DOI: https://doi.org/10.4038/ta.v168i3.59

Bw312: A New High Yielding Early Maturing Red Rice Variety For General Cultivation In Sri Lanka

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Abstract

There is an increasing demand for high yielding rice varieties maturing within 85-90 days in Sri Lanka. In addition, availability of red rice varieties is limited in the short maturity duration group. A promising red rice variety was identified in the short duration rice variety improvement program at the Regional Rice Research and Development Center (RRRDC), Bombuwela. The advanced rice breeding line Bw 11-3403 was a superior line as it performed well in station yield trials and it was nominated for testing in National Coordinated Rice Varietal Trials (NCRVT), Variety Adaptability Trials (VAT) and Large-Scale Variety Adaptability Trials (LSVAT). Based on its outstanding performance at all these trials, it was selected as a promising variety. It was then released and recommended for general cultivation by the name of Bw 312 in Sri Lanka. Bw 312 is a high yielding red rice variety maturing around 90 days and resistant to blast disease, moderately resistant to brown plant hopper, gall midge and tolerant to iron toxicity.

Keywords: Climate change, Conventional breeding, Red rice, Short maturity duration

Introduction

Rice (*Oryza sativa* L.) is the staple food crop for nearly half of the world's population, especially in developing regions of Asia and Africa. About 92% of all the rice is grown and consumed in Asia. Approximately, 90% of the global rice comes from Asian countries such as China, India, the Philippines, and Thailand (FAO, 2016). Demand for rice is steadily increasing with the increase in number of rice consumers, especially in developing countries (Khush and Jena, 2009). It is a challenging task to meet the growing demand catering to a booming population that is expected to reach 9.6 billion in 2050 (Kochhar, 2014). Demand for different grain types in Sri Lanka varies according to the consumer preference as white long (56%), white short (25%), red long (17%) and red short (2%) (RRDI, 2016). According to the distribution of new improved varieties based on their maturity group, 70% of varieties are under 3 ½ months and 23.3% of varieties are under 3 months maturity group in Sri Lanka. Only 6% of varieties are under 4-4 ½ month maturity group. In addition, less than 1 % of the varieties are under 2 ½ and 5-6 month age group (RRDI, 2016).

At present there is an increasing demand for rice varieties with short maturity duration (90 days or less) in Sri Lanka as they are well fitted into water limited ecosystems to escape drought and flood prone ecosystems where they can be grown after flood is receded. Furthermore, short duration rice varieties with high yield potential are needed for irrigated rice lands to increase cropping intensity and water use efficiency.

To date only a few red pericarp rice varieties have been released by the Department of Agriculture (DOA), Sri Lanka under three months maturity group. These include, Bw 272/6b, At 303 and At311. Among them Bw 272/6b, which was released in 1981, is a red short round (samba) grain variety. Though it is popular among farmers who cultivate paddy in non-iron toxic rice soils owing to its grain quality. The rice variety At303 is well adapted in the Dry Zone (DZ) and Intermediate Zone (IZ) of the country. However, it is not much popular among Wet Zone (WZ) rice farmers due to lodging and susceptibility to most major pests and diseases. Rice variety At 311 is also a red Basmati type rice variety and cultivated for special purposes. Thus, there is a heavy demand for high yielding short maturing red pericarp variety with tolerance to major abiotic and biotic stresses for general cultivation, particularly in the WZ. This paper presents information on an outstanding red pericarp rice variety developed at RRRDC, Bombuwela for general cultivation in Sri Lanka.

Materials and Methods

Variety Bg 250 and line IR 66-700-3-3-3 were crossed in *Yala*, 2006 at RRRDC, Bombuwela, targeting the maturity duration of 85-90 days and high yields. The variety was developed through the conventional breeding technique. Emasculation of female parent was done by hot water method and controlled pollination was done. Rice variety Bg 250, is a white pericarp variety that matures within 80-85 days. Line IR 66-700-3-3-3 was received from the International Rice Research Institute (IRRI) as a short age potential rice germplasm.

The F_1 generation was planted in research field at a spacing of 40×15 cm with one plant per hill and seeds were harvested at maturity for F_2 generation. Generations were advanced from F_2 to F_4 as bulk populations in subsequent seasons. The size of each bulk population was maintained between 5,000 to 6,000 plants. At the F_4 generation single plants were selected visually for maturity duration, grain type, plant type and grain yields and were planted in the field on plant to progeny basis in subsequent generations. Each progeny was a three-row plot planted with the spacing of 15×20 cm with 120 plants per progeny. Generations were advanced by selecting better performing progeny lines in subsequent seasons until adequate within progeny uniformity was achieved.

Preliminary and major yield trials of selected lines were conducted in 2012 *Yala* and 2012/13 *Maha* with the standard check At 303. Based on the yield and other agronomic characteristics, Bw 11-3403 was selected to nominate for further testing in the national coordinated rice varietal testing (NCRVT) conducted during 2015 *Yala* and 2015/16 *Maha* in ten research stations representing different agro ecological regions of the country. National coordinated rice varietal testing was conducted under researcher management as randomized complete block design (RCBD) with three replicates. Based on the results of NCRVT, further evaluation was done in Varietal Adaptability Testing trials (VAT) conducted in 14 farmer fields in DZ, IZ and six locations in WZ during 2016 *Yala* and 2016/17 *Maha* with Bg 300 and At 303 as the standard checks. Large Scale Variety Adaptability Trials (LSVAT) were conducted in six locations of DZ ,12 locations in WZ and, two locations in IZ in farmer fields under farmer management practices during 2018 *Yala* and 2018/19 *Maha* with Bg 300,to get the farmer's response on its performance and to identify deficiencies and strengths.

The test line was screened against major rice diseases, leaf blast (LB) and bacterial leaf blight (BLB) and major pests like, brown plant hopper (BPH) and gall midge (GM) at the RRDI, Batalagoda and RRRDC, Bombuwela followed by standard procedures in IRRI. (IRRI standard evaluation system, 2014).

In addition to that, the line was screened for tolerance to iron toxicity based on leaves symptoms and general appearance using a scale from 0 to 9 (0-normal or nearly normal plant; 9 - nearly dead or dead plant) as described by the standard evaluation system for rice (IRRI, 2014) in the location in Kalutara district where soil iron level recorded more than 300 mg kg^{-1} ppm. In addition to that, milling, physical, cooking, eating and keeping qualities of rice grains were also evaluated (IRRI standard evaluation system, 2014).

Data of the station yield trials were analyzed using ANOVA and NCRVT results were analyzed by the methods described by Abeysiriwardana *et al*. (1991) and Das (1982). VAT results were analyzed by the method described by Abeysiriwardana (2001).

Results and Discussion

Plant height, days to 85% maturity and yield performance of the Bw 11-3403 at RRRDC, Bombuwela are presented in Table 1. According to the grain yield results of 2012 *Yala* season, Bw 11-3403 was given significantly higher grain yield than the check variety At 303 and, 2012/13 *Maha* season, grain yield is comparatively similar with the check variety. In addition to that the plant height is less than the check variety and days taken to 85% maturity is similar with the check variety.

Table 1. Mean grain yield of Bw 11-3403 in comparison to the standard check At 303 in the yield trials conducted during 2012 *Yala* and 2012/13 *Maha* at RRRDC, Bombuwela

Variety	Plant height (cm)	Days to 85% maturity	Grain yield (t ha^{-1})
2012 *Yala*			
Bw10-31138	88.2	83	4.563^{b}
Bw10-31221	76.7	79	4.423^{b}
Bw10-31004	84.6	83	3.633^{c}
Bw10-31005	79.2	83	3.860^{bc}
Bw11-3403	89.3	88	5.477^{a}
At 303	97.8	90	4.113^{bc}
			CV: 9.816, LSD (0.05): 0.776
2012/13 *Maha*			
Bw10-31138	73.6	88	3.547^{a}
Bw10-31221	68.1	84	2.907^{b}
Bw10-31004	74.3	88	3.600^{a}
Bw10-31005	79.1	88	2.943^{b}
Bw11-3403	74.5	88	2.640^{b}
At 303	79.4	92	2.847^{b}
			CV: 9.633, LSD (0.05): 0.540

Means with same letters within a Colum are similar p=0.05

Grain yield in NCRVT trials

Mean grain yield, adaptability rank over diverse environments and maturity duration of Bw 11-3403 in comparison with the standard checks At 303 and Bg 300 during 2015 *Yala* and 2015/16 *Maha* in the DZ, IZ and WZ of Sri Lanka are presented in Table 2. The rice line Bw 11-3403 recorded equal or higher grain yields compared to the standard checks At 303 and Bg 300 by recording adaptability rank 1 in the WZ in both seasons indicating that it was the most adaptable line over diverse environments in the WZ when compared to the other lines and varieties included in the test. In the DZ and Intermediate Zones, the new line showed better adaptability than At 303 in the *Yala* season and better adaptability than both of the standard checks in *Maha* season. In addition, Bw 11-3403 matured almost around 90 days in the all agroecological zones of the country.

Table 2. Mean grain yield (t ha^{-1}), adaptability rank and maturity duration (days) of Bw 11-3403 in comparison with the standard checks; At 303 and Bg 300 in NCRVT over *Yala* and *Maha* seasons in DZ, WZ and IZ of Sri Lanka.

Season	CZ*	No. of locations	Variety**								
			Bw 11-3403			At 303			Bg 300		
			MD	MY	AR	MD	MY	AR	MD	MY	AR
2015 *Yala*	DZ &IZ	9	94	4.92	2	98	5.01	3	95	5.59	1
	WZ	3	86	3.61	1	90	3.14	3	89	3.20	2
2015/16 *Maha*	DZ &IZ	9	90	6.26	1	93	5.48	3	92	5.74	2
	WZ	2	89	4.85	1	90	4.18	2	89	4.84	1

*Note: *CZ=climatic zones, DZ=dry zone, WZ=wet zone, IZ=intermediate zone, MD=maturity duration, MY=mean yield, AR=adaptability rank. Lower the rank higher the adaptability.*
Source: RRDI (2015a), RRDI (2015b)

Lodging assessments

The visual lodging assessments was measured in the field during dough and mature stage of the variety presented in the Table 3. It was measured in using the scale described in IRRI 2014, (Degree of lodging: 1-No lodging, 2-Most plants slightly lodge, 3-Most plant moderately lodging, 4-Most plant nearly flat and,5-All plants flat. According to the results Bw 11-3403 was not lodged in almost all the locations. Therefore, this rice line is more preferable for mechanical harvesting as well as suitable to cultivate in wind prone areas as a non-lodging rice variety.

Table 3. Lodging assessment in ten locations of 3-month age group of rice varieties in CRVT in 2014/15 *Maha*, 2015 *Yala*

Season	Variety	At		Bg		Gk		Mi		Mu		Pa		St		Vau		Bw		Ld	
		D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M
2014/15 *Maha*	Bw11-3403	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Bg300	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1
	At303	1	1	1	1	1	1	3	1	1	1	1	1	1	1	3	1	1	1	1	1
2015 *Yala*	Bw11-3403	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Bg300	1	1	7	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	At303	1	1	9	9	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note: 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.

Variety adaptability trials (VAT)

Average grain yield and adaptability rank of Bw 11-3403 in comparison to the standard check Bg 300 in VAT's conducted in farmer's fields over two seasons in the DZ and IZ, and WZ are presented in Table 4. The proposed line performed similar to the most popular white pericarp variety Bg 300 in its adaptability over diverse environments recording adaptability rank 1 within all climatic zones.

Table 4. Average grain yield and adaptability rank of Bw 11-3403 in comparison with the standard check Bg 300 in variety adaptability trials (VAT) conducted in farmer's fields over two seasons in Dry and Intermediate Zone and Wet Zone.

Season	Climatic zone*	No. of locations tested	Mean grain yield (t ha^{-1})			
			Bw 11-3403		Bg 300	
			Yield	AR**	Yield	AR
2016 *Yala*	DZ &IZ	14	4.55	1	4.46	1
	WZ	06	2.66	1	2.57	1
2016/17 *Maha*	DZ &IZ	14	5.16	1	5.38	1
	WZ	06	4.15	1	4.19	1

*Note; *DZ-Dry zone, IZ-Intermediate zone, WZ-Wet zone** AR – Adaptability rank*
Source: RRDI 2016a; RRDI 2017 b)

Large scale variety adaptability trials (LSVAT)

Average grain yield of Bw 11-3403 in comparison to the standard check Bg 300 in LSVAT conducted in *Yala* and *Maha* seasons in DZ, IZ and WZ are presented in Table 5. The rice line Bw 11-3403 performed similar to or better yield than the most popular variety Bg 300 under large scale cultivation in the DZ, IZ and particularly in the WZ in both *Yala* and *Maha* seasons.

Table 5. Average grain yield of Bw 11-3403 in comparison with the standard check Bg 300 in large scale variety adaptability trials (LSVAT) conducted over *Yala* and *Maha* seasons in the Dry and Intermediate Zones and in the Wet Zone.

Season	Climatic zone*	No. of locations tested	Average yield (t ha^{-1})	
			Bw 11-3403	Bg 300
2017 *Yala*	DZ	04	5.2	4.7
	WZ	06	3.3	2.9
	All	10	4.3	3.9
2017/18 *Maha*	DZ	02	3.9	5.2
	WZ	06	4.8	4.2
	IZ	02	5.1	4.2
	All	10	4.6	4.5

*Note: *DZ-Dry Zone, IZ-Intermediate Zone, WZ-Wet Zone; Source: RRDI 2017a; RRDI 2018b*

Grain quality assessment

Based on the grain quality assessment, Bw 11-3403 had intermediate bold (IB) grain type and high amylose content (>25%). The amylose content of the rice grain strongly influences the cooking and eating quality characteristics of rice. Rice with high amylose content (25-30 %) tends to cook firm and dry, not sticky. Milling quality (61.8% head grains of raw rice) of Bw 11-3403 was much higher than that of both the standard checks and this is the most important quality parameter for acceptance by millers. In addition, the gelatinization temperature of the proposed variety is low so that the cooked rice of this variety is softer than that of standard checks with intermediate to high gelatinization temperature (IRRI, Rice Knowledge Bank).

Table 6. Milling and Grain quality characters of Bw 11-3403, At 303 and Bg 300 during 2015 *Yala*, 2015/16 *Maha*

Season	Variety	Grain quality characters								
		BR%	TMR %	HG% (Raw)	HG% (Par)	S/S	GT	AC	WB/ WC	TL
2015 *Yala*	Bw11- 3403	77.60	71.20	69.30	71.90	I/B	L	H	WB 2	I
	Bg300	79.90	74.10	67.30	71.90	I/B	I/H	H/I	WB2/3	I
	At 303	78.40	71.40	61.50	69.60	L/M	I	H/I	WB 3	I
2015/16 *Maha*	Bw11-3403	77.60	71.70	61.80	71.40	I/B	L	H	WB-2	I
	Bg 300	78.60	72.60	55.10	73.60	I/B	I/H	H/I	WB 2/3	I
	At 303	78.20	70.10	54.50	73.20	L/M	I	H/I	WB3	I

Note: BR= Brown Rice, TMR= Total Milled Rice, HG= Head Grain, S/S= Size/Shape, GT= Gelatinization Temperature (L=55-69 0C, I=70-74 0C and H=> 75 0C), 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 2015a, RRDI 2016b.

Reaction to biotic and abiotic stresses

Reaction of Bw 11-3403 to biotic and abiotic stresses are shown in Table 7. Rice line Bw 11-3403 is resistance to blast disease, moderately susceptible for BLB and moderately resistance to BPH and GM. Furthermore, Bw 11-3403 exhibited tolerance to iron toxicity, which is a serious disorder in the Low Country Wet Zone (LCWZ) of Sri Lanka whereas both the standard checks showed only moderate tolerance to the iron toxicity condition therefore, it can be grown in iron toxic paddy fields.

Table 7. Reaction of Bw 11-3403 to biotic and abiotic stresses with check varieties.

Stress*	Variety**		
	Bw 11- 3403	At 303	Bg 300
LB	R	R	R
BLB	MS/S	MS/S	MS/S
BPH	MR	MR	MR
GM	MR	MR	MR
Iron toxicity	T	MT	MT

LB - Leaf blast disease, BLB - Bacterial leaf blight disease, BPH - Brown planthopper, GM - Gall midgeR-resistant, MR-moderately resistant, MS-moderately susceptible,S - susceptible, T-tolerant, MT-moderately tolerant*

Bandara *et al*. (2018) reported that Bw 11-3403 showed a comparatively faster canopy growth over time and this is a favorable character for weed suppression ability of the variety. Thus, Bw 11-3403 was identified as a weed competitive germplasm, which is good for minimizing herbicide usage.

Conclusion

The rice line, Bw 11-3403 has been identified as an outstanding red rice variety that matures around 90 days. It is tolerant to iron toxicity conditions and suitable variety for iron toxicity prevailing paddy fields in the country.it was released and recommend by the varietal release committee of the DOA as Bw 312 for the general cultivation in Sri Lanka.

Acknowledgement

Author wishes to acknowledge Dr. DMJB Senanayake, Director, RRDI, Batalagoda, RMSU Bandara, Assistant Director (Research), Weed science, RRDI, Batalagoda. Principal Scientists and Assistant Directors (Research) in pathology, entomology and grain quality divisions at RRDI, Batalagoda and RRRDC, Bombuwela and all the extension staff for their invaluable support for conducting VAT and LSVAT trials are greatly appreciated. Mr. D.M. Jayasundara (AMO), Mr. Nadun Karunathilaka (FM) and all the officers at RRRDC, Bombuwela, who helped in various ways to make the variety development program successful are kindly acknowledged.

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