Research Paper

Bg 409: A New High Yielding Rice Variety for High Potential Rice Growing Environments

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ARTICLE INFO

Article history:
Received: 29 May 2020
Revised version received: 30 September 2020
Accepted: 02 October 2020

Citation:
Senanayake RMNH, Silva LS, Abayawickrama ASMT, Kumararathna JMMP, Gunapala KRD, Mandanayake MARA, Rathnayake RJ, Rathnayake WMUK, Sandaruwan HMLU, Wijerathna DGKP, Kodithuwakku WKACP and Wijepala WG 2021. Bg 409: a new high yielding rice variety for high potential rice growing environments. Tropical Agriculturist 169 (2): 31-40.

Abstract

Breeding rice for high yield is one of the important factors to increase productivity and ensure food security. A high yielding rice variety development program was conducted at the Rice Research and Development Institute, Batalagoda to increase the productivity of rice under favourable edaphic conditions. Out of the three lines selected from the cross of IR 72052-72-1-3/Bg 380, the best performed line Bg 08-1909 was nominated for the National Coordinated Rice Variety Testing (NCRVT) program. The line Bg 08-1909 performed better in the NCRVT, and tested with farmers' adaptability trials with the check variety Bg 403. The line Bg 08-1909 recorded the highest yield of 8.8 t ha^{-1} at Narammala (Intermediate Zone), and more than 6 t ha^{-1} average yield in the Dry and Intermediate Zones during Varietal Adaptability Trials (VAT). The highest yield in the Wet Zone was recorded at Kesbawa (5.56 t ha^{-1}) and the average yield in the Wet Zone VAT trials was 4.6 t ha^{-1}. The line is resistant to leaf blast and moderately resistant to rice gall midge, brown plant hopper and bacterial leaf blight and well adapted to environmental conditions of Dry, Intermediate and Wet Zones. The line Bg 08-1909 recorded good response from farmers on the aspects of non-lodging, high yielding ability and better resistance to pests and diseases. The line Bg 08-1909 was released as the variety Bg 409 for general cultivation. The Bg 409 is a four months age (115 days) rice variety with white pericarp, intermediate bold type grains, and acceptable grain quality characteristics and good appearances of cooked rice.

Keywords: Bg 409, High yielding, 4-month rice variety

Introduction

Sri Lanka was aimed at improving self-sufficiency in rice production. Due to the use of high yielding rice varieties, expansion in cultivation extent, and increased use of irrigation and fertilizer, rice production has increased steadily to meet this target (Davis *et al*., 2016). Department of Agriculture (DOA), Sri Lanka has contributed immensely to ensure food security in the country through the recommendation of relevant and timely needed agricultural technologies including the development and release of new improved crop varieties. Breeding rice for high yield is one of the important practices to increase rice production and ensure food security. Different breeding methods can be used to develop high yielding rice varieties. In Sri Lanka, most of the varieties have been developed through conventional hybridization and selection. Success of breeding programs depends on the choice of parents for potential crosses in order to develop superior lines and appropriate selection methods (Janwan *et al*., 2013). New improved high-yielding rice varieties developed at the Rice Research and Development institute (RRDI) ultimately increased the yields and reduced the market prize for consumers. In Sri Lanka, Newly Improved Rice varieties (NIVs) cover more than 99% of the cultivated extent and have contributed to increase the average yield up to 4.4 t ha^{-1} in 2018 (Department of Census and Statistics, 2019). Cultivation of long duration high yielding rice varieties is one of the options to increase productivity under favorable conditions. Hence, the present study was conducted to develop four months age high yielding rice variety with pest and disease resistance and acceptable grain quality to increase rice productivity in potential lowlands under favourable conditions.

Materials and Methods

Hybridization and selection

Crosses were made at the RRDI, Batalagoda for the development of four months age high yielding rice variety with acceptable grain quality. Hybridization was done in 2004/05 *Maha* between two parents of IR 72052-72-1-3 and Bg 380 (RRDI, 2005). Hand emasculation and hand pollination techniques were practiced for hybridization. Plants of F_1 generation were established in the field and advanced as bulk populations from F_2 generation to F_4 generation (Jennings *et al*., 1979). In the bulk population four thousand to six thousand plants were maintained as single plant per hill with the spacing of 40×15 cm. Visual selection was practiced with bulk populations for age, grain type, yield, plant height and reaction to biotic stresses. At the F_4 generation, few single plants were individually tagged and seedlings derived from those selected plants were transplanted as progenies in the following season. Each progeny was maintained as three rows with the spacing of 20×15 cm and having 120 plants per progeny. From F_5 generation, progenies were screened for pest and diseases. Lines were screened for brown plant hopper (BPH), gall midge (GM) and leaf blast at RRDI according to the standard protocol (SES, 2002). Accepted promising progenies were selected to obtain three single

plants. Selected plants were established as separate progenies in a subsequent season.

Rice lines with intermediate bold grain type and white pericarp (Bg 08-1909, Bg 08-301 and Bg 09-606) were selected from the cross between IR 72052-72-1-3/Bg 380 in advance generations and lines were evaluated in the preliminary yield trial and major yield trials in 2010 *Yala*, 2010/11 *Maha* and 2011 *Yala* seasons with the check variety Bg 379-2. Based on the yield and other favorable agronomic traits such as plant height, panicle number per plant and maturity duration, line number Bg 08-1909 was identified and nominated to National Coordinated Rice Variety Testing (NCRVT) trials and further tested in 2011/12 *Maha*, 2012 *Yala* and 2012/13 *Maha*. NCRVT trials were conducted in seven research stations representing different agro-ecological regions. The NCRVT trials in each location was conducted as Randomized Complete Block Design (RCBD) with three replicates. The plot size was 6 m × 3 m, and the seed rate per plot was as recommended by the Department of Agriculture. Bg 403 was used as the standard check variety.

Bg 08-1909 was tested in farmer fields in Variety Adaptability Testing (VAT) trials in 2013/14 *Maha* and 2014/15 *Maha* to test their adaptability in farmers' field. Trials were managed adopting farmer practices, but under the research guidance. Bg 08-1909 was tested in two location in the Wet Zone, and ten locations in Dry and Intermediate Zones in 2013/14 *Maha*, and at two locations in Wet Zone and seven locations in Dry and Intermediate Zones in 2014/15 *Maha*. The VAT trials in each location was conducted as RCBD with two replicates. As the standard check, Bg 403 was used. Bg 08-1909 was tested in Large Scale VAT (LSVAT) in 2015/16 *Maha* and 2016/17 *Maha* to test their strength, drawbacks and farmer preferences in large scale in farmers' fields. It was tested at four locations in the Wet Zone, one location in the Intermediate Zone and three locations in Dry Zone in 2015/16 *Maha*, and at two locations in Wet Zone, one location in Intermediate Zone and six locations in Dry Zone 2016/17 *Maha*. Candidate line was compared with the standard check Bg 403. Nitrogen response was evaluated with four different nitrogen levels (0, 50, 100, 150 N kg ha^{-1}) using two entries Bg 08-1909 and Bg 403, during 2018 *Yala* and 2018/19 *Maha* at RRDI, Batalagoda.

Grain quality assessment, pest and disease screening

Grain quality, and pest and disease reaction assessments were evaluated at the RRDI at Batalagoda with the standard procedures by Grain Quality, Entomology and Pathology divisions. Visual assessments were conducted using samples of two rice varieties Bg 08-1909 and Bg 403. Quality of cooked rice was evaluated with the participation of panel evaluators at the RRDI, Batalagoda, for taste, aroma, stickiness, tenderness and appearance of cooked rice. Ranks (1= very good, 2= good, 3= moderate and 4 = not acceptable) were given to each assessed character by the individual evaluator.

Data analysis

Analysis of variance was performed for yield trial evaluations using SAS 9.1.3 (SAS

Institute Inc, USA). Adaptability of varieties were analyzed using variance component method (Abeysiriwardena *et al*., 1991) and ranking method (Das, 1982). Visual assessment data of tasting panel were presented as percentage using Microsoft Excel package.

Results and Discussion

Yield performance at the research station trials are presented in Table 1. Bg 08-1909 is a long duration white rice variety which flowered within 84-85 days and matured within 114-115 days. The duration of Bg 08-1909 was lower than that of Bg 379-2 (Table 1). Among the selected three lines from the cross IR 72052-72-1-3/Bg 380, Bg 08-1909 performed better than the other two lines.

Yield potential is the maximum yield that a variety can reach under the best environment where as potential yield is the maximum yield that can be realized by a variety and environment combination (Emitiyagoda *et al*., 2007). Vergara (1970) mentioned that the varieties with longer duration could produce higher yield than the varieties with shorter duration under certain environment and cultural conditions. If water is not limited, 4- 4 ½ months varieties show the best fit into those environments (Bentota *et al*., 2010).

Varietal performances of NCVT trials are presented in Table 2, and lodging assessment in each location is presented in Table 3.

Table 1. Plant height and yield-related traits of the tested rice varieties in three seasons

Variety	Plant height (cm)	Number of panicles per plant	Days to flowering	Days to maturity	Grain yield (t ha^{-1})
2010 *Yala*					
Bg 08-1909	109.7	6	85	115	3.876 [a]
Bg 379-2	94.1	7	92	122	3.013 [b]
Bg 08-301	102.3	6	84	114	3.162[b]
Bg 09-606	106.9	6	84	114	3.04[b]
2010/11 *Maha*					
Bg 08-1909	106.12	8	84	114	4.13[a]
Bg 379-2	99.79	10	88	118	3.12[b]
Bg 08-301	101.69	8	84	114	3.38[b]
Bg 09-606	104.42	8	84	114	3.19[b]
2011 *Yala*					
Bg08-1909	106.5	7	85	116	3.876[a]
Bg 379-2	99.8	9	90	122	3.013[b]
Bg 08-301	101.7	7	85	115	3.162[b]
Bg 09-606	104.4	8	87	117	3.240[b]

Note: means followed by the same letter within a column are similar P=0.05

All the tested varieties of four months age category required 114 to 122 days for the maturity. According to Illangakoon *et al*. (2016) late maturing rice varieties have higher yield potential than the early maturing varieties. Therefore, highly adaptable and stable four months duration rice varieties are needed to reduce the yield gap between potential and realizable yields at farmer fields. Identification of widely adaptable rice varieties across environments is important to increase national rice productivity (IRRI, 2005).

Table 2. Maturity durations, grain yield and adaptability ranks of NCRVT tested rice varieties during 2011/12 *Maha*, 2012 *Yala* and 2012/13 *Maha*

Season	Variety	Maturity duration (Days)		Yield (kg ha^{-1} day^{-1})		Grain yield (t ha^{-1})		Adaptability rank**			
		DZ		WZ		DZ & IZ	WZ	Ranking method		Various component method	
								DZ & IZ	WZ	DZ & IZ	WZ
2011/12 *Maha*	Bg 08-1909	113		114		52.9	44.5	6.34	3.60	1	2	1	2
	Bg 403	113		114		51.6	40.7	6.19	3.73	2	1	2	1
2012 *Yala*	Bg 08-1909	113		114		58.2	44.5	6.58	4.97	1	2	1	2
	Bg 403	113		114		53.3	45.2	6.02	5.15	2	1	2	1
2012/13 *Maha*	Bg 08-1909	111		105		60.0	30.7	6.66	3.22	1	1	1	2
	Bg 403	113		106		51.1	35.1	6.00	3.18	2	2	2	1

*Note: *DZ=Dry Zone, WZ= Wet Zone, IZ= Intermediate Zone ** Lower the rank higher the adaptability; Sources: RRDI testing reports (Unpublished data)*

Table 3. Lodging assessment in seven locations of 4 - 4 1/2 month age group of rice varieties in CRVT in 2011/12 *Maha*, 2012 *Yala* and 2012/13 *Maha*

Season	Variety	Arl		At		Bg		Bw		Pa		MI		Ld		Vau		Mu	
		D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M
2011/12 *Maha*	Bg 08-1909	1	1	1	3	1	7	1	1	1	1	1	1	1	1	1	5	1	1
	Bg 403	1	1	1	1	1	9	1	1	1	1	1	1	1	1	1	7	5	5
2012 *Yala*	Bg 08-1909	1	1	-	-	1	1	1	1	1	1	-	-	1	1	-	-	-	-
	Bg 403	1	1	-	-	1	7	1	1	1	1	-	-	1	1	-	-	-	-
2012/13 *Maha*	Bg 08-1909	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Bg 403	1	1	1	1	1	5	1	1	1	1	1	1	1	1	1	1	1	1

Note: Arl = Aralaganwila, At = Ambalanthota , Bg = Batalagoda, Bw = Bombuwela, Pa = Paranthan, MI = Mahailluppallama, Ld= Labuduwa, Vau = Vauniya, Mu = Murunkan, D=Dough stage, M-Maturity stage, Degree of lodging : 1-No lodging 2-Most plants slightly lodge 3-Most plant moderately lodging 4-Most plant nearly flat 5-All plants flat.

During 2011/12 *Maha*, 2012 *Yala* and 2012/2013 *Maha* NCRVT trials, Bg 08-1909 recorded an equal or better performance compared to the standard check Bg 403. When consider the adaptability ranks, variety Bg 08-1909 showed better adaptability in the Dry and Intermediate Zones. Tested line Bg 08-1909 had higher per day yield than the stranded check during all tested seasons. The newly identified line with a higher yield was promoted to VAT for further testing under farmer field conditions. Varietal performance in VAT trials at farmer fields during 2013/14 *Maha* and 2014/15 *Maha* are presented in Table 4.

Bg 08-1909 performed well in farmer fields of the Dry and Intermediate Zones, and Wet Zone which received an adaptability rank of one during 2013/14 *Maha* and 2014/15 *Maha* and showed superiority over Bg 403 (Table 4). During VAT trials Bg 08-1909 recorded the highest yield for both Dry and Wet Zones (Table 4). Bg 08-1909 recorded the highest yield of 8.18 t ha^{-1} during 2013/14 *Maha*.

In large scale VAT trials, the candidate variety performed better than Bg 403. Seed yields of Bg 08-1909 and Bg 403 were similar (P>0.05) when tested at different nitrogen levels (Figure 1).

Grain quality assessment and pest and disease responses

Among the biotic factors, rice blast (BL), Bacterial Leaf Blight (BLB), and Sheath Blight (SB) are major diseases, and Brown Plant Hopper (BPH), Rice Gall Midge (RGM), and Rice Thrips (RT) are considered as major pests in rice cultivation. Rice varieties resistant to BL, BLB, BPH and RGM have been developed and released for cultivation in the country (Rajapakse *et al*., 2000). Reaction to pests and diseases are shown in Table 5. Rice line Bg 08-1909 is moderately resistant to RGM, BPH and BLB, and resistant to BL. It is similar in reactions to pests and diseases with Bg 403.

Table 4. Varietal performances in varietal adaptability testing (VAT) trials at the farmer fields during 2013/14 *Maha* and 2014/15 *Maha*

Season	Variety	Climatic Zone					
		Dry & Intermediate Zones			Wet Zone		
		Average yield (t ha^{-1})	Highest yield (t ha^{-1})	Adaptability Rank	Yield (t ha^{-1})	Highest yield (t ha^{-1})	Adaptability rank
2013/14 *Maha*	Bg 08-1909	6.10	8.18(N)	1	5.12	5.15(D)	1
	Bg 403	5.65	7.85(N)	2	4.77	4.95(D)	2
2014/15 *Maha*	Bg 08-1909	6.03	7.9(R)	1	4.62	5.56(K)	1
	Bg 403	5.31	8.03(R)	2	4.52	5.56(K)	2

Note: N= Narammala, D=Dikwella, R= Rambewa, K= Kesbewa; Source: RRDI testing reports (Unpublished data)

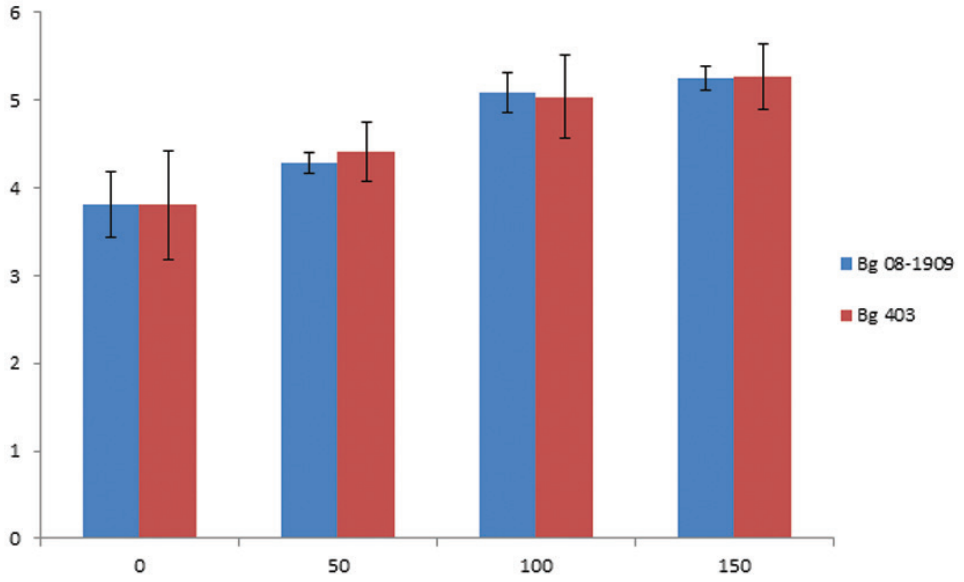

Figure 1. Response of Bg 08-1909 to added nitrogen (kg ha^{-1}) compared to the standard variety Bg 403 at RRDI, Batalagoda

Table 5. Reaction to pests and diseases of Bg 08-1909 and Bg 403 during 2011/12 *Maha*, 2012 *Yala* and 2012/13 *Maha* at RRDI, Bathalagoda

Season	Variety	Reaction to pest and diseases			
		RGM	BPH	BLB	BL
2011/12 *Maha*	Bg 08-1909	R/MR	MR	MR	R
	Bg 403	R/MR	R/MR	MR	R
2012 *Yala*	Bg 08-1909	R/MR	MR	MR	MR
	Bg 403	R/MR	R/MR	MR/MS	R
2012/13 *Maha*	Bg 08-1909	R/MR	MR	MR	R
	Bg 403	R/MR	R/MR	MR	R

Note: RGM=Rice Gall Midge, BPH = Brown Plant Hopper, BLB= Bacterial Leaf Blight, BL= Rice Blast, R= Resistant, MR= moderately resistant, MS = Moderately Susceptible, S= Susceptible, Sources: RRDI testing reports (Unpublished data)

According to laboratory grain quality assessments, Bg 08-1909 was categorized as intermediate bold grain type and possesses high level of amylose content and intermediate gelatinization temperature (Table 6). Bg 08-1909 is a rice variety with good appearance in cooked rice. Preference for cooked rice of Bg 08-1909 and Bg 403 was similar (Table 7).

Considering all the performance of the candidate rice line Bg 08-1909, it was released as a high yielding new improved rice variety as Bg 409 to increase the productivity of rice in high potential areas in the country.

Table 6. Grain quality assessment of Bg 08-1909 and Bg 403 during 2011/12 *Maha*, 2012 *Yala* and 2012/13 *Maha* at RRDI, Batalagoda

Season	Variety	Grain quality characters								
		BR%	TMR %	HG% (Raw)	HG% (Par)	S/S	GT	AC	WB/WC	TL
2011/12 *Maha*	Bg 08-1909	82.7	75.8	66.2	75.6	I/B	I	H	WB 2/3	I
	Bg 403	80.7	75.3	64.4	74.9	I/B	L	H	WC-2	I
2012 *Yala*	Bg 08-1909	81.9	74.4	56.4	76.8	I/B	I	H	WB 2/3	I
	Bg 403	80.9	74.2	49.6	73.0	I/B	L	H	WC-2	I
2012/13 *Maha*	Bg 08-1909	81.9	74.7	51.9	76.9	I/B	I	H	WB 2/3	I
	Bg 403	80.9	74.6	36.4	74.8	I/B	L	H	WC2	I

Note: BR= Brown Rice, TMR= Total Milled Rice, HG= Head Grain, S/S= Size/Shape, GT= Gelatinization Temperature (L=55-69 °C, I=70-74 °C and H=> 75 °C), AC= Amylose content (L=8-20%, I =21-25%, and H= > 25%), TL= translucency, WB/WC = white center or white belly, S/R= Short round, I/B intermediate bold, L/M= Long medium, L/S = Long slender. Sources: RRDI testing reports (Unpublished data)

Table 7. Preference for cooked rice samples of Bg 08-1909 and Bg 403

Variety	Response	Taste (%)	Smell (%)	Appearance (%)
Bg 08-1909	Good	13	12	13
	Moderate	87	88	87
	Week	0	0	0
Bg 379-2	Good	13	13	13
	Moderate	87	87	87
	Week	0	0	0
Bg 403	Good	16	14	16
	Moderate	84	86	84
	Week	0	0	0

Conclusions

The new rice line Bg 08-1909 developed at the RRDI, Batalagoda was released as Bg 409 by the Varietal Releasing Committee of the Department of Agriculture in 2019. It can be recommended as a high yielding, four months age, white-intermediate bold rice variety with acceptable grain quality characteristics, and pest and disease resistance. It is suitable for general cultivation in the country.

Aknowledgements

Authors wish to acknowledge Mr. Abeysekara, Dr. D.M.J.B.Senanayake (Director, RRDI), Additional Director, Deputy Director and staff of the RRDI, Batalagoda, all the NCRVT, VAT and LSVAT trials coordinators and co-operators in all the Research Stations, and Extension staff for their enormous support throughout the variety development period.

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