulding [4]. The greatest yield reduction occurs when lodging occurs at anthesis or early grain filling [14].

The importance of farmer participatory research must be emphasised, complete research managed solely by research personnel or by farmers themselves are often found to be biased in one way or another. Abeysiriwardena et al. in 2005 [15] studied the management of on-farm trials for testing adaptability of crop varieties and recommended that site-specific farmer practices be employed under the supervision of researchers during on-farm trial evaluations. It was determined that farmers practices were superior as they are site specific, representing an improvement on blanket recommendations to suit local farm conditions. Management of trials by farmers themselves however was discouraged as accurate estimates of varietal performance may not be achieved due to non-uniformity of management.

The replication of a multi-location trial within a given location is difficult, expensive and cumbersome, in addition, problems of error heterogenicity among location is frequent. The need of having within location replications for accurate determination of varietal yield can be avoided by using larger plot sizes [16] as was utilized within this trial.

The positive interaction of candidate variety FG12-259 within the various regions ensures valid recommendations of a suitable variety as it has proven to be able to overcome the pressure of variable occurring conditions. Since rice is often grown in complex, diverse and sometimes risk prone environments where factors influencing environmental diversity are highly unpredictable, acceptance of rice varieties by farmers is dependent upon their general adaptability over diverse environments.

Increasing the total rice production is critical to ensuring food security. Should global per capita rice consumption continue as in the past two decades, then total consumption will grow at the rate of population growth [17]. Moreover, a growing population could also shrink rice acreage in future, hence the increase of rice yield will have to be met through an increase in productivity per unit land. The main contributory factor for increasing rice production is the high yielding rice varieties. The development of an improved high yielding variety involves rigorous in-house screening followed by adaptability evaluations. Developing high yielding varieties with the potential of producing above seven tonnes per hectare in the farmers' field is a prime objective of the local breeding program. Taking into consideration the conditions in which rice is being grown in Guyana, it is crucial that varieties possess good field characters and tolerance to lodging. In Guyana, tolerance to lodging contributes positive to harvest yields and grain quality. Good grain qualities are crucial in ensuring Guyana maintains and expands its international markets.

Breeding line FG 12-259 is an early duration (110-112 days), Blast (Pyricularia grisea cav.) resistant, semi-dwarf rice genotype with good tillering ability and canopies very well at an early stage. It also possesses excellent early vigour and has the ability to emerge well from 7.6 cm to 15.2 cm (3-6 inches) of standing water in the field. These traits are particularly important for good crop establishment and weed competitiveness in Guyana. This genotype produces long panicles (24-27 cm) with long to extra-long (7.8 mm ± 0.3 mm) slender grain with excellent head rice recovery from paddy (58.0% ± 3.0%). These traits along with its consistent grain yield and lodging tolerance over the multiple locations, coupled with the positive reaction and recommendation by farmers who conducted the trials and those participated in the field visits, favours recommending this genotype (FG 12-259) for commercial cultivation countrywide. An 8% yield advantage over the best yielding varieties means that the farmer's profit and livelihood will be directly and positively impacted.

Conclusion

The successful adaptation of a plant in a particular environment depends on the possession of an optimum combination of characters that minimize deleterious effects and maximises advantageous effects. Based on the superior grain yield performance and tolerance to lodging across the 29 farmers field over two season, breeding line FG12-259 was recommended for varietal release as GRDB FL 16 for commercial cultivation in Guyana.

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