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Yield Performance of Some Advanced Aromatic Rice Genotypes in Guyana

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Abstract: Breeding for quality traits is one of the major objectives of the Rice Breeding programs in Guyana and many other countries that are self-sufficient in rice production. Aromatic rice constitutes a special group of rice which is known as the best quality of rice worldwide. It is known for its nut/popcorn-like aroma and taste. This group is estimated to account for only 15-18% of the total rice trade on the world market. They are rated as the best in quality and sell for a much higher price than high quality non-aromatic rice on the international market. Due to this fact, considerable attention has been given towards developing aromatic varieties with the view of allowing the Guyanese farmers the opportunity to enter this niche aromatic rice market and enjoy the premium price offered. So far, the breeding program has released one aromatic variety (*viz.* GRDB 13) for commercial cultivation in Guyana. Further, more than 200 breeding lines were evaluated and of which 14 elite genotypes were selected for further testing of their yielding ability and agronomic traits for developing and released as an aromatic rice variety. These strains were tested during the spring crop of 2019 at Rice Research Station, Burma, Mahaicony, East Coast Demerara, Guyana in a Randomized Complete Block Design with three replications. The study identified three high yielding genotypes *viz*., G13-113 (7840.5 kg/ha), G13-114 (7761.8 kg/ha) and G17-138 (7526.5 kg/ha) with statistically similar to the high yielding ability as the aromatic check variety, GRDB 13. In addition, all except two genotypes (G13-116 and G17-138), showed good tolerance to lodging. There was significant variability among the aromatic genotypes evaluated for days to maturity, plant height, tillers, grain length, fertility of grains, panicle length and grain weight. Also the aromatic genotypes showed similar excellent milling and cooking qualities as the local varieties.

Keywords: Aromatic, Rice, High Yielding, Lodging Tolerant

1. Introduction

Rice is the main food crop in Guyana and major foreign exchange earner for agriculture. It contributes 3.3% to the gross domestic product (GDP) and approximately 20.5% of the agricultural GDP in 2020 [17]. Guyana exported more than 75% of its production in 2020 [17]. Grain quality is of great importance to ensure the export markets are maintained and to provide an opportunity to bargaining for a higher price than the average world market price. Aromatic rice forms a special group of rice which is known as the best quality of rice worldwide [18]. It is known for its nut/popcorn-like aroma and taste [18]. Aromatic rice contains several bio-chemicals, the most important is 2-acetyl-1-pyrroline (2AP) which is responsible for the aroma [8, 21]. Some of the most popular varieties of aromatic rice include ambemohar, basmati, jasmine, etc. Aromatic rice is known to attract a higher premium prices on the international market (approximately 950-1200 USD/ton) as compared to ordinary, non-aromatic, rice (which is 320 to 500 USD/ton) [6]. Therefore, it is reasonable to assume that farmers can receive a 50% share of the increase in profits derived from such rice which can translates to an additional 200 USD/ton of paddy. Also, aromatic variety utilizes a similar cultivation and agronomic practices as well as, it has similar yielding ability as the

existing non-aromatic varieties and therefore no noticeable increase in production cost is foreseen. GRDB has recognised the tremendous financial returns that can be garnered from the exportation of aromatic rice [14], Taking into consideration the increasing demand for aromatic rice on the international market [14] it is reasonable to believe that Aromatic rice can be the game changer of the face of Guyana's' rice industry.

Breeding for aroma in rice has always been an uphill task for breeders due to the narrow genetic base, poor combining ability of the trait, low yielding ability, late maturity and the recessive nature of the genes involved [1]. However, due to the increasing demand by importing countries for aromatic rice, there has been a growing focus and attention to develop the aromatic breeding program. In view of this, Guyana has embarked on a breeding program to develop its own aromatic rice to allow farmers an opportunity to enter the niche aromatic rice market and enjoy the higher price for it aromatic rice. It first Aromatic Rice Variety (GRDB 13) was released in 2015. The selections and testing are on the way for a second Aromatic rice variety. In this background fourteen superior breeding lines were selected from the breeding nursery of over 200 genotypes, for advanced yield testing to identify promising strains for possible release as an aromatic variety for farmers to cultivate in Guyana.

2. Materials and Method

The investigation was carried out at the Rice Research Station, Burma Mahaicony by the Guyana Rice Development Board during the spring crop of 2019. Fourteen advanced Aromatic breeding lines were tested against two commercial varieties (Table 1). The experiment was set up using a Randomised Complete Block Design (RCBD) with three replicates under lowland irrigated field conditions. Genotypes were sown in a $24m^2$ plots size at a seed rate of 157.2 kg ha^{-1} (378 g per plot). Fertilizer was applied at a rate of 185 kg N ha^{-1} + 84 kg P_2O_5 ha^{-1} + 84 kg K_2O ha^{-1}. Weeds, pest and disease control was carried out using standard recommended chemicals at the GRDB recommended rates and timings. Field sanitation and routine husbandry practices were followed throughout the trial duration.

2.1. Data Collection

Plant height, tiller per meter square, lodging incidence, grain yield ($kgha^{-1}$), days to maturity, panicle length, fertility, 1000 grain weight, head rice recovery from paddy, head rice recovery from cargo, percentage of chalkiness, grain length expansion, grain width expansion and alkaline spreading value of rice were measured, collected and recorded for the fourteen advance aromatic rice genotypes and the two check cv. GRDB 13 and GRDB 15.

2.2. Statistical Analysis

The variance of data was analysed using analysis of variance (ANOVA) with Statistix 10 software, and grand mean values for traits were compared according to Least Significant Difference (LSD) statistical test.

Table 1. *List of all entries and check varieties tested during spring Crop, 2019.*

S. N	Strain	Designation	Parentage	Aroma Present
1.	G13-112	GR 1562-25-16-2-1-2-1	GR1107-10-2-1-2/G98-135	Strong
2.	G13-113	GR 1562-25-26-1-1-2-1	GR1107-10-2-1-2/G98-135	Moderate
3.	G13-114	GR 1562-25-26-1-1-2-1	GR1107-10-2-1-2/G98-135	Moderate
4.	G13-115	GR 1568-31-9-1-1-1-1	GR1107-10-2-1-2/FG07-174	Strong
5.	G13-116	GR 1568-31-9-1-1-2-1	GR1107-10-2-1-2/FG07-174	Very strong
6.	G13-117	GR 15678-32-3-2-2-1-1	GR1107-10-2-1-2/FG07-174	Moderate
7.	G13-118	GR 1568-32-3-2-2-2-1	GR1107-10-2-1-2/FG07-174	Strong
8.	G13-123	GR1580-43-23-1-1-1-2	ADRON/FG07-182	Strong
9.	G17-135	GR1660-6-10-2-2-1-1-2-1-1-1-1	GR1576-39/ADRON 102	Moderate
10.	G17-136	GR1660-6-10-2-2-1-1-2-1-1-1-3	GR1576-39/ADRON 102	Moderate
11.	G17-137	GR1676-22-1-2-1-2-2-1-1-1-1-1	GR1107-10-2-1-1-2/ADRON 102	Moderate
12.	G17-138	GR 1678-24-39-1-1-1-2-2-1-1-1	GR1117-12-2-3-4-3-2-1/ADRON 102	Very strong
13.	Aromatic Gold	NA	NA	Moderate
14.	Aromatic Straw	NA	NA	Moderate
15.	GRDB FL 15 (check)			Absent
16.	GRDB 13 (check)			Strong

NA= Not Available.

3. Results and Discussion

In the presented study, 14 elite advance aromatic rice strains were tested against two local check varieties (GRDB 13 and GRDB 15). The GRDB 15 is not an aromatic variety rather a newly high yielding non-aromatic rice genotype while the GRDB 13 is Guyana's first and only released aromatic variety.

In Figure 1 it was observed that the high yielding check variety (GRDB 15) obtained the highest yield followed by the aromatic check variety and then the evaluated strains G13-113, G13-114 and others while strains G 13-123 and G 13-115 yielded the least. As indicated in table 1, the high yielding check variety (GRDB 15) produces yields (8850.0 kg ha^{-1}) that are significantly (P=0.05) higher than all the strains tested except for the aromatic check variety (GRDB 13) while there was no significant difference between the aromatic check variety (GRDB 13) and strain G 13-113, G 13-114 and G 13-138 with

strain G 13-113 yielding the highest (7840.5 kg ha^{-1}). Strains G 13-115 and G 13-123 yielded the least with 6662.0 kg ha^{-1}and 6587.0 kg/ha, respectively. The yields obtain by these strains were all superior to that obtained by Hossain and Islam [9], where they recorded the highest yield of 3200 kg ha^{-1} from one of the ten most popular aromatic varieties studied in Bangladesh. In another study carried out by Rashid and Kumar [15] where they evaluated seven aromatic varieties for their yielding ability and gained the highest yield of 2540.0 kg ha^{-1}for one variety while the lowest being 1830.0 kg ha^{-1}.

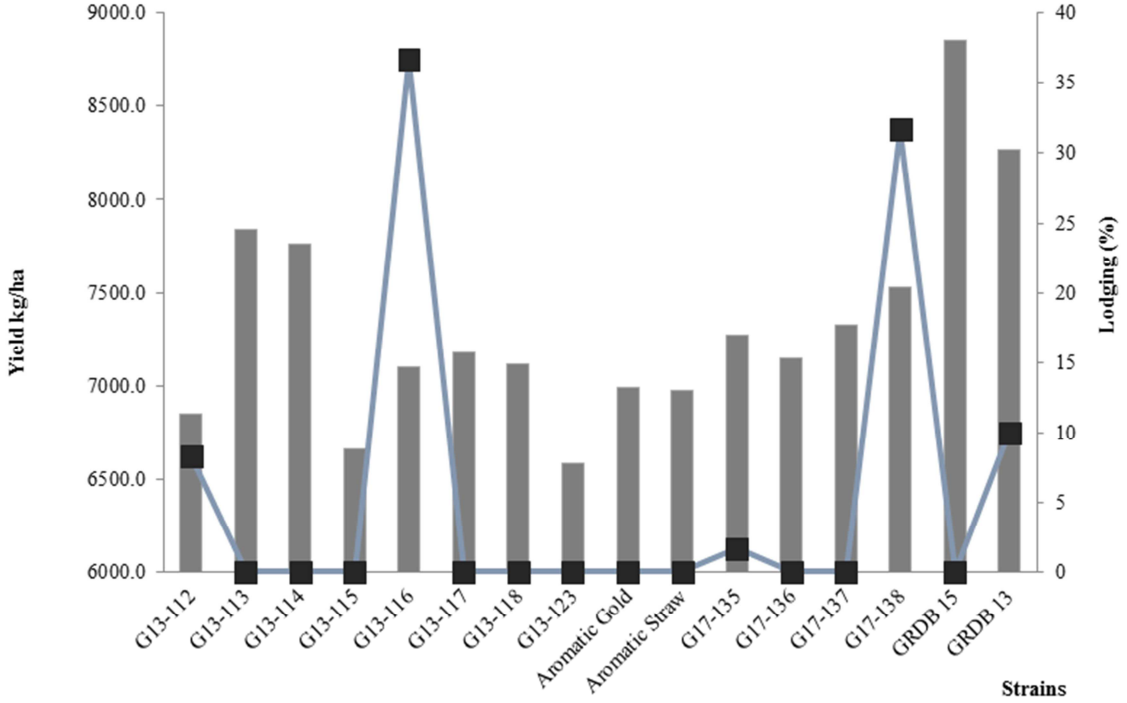

Figure 1. *Grain yield and lodging comparison for strain tested during the spring crop of 2019.*

Also seventy two percent of the strains (G13-113, G13-114, G13-115, G13-117, G13-118, G13-123 G17-135, G17-136, G17-137 and check GRDB 15) showed good tolerance to lodging (0%), while the other twenty eight percentage of strains including the check variety (GRDB 13) showed lodging incidence ranging from 2-36% (Figure 1). Strains G13-116 and G 17-138 shows a significant higher lodging incidence when compared to the other strains tested (Table 2).

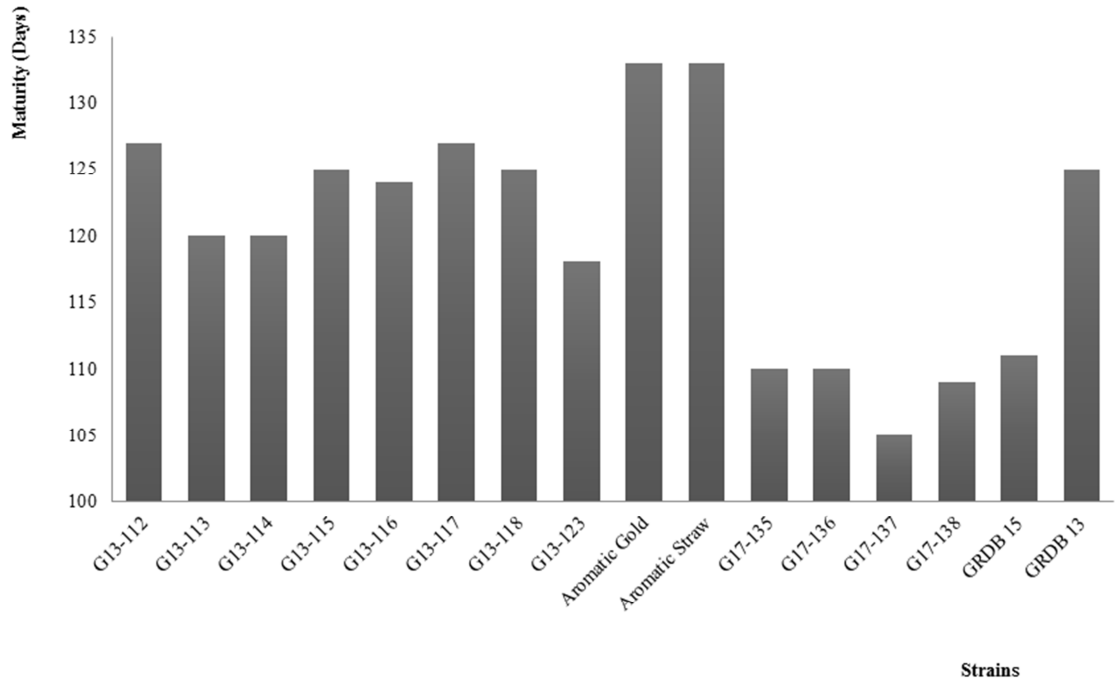

Figure 2. *Maturity comparison for strain tested during the spring crop of 2019.*

Over seventy-two percent of the strains tested including the check variety (GRDB 13) ranged from 120 to 133 days to maturity. Strains Aromatic Gold and Aromatic Strew took the longest to mature with 133 days while the G17-138 matured in the shortest time with 105 days (Figure 1). Strains such as, G17-137, G17-138, G17-136 and G17-135 mature between 105 and 110 days which is significantly lower when compared to GRDB 13 (Table 2). All strains tested in this experiment matured much earlier that those studied by S. Kumar and I. Deo [12] where they studied 88 advance aromatic lines in India and observed maturity between 158 to 183 days after sowing.

The comparison of plant high for the entries tested showed that fourteen strains including the check varieties recorded a desirable plant height which is between 85 cm to 98 cm tall. The tallest plant height was observed in strain G 17-136 (97.87cm) while the shortest beings strain G 13- 114 (79.03 cm) (Table 2). Strains G 13-113 and G13-114 recorded a significantly lower plant height when compared to the other entries with 79.50cm and 79.30cm respectively (Table 2). This vast difference in plant height from 79.30 cm to 97.87 cm in plant height for the various strains according to [3, 10, 11, 16, 19] may be due to the genetic characteristics of each variety/strain.

Table 2. *Grain yield, lodging, maturity and plant height comparison for strain tested during the spring crop of 2019.*

Strains	Yield (kg/ ha^{-1})	Lodging (%)	Maturity (days)	Plant Height (cm)
G13-112	6847.37 ^{ef}	8.33 ^{b}	127.00 ^{a}	94.93 ^{ab}
G13-113	7840.47 ^{bc}	0.00 ^{b}	120.00 ^{c}	79.50 ^{f}
G13-114	7761.83 ^{bcd}	0.00 ^{b}	120.00 ^{c}	79.30 ^{f}
G13-115	6662.20 ^{f}	0.00 ^{b}	125.00 ^{b}	93.37 ^{ab}
G13-116	7103.03 ^{cdef}	36.67 ^{a}	123.67 ^{b}	92.77 ^{abc}
G13-117	7174.23 ^{cdef}	0.00 ^{b}	127.00 ^{a}	95.40 ^{ab}
G13-118	7115.80 ^{cdef}	0.00 ^{b}	125.00 ^{b}	95.00 ^{ab}
G13-123	6587.00 ^{f}	0.00 ^{b}	117.67 ^{d}	91.23 ^{e}
Aromatic Gold	6988.87 ^{def}	0.00 ^{b}	133.33 ^{e}	85.03 ^{bc}
Aromatic Straw	6971.50 ^{def}	0.00 ^{b}	133.33 ^{e}	85.70 ^{de}
G17-135	7271.50 ^{cdef}	1.67 ^{b}	110.67 ^{f}	97.57 ^{a}
G17-136	7144.10 ^{cdef}	0.00 ^{b}	110.67 ^{f}	97.87 ^{a}
G17-137	7322.27 ^{cdef}	0.00 ^{b}	105.00 ^{g}	90.73 ^{bcd}
G17-138	7526.50 ^{bcde}	31.67 ^{a}	109.33 ^{f}	95.13 ^{ab}
GRDB 15	8856.37 ^{a}	0.00 ^{b}	110.67 ^{f}	87.53 ^{cde}
GRDB 13	8270.30 ^{ab}	10.00 ^{b}	125.00 ^{b}	91.53 ^{bc}
Grand Mean	7340.21	5.52	117.71	90.79
C. V	*12.98*	*12.06*	*0.77*	*3.46*
P. Value (0.05)	*0.06*	*0*	*0*	*0*
F. Value	*1.88*	*5.92*	*193.83*	*10.35*

Table 3. *Some other agronomic parameter for strain tested during the spring crop of 2019.*

Strains	Productive tiller (m^{2})	Spikelet fertility (%)	Panicle length Length (cm)	1000-grain wright Wt. (g)
G13-112	464.00 ^{ab}	85.97 ^{abc}	22.12 ^{abcd}	30.80 ^{bcd}
G13-113	479.33 ^{ab}	75.50 ^{def}	18.98 ^{d}	27.20 ^{efg}
G13-114	456.00 ^{abc}	83.90 ^{bcd}	25.21 ^{abc}	28.33 ^{efg}
G13-115	483.33 ^{a}	72.80 ^{ef}	24.12 ^{abcd}	28.87 ^{def}
G13-116	469.33 ^{ab}	73.60 ^{ef}	25.88 ^{ab}	26.93 ^{fg}
G13-117	483.33 ^{a}	68.23 ^{f}	25.00 ^{abc}	24.53 ^{h}
G13-118	448.67 ^{abc}	71.63 ^{ef}	25.67 ^{ab}	28.00 ^{efg}
G13-123	427.33 ^{abcd}	83.87 ^{bcd}	22.52 ^{abcd}	28.33 ^{efg}
Aromatic Gold	420.00 ^{abcd}	79.40 ^{bcde}	27.65 ^{a}	31.80 ^{ab}
Aromatic Straw	391.33 ^{cd}	80.23 ^{bcd}	22.01 ^{bcd}	29.47 ^{cde}
G17-135	377.33 ^{d}	79.30 ^{bcde}	19.78 ^{cd}	32.27 ^{ab}
G17-136	447.33 ^{abc}	76.73 ^{cdef}	20.97 ^{bcd}	33.13 ^{a}
G17-137	418.00 ^{bcd}	95.00 ^{a}	23.18 ^{abcd}	31.20 ^{abc}
G17-138	455.33 ^{abc}	87.17 ^{ab}	21.74 ^{bcd}	31.80 ^{ab}
GRDB 15	438.67 ^{abcd}	86.37 ^{abc}	22.57 ^{abcd}	26.23 ^{gh}
GRDB 13	433.33 ^{abcd}	84.87 ^{bcd}	20.79 ^{bcd}	28.87 ^{def}
Grand Mean	443.29	80.29	23.01	29.24
C. V	*8.77*	*7.26*	*14.46*	*4.76*
P. Value (0.05)	*0.0616*	*0.0003*	*0.1456*	*0*
F. Value	*1.93*	*4.35*	*1.56*	*9.08*

3.1. Productive Tillers

All entries in this trial performed well above the required effective tillers per square meter (350 tillers m^2). The number of effective tillers was found to be within the range of 377 to 483 tillers per meter square. Strains G 13-115 and G 13-117 obtained the most number of effective tillers (483) as compared to G 17-135 with the least (377). There was no significant difference found between strains tested with the exception of aromatic straw and G17-135 being lower (Table 3).

3.2. Spikelet Fertility

Strain G17-137 produced the highest significant number of fertile grains per panicle with 95% fertility, but was on par with G13-112 (85.9%), G17-138 (87.1) and check GRDB 15 (86.3%), while strain G13-117 produce the lowest number of fertile grains per panicle at 69.2% (Table 3). According to Standard Evaluation System for Rice, 5th Edition, 2013, Strain G17- 137 was classified as highly fertile while G13- 115, G13-116, G13- 117 and G13- 118 were found to be partly fertile. The other eleven (11) strains including the two check varieties were deemed as fertile. S. Kumar and I. Deo (2015) studied 88 advance aromatic lines in India shows similar results with spikelet fertility ranging from 65.9 to 83%.

3.3. Panicle Length

The longest panicle length (27.65cm) was obtained in the strain Aromatic Gold which was significantly longer to that of strains G13-113, aromatic straw, G17-135, G17-136 and G13-138. Strain G13-113 recorded the shortest panicle (18.98cm) among the sixteen entries evaluated (Table 3). This variation might be heredity as it may be directly related to genetic characteristics of those varieties/ strains. Similar result was recorded by ldris and Motin (1990) and Golam *et al.,* 2011 [7].

3.4. 1000-grain Weight

In table 3, it can be noted that G17-136 obtain the heaviest grain weight (33.13g) for every 1000 grains weighted whereas, G13-117 obtained the lowest weight (24.53g). The high yielding check variety (GRDB 15) and strain G13-117 produces grain that are significantly lower in weight when compared to the rest of entries tested. In 2015, S. Kumar and I. Deo studied 88 advance aromatic lines in India and obtained an average 1000 grain weight of 14.70g which is far lower (29.24g) than what the fourteen aromatic strains in this trial obtained [12].

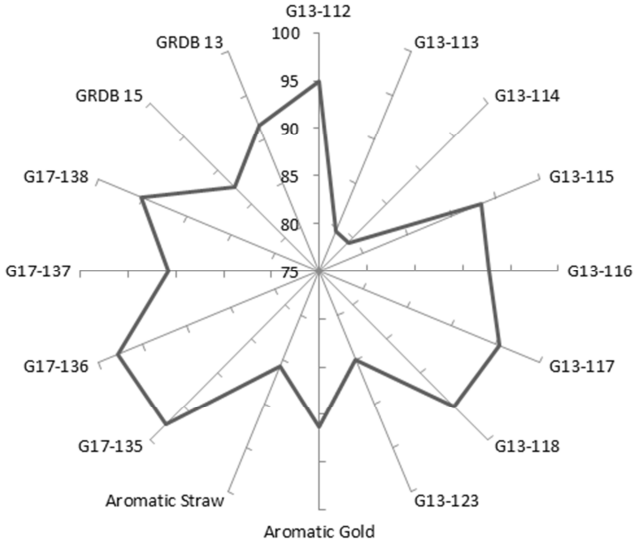

Figure 3. *Plant height comparison for strain tested during the spring crop of 2019.*

Table 4. *Comparison of milling characters for strain tested during the spring crop of 2019.*

S. N	Strain	HRR paddy	HRR cargo	Chalkiness	Expansion Width (%)	Expansion Length (%)	ASV
1	G13-112	50.20^{bcd}	77.84^{bcde}	0.10^{b}	67.06^{ab}	66.98^{c}	5.33^{a}
2	G13-113	56.48^{ab}	83.01^{abcd}	0.00^{b}	71.31^{a}	70.47^{abc}	3.67^{abc}
3	G13-114	53.99^{abc}	81.70^{abcde}	0.40^{a}	69.86^{a}	73.28^{ab}	4.00^{abc}
4	G13-115	50.82^{bcd}	83.65^{abc}	0.10^{b}	70.034^{a}	70.12^{abc}	4.67^{ab}
5	G13-116	52.07^{abcd}	85.22^{a}	0.13^{b}	69.98^{a}	67.69^{bc}	4.33^{abc}
6	G13-117	42.16^{ef}	78.09^{bcde}	0.10^{b}	70.99^{a}	68.063^{bc}	4.00^{abc}
7	G13-118	49.56^{cd}	84.56^{a}	0.10^{b}	66.69^{ab}	67.79^{bc}	4.00^{abc}
8	G13-123	53.65^{abc}	80.70^{abcde}	0.10^{b}	66.97^{ab}	71.49^{abc}	2.67^{c}
9	Aromatic Gold	54.56^{abc}	77.23^{cde}	0.03^{b}	68.28^{ab}	71.01^{abc}	4.33^{abc}
10	Aromatic Straw	54.72^{abc}	80.38^{abcde}	0.03^{b}	64.91^{ab}	70.47^{abc}	3.33^{bc}
11	G17-135	51.37^{bcd}	76.33^{e}	0.10^{b}	71.37^{a}	69.61^{bc}	4.33^{abc}
12	G17-136	39.83^{ef}	55.77^{f}	0.13^{b}	69.58^{a}	70.25^{abc}	4.00^{abc}
13	G17-137	56.32^{ab}	76.96^{de}	0.07^{b}	61.50^{b}	69.26^{bc}	4.00^{abc}
14	G17-138	36.63^{f}	56.69^{f}	0.40^{a}	63.62^{ab}	75.90^{a}	3.67^{abc}
15	GRDB 15	58.41^{a}	83.90^{ab}	0.10^{b}	64.79^{ab}	68.31^{bc}	3.00^{bc}
16	GRDB 13	46.05^{de}	77.47^{bcde}	0.20^{ab}	68.46^{ab}	66.84^{c}	4.00^{abc}
Grand Mean		50.43	77.47	0.13	67.84	69.85	3.96
C. V		7.69	4.99	104.98	6.89	5.33	26.43
P. Value (0.05)		0	0	0.04	0.33	0.73	0.4
F. Value		7.82	15.55	2.07	1.19	0.12	1.09
SEM		2.2399	2.2325	0.0796	2.6977	2.1506	0.604
SEM (diff.)		3.1677	3.1572	0.1125	3.8151	3.0415	0.8542

3.5. Milling Recoveries

In the Head Rice Recovery (HRR) from paddy, seventy five percent (75%) of the all stains tested recorded more the 50% recovery. The GRDB 13 (check variety) along with G 17-138, G 17-136 and G 13-117 obtained less than 50% recovery from paddy. Strain G 13-113 recorded the highest recovery of the aromatic strain tested while statically G13-117, G17-136 and G17-138 recorded the lowest head rice recovery from paddy (Table 4). In 2012 Parikh, M., Rastogi, N. K. and Sarawgi, A. K. studied 36 aromatic rice genotypes in Bangladesh and observed a 50-69% head rice recovery from paddy [13].

3.6. Chalkiness of Endosperm

The chalkiness of the rice grain was classified into white belly, white center and white back according to Standard Evaluation System for Rice, 5th Edition, 2013. Among the strains tested, G13-113 is the only strain that showed 0% chalkiness whereas strains G13-114 and G17-138 recorded the highest percentage. All the other aromatic strains showed less than 20% chalkiness (table 4). Bhonsle S. J. [2] evaluated 14 aromatic rice varieties in India and attained chalky grains ranging from 0 to 64.36%. The chalky grains reduce the palatability of cooked products, thus the presence of more than 20% chalkiness in rice kernels is not acceptable in world markets [4].

3.7. Grain Expansion After Cooking

All strains expanded more the 60% in length and width. Strain G17-138 and G13-114 expanded the most in length with 75.90% and 73.28% respectively, which was significantly higher when compared to the check variety (GRDB 13); while the G13-112 showed the least expansion in length with 66.99%. With respect to the expansion in grain width, G13-113, G13-117 and G17-135 recorded the highest expanding property with more that 71% and G17-137 recorded the lowest expansion percentage in width (61.50%) and statically, it is the lowest expansion percentage in width when compared to the other entries in the trial (Table 4).

3.8. Alkali Digestion

The Alkaline spreading value (ASV) allows for estimation of the gelatinization temperature and is partly associated with the amylose content of the starch. Low amylose rice grains allow fast disintegration whereas the high amylose grains retain its shape. As indicated in table 4, G13-112 has a high ASV (5.33) which is significantly different to G13-123 the high yielding check variety (GRDB 15). The majority of these aromatic strains have an ASV ranging from 4 to 4.67. Chowdhury *et al* 2016, studied 65 rice genotypes where he obtained similar results (ASV ranging from 3 to 6.06) [5].

4. Conclusion

During the spring crop of 2019, 14 elite aromatic lines were evaluated at the Rice Research Station, Burma, Mahaicony, East Coast Demerara. These lines were observed and the several findings were made. From data recorded, it was found that strains G13-113, G13-114 and G17-138 yielded at par with the check variety GRDB 13 with good resistance to lodging. However, G13- 116 and G17-138 did not follow this trend and had a significantly higher lodged incidence (>30%) when compared to the other test entries. The check variety GRDB 13 has a maturity period of 125 days however; strains G13-113, G13-114, G 13-116, G13-123, G17-135, G17-136, G 17-137 and G17-138 recorded a significantly shorter maturity period.

The grain length expansion of strains G17-138 and G13-114 were significantly higher while milling recovery was significantly greater for G13-113, G13-124, Aromatic gold, Aromatic straw and G17-137 when compared to the GRDB 13. All strains evaluated showed low levels of chalkiness (<0.4%).

It was observed that strains G13-113 and G13-114 show promising results when compared to the GRDB 13 and the other strains since they have a shorter maturation period, better yield capability, tolerance to lodging and a higher Head Rice Recovery from paddy.

5. Recommendations

The study identified significant better performance of the important characters among the strains tested compared to the GRDB 13. Repeat of studies for at least one to two season more to confirm stability of traits and the superiority of the promising strains for possible large scale testing in farmers field.

Declarations

Availability of Data and Material

The data generated and analysed in this study is available in this publish manuscript.

Competing Interests

There is no potential conflict of interest to declare.

Authors' Contributions

First author Mahendra Persaud design and execute the experiments, second authors analyzed the data and drafted the manuscript. Fourth provide technical advice, format and edit the manuscript. All other authors provide moral support, technical advice, read and agree with the content of the manuscript.

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