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RESEARCH ARTICLE

IMPROVEMENT OF HIGH YIELDING INBRED RICE WITH BETTER GRAIN QUALITY: VARIETY Ld376 FOR GENERAL CULTIVATION IN SRI LANKA

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ABSTRACT

Aiming at yield increase through plant type improvement, pest and disease tolerance, and wide adaptability, the locally developed high-yielding rice variety At362 was hybridized with Milyang23, a high-yielding Korean rice variety. From the resulting cross, a line, Ld8-13-4, was selected based on better yield and agronomic characters and was crossed again with IR79200-65-2-2, a bacterial leaf blight-resistant line with proven phenotypic acceptability. The study was conducted at the Rice Research Station, Labuduwa, Sri Lanka, from 2009–2015. Generation advancements from F_1 to F_8 were carried out from the *Yala* – 2010 to 2013/14 *Maha* seasons. From the preliminary evaluation of the 2013/14 *Maha* and 2014 *Yala* trials, six lines were selected for the major yield trials and evaluated in a Randomized Complete Block Design with standard check varieties and three replicates during the 2014/15 *Maha* and 2015 *Yala* seasons. The long slender line, Ld12-6-22-1-2, performed better in yield and had acceptable grain qualities. It was nominated to National Coordinated Rice Variety Test (NCRVT) and tested with Bg94-1 from the 2017 *Yala* to 2018 *Yala* seasons. The line was tested at different farmer fields during the 2019 *Yala* and 2019/20 *Maha* in Variety Adaptability Trials (VAT). Ld12-6-22-1-2 recorded better yields than the standard check variety Bg94-1, was superior in both Dry and Wet Zones, and ranked first for both variance component and rank method. Ld12-6-22-1-2 recorded more than 10 t/ha in four locations in the farmer fields, resembling the potential for high yield. The line showed an acceptable tolerance level to brown plant hopper, rice gall midge, bacterial leaf blight, and rice blast, with quality milled rice and good taste. It was the first long, slender white rice in the 3.5-month age category.

Keywords: Adaptability, High yield, Long slender, Rice variety

INTRODUCTION

The ever-increasing demand for food in the global context is not an exception for Sri Lanka. Variety improvement for the enhancement of yield through high-yielding varieties with significant pest and disease tolerance and acceptable grain quality was the primary concern of the rice breeding program of Sri Lanka. Furthermore, abiotic stress tolerance was also evaluated in parallel with the main breeding program. Global rice breeding has achieved rapid progress, primarily through the hybridization process, which has significantly enhanced rice grain yield potential in the last three decades (Yuan, 2017). In Sri Lanka, the national average rice yield has gradually increased from about 0.65 t/ha in the 1940s and around 3.70 t/ha in 1990s to 4.85 t/ha in late 2019. The main reason for this yield improvement is the development of improved technology mainly in the areas of variety development and agronomic practices such as nutrient management and proper pests and disease management (Abeysiriwardena, 2000; Weerakoon *et al.,* 2017; Dhanapala *et al.,* 2020).

Though the theoretical maximum potential yield of rice verities has been estimated to be 23.8 t/ha (Abeysiriwardena, 2016), it has not yet been achieved by either hybrids or inbred rice varieties. The highest rice yield recorded

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in a subtropical environment is 17.1 t/ha (Yuan, 1998), and under a tropical climate is 11.73 t/ha (Emitiyagoda *et al.,* 2010). Sri Lankan inbred rice varieties recorded more than 10 t/ha yield. At362, a red pericarp long medium variety is the most popular grown rice variety in Sri Lanka, securing more than 10 t/ha of yield (Department of Agriculture, 2023). Hence, the rice breeding priority of the country is to enhance further the genetic potential of new varieties for high yield, better grain qualities, and wide adaptability to the existing tropical environmental conditions. Against this background, a variety improvement program was conducted by Rice Research Station, Labuduwa, aiming at improving new high-yielding varieties by combining improved foreign genotypes with locally bred elite varieties.

MATERIALS AND METHODS

Locally developed high-yielding rice variety At 362 was hybridized with Milyang23, a high-yielding rice variety which was developed in South Koria and used by many other counties to develop high-yielding varieties (Chung and Heu, 1991; Anonyms, 2009). A line Ld8-13-4, selected from the cross, was crossed again with IR 79200-65-2-2, a Bacterial Leaf Blight (BLB) resistant line with proven phenotypic acceptability. The selected IR 79200-65-2-2 line was selected from the BLB nursery of the International Rice Research Institute (IRRI) and screened under local conditions at Rice Research Station (RRS), Labuduwa, in 2009/10 *Maha* season (SES, 1996). The F_1 generation of the cross was advanced during the 2010 *Yala* season. The F_2 to F_4 populations were advanced from the 2010/11 *Maha* season to the 2011/12 *Maha* season, respectively, using a modified bulk method. (Ikehashi and Fujimaki, 1980). Plants were selected based on yield components such as filled seeds per panicle, panicle weight, number of effective tillers and better plant architecture with acceptable plant height (100 cm), non-lodging, stay green character, culm diameter, culm strength, tillering angle, length of flag leaf and not infected with pest and disease. F_5, F_6, F_7 and F_8 progeny line evaluations were carried out from the 2012 *Yala* to the 2013/14 *Maha* seasons. Progeny lines were selected with visual observations in bulk populations and screened for BLB by artificial inoculation (SES, 1996). Preliminary yield evaluations were carried out in 3 x 6 m plots during 2013/14 *Maha* with 12 lines and 2014 *Yala* as an observational yield trial consisting of 15 lines along with the rice variety Bg359. Plot yield was recorded after removing 30 cm from each side. From the preliminary evaluation trials, six lines, Ld12-8-2 (Ld8-13-3-2/ Ld7-18-7-2), Ld11-4-3-1-2 (Ld4-10-30-2/ Tox 3116), Ld12-6-22-1-2 (LS) (IR 79200-65-2-2/ Ld8-13-4), Ld12-9-3-1 (Ld7-17-5-2/ Ld362), Ld1-5-15 were selected for the Major Yield Trials (MYT) and Bg359 and Bg94-1 used as standard check varieties. Yield evaluations were conducted in Randomized Complete Blocks with three replicates in 3x6 m plots during the 2014/15 *Maha* and 2015 *Yala* seasons. All the agronomic practices were done according to the recommendations of the Department of Agriculture (Department of Agriculture, 2023). In parallel, screening of major pests and diseases (rice blast and brown pant hopper) was carried out at Rice Research and Development Institute (RRDI) Bathalagoda and (rice blast and BLB) Regional Rice Research and Development Center (RRRDC) at Bombuwala according to the standard evaluation system introduced by IRRI (SES, 1996). Grain quality assessments were carried out (colour, size, appearance of row rice and appearance, colour, smell, and taste of cooked rice) by the tasting panel of 18 members of RRS Labuduwa. Based on the performance of yield trials, pest and disease evaluations from RRDI and RRRDC Bombuwala, and tasting panel results, line Ld 12-6-22-1-2 was nominated for the National Coordinated Rice Variety Test (NCRVT). During the NCVT, the lines were evaluated at all the rice research stations (Labuduwa, Bentota, Bombuwala, Bathalagoda, Mahailluppallama, Ambalntota, Girandurukotte, Murunkan, Paranthan, Samnthurai and Vaunia) representing Wet zone, Dry Zone and Intermediate Zone as multi locations trials.

The long slender line Ld12-6-22-1-2 was compared with Bg94-1 (Long medium) as a standard check during 2017 *Yala,* 2017/18

Maha and 2018 *Yala* at different research stations representing the three major climatic zones. Ld12-6-22-1-2 was tested at different farmer fields during 2019 *Yala* and 2019/20 *Maha* along with the Bg94-1 and Bw367 in the Dry Zone and Bg359 also included for Wet Zone, Variety Adaptability Trials (VAT) for testing of adaptability under farmer manage conditions in Ampara, Anuradhapura, Monaragala, Polonnaruwa, Puttalam, Galle, Kaluthara and Kegalle. Large Scale Variety Adaptability Trial (LSVAT) was conducted for Ld 12-6-22-1-2 at farmer fields during 2020/21 *Maha* and 2021 *Yala* to have further confirmation on farmers' response regarding the new variety with a questionnaire.

Grain quality assessment and pest and disease screening

Grain quality and pest and disease reaction assessments were done at the Rice Research and Development Institute (RRDI) at Bathalagoda along with the NCRVT with the standard procedures of rice grain quality assessments and pest and diseases screening (SES, 1996) by Grain Quality, Entomology and Pathology divisions, respectively.

Sensory assessments were conducted using samples of two rice varieties, Ld12-6-22-1-2 and Bg94-1, with the participation of a panel of 17 evaluators at RRS, Ambalantota for the appearance of milled rice, the appearance of cooked rice, cooked rice aroma, and taste with scores assigned based on a five-point scale: 5 = Very Good, 4 = Good, 3 = Moderate, 2 = Poor, and 1 = Very Poor.

Iron and Zinc content of seed samples of Ld 12-6-22-1-2 and the other recommended lines (Ld371 and Ld365) grown at RRS Labuduwa were analyzed using acid digestion extraction followed by atomic absorption spectrophotometry described by Amorim (2016). Nitrogen content was analyzed using the Kjeldahl digestion method at the RRRDC, Bombuwala. Protein content was calculated with the equation,

Protein content = Nitrogen content x 0.595.

Data analysis

Analysis of variance was carried out for yield trial evaluations using the SAS statistical package, version 9.2. (SAS Inc. 2013). Adaptability based on the yield was analyzed using variance component method (Abeysiriwardena *et al.,* 1991) and ranking method (Das, 1982). In the ranking method, yield of individual varieties was analyzed separately for each location, and the mean yields were ranked according to DMRT groups. The mean rank of the particular locations and the variance of ranks over locations were calculated. Finally, the adaptability rank was computed based on mean rank and variance of ranks. Adaptability rank 01 was given to the lines with the highest mean rank and lower rank variance. The variance component method calculated deviation from the individual variety's location mean. These deviations within locations were subjected to variance analysis using SAS, and the mean deviation over location was calculated. Several positive deviations over locations, mean deviation over the location and interaction variance between 'location x variety' were computed. Based on the above three parameters, adaptability ranks were calculated. Tasting panel data were analyzed with the Kruskal Wallis Test in the SPSS, 16.0 version (SPSS Inc. 2012).

RESULTS AND DISCUSSION

The yield performance of selected lines is given in Table 1. According to the analysis of variance, there were no significant differences among the tested lines during the 2014/15 *Maha* season for the yield. However, during the 2015 *Yala* season, tested lines displayed significant differences in yield performances, where Ld12-6-22-1-2 recorded the highest mean yield. The observational trials conducted during 2013/14 *Maha* and 2014 *Yala* recorded higher plot yields of 8.25 kg and 8.75 kg, respectively for the line Ld12-6-22-1-2, while Bg359 recorded 6.83 kg and 4.7 kg, respectively. According to the panel evaluations conducted at RRS Labuduwa, the line Ld12-6-22-1-2 was preferred for raw rice with good colour, size and appearance.

Table 1. Performance of short-duration rice varieties at yield trials at RRS Labuduwa during 2014/15 *Maha* and 2015 *Yala*

Variety	Days to 50% flowering	Days to maturity	Yield kg/ha
2014/15 *Maha*			
Ld12- 8-2 (IB) (Ld8-13-3-2/ Ld7-18-7-2)	74.3[a]	101.7[bc]	4.81 ±0.31[a]
Ld11-4-3-1-2 (IB) (Ld4-10-30-2/ Tox 3116)	73.0[a]	104.0[a]	4.48 ± 0.62[a]
Ld12-6-22-1-2 (LS) (IR79200-65-2-2/ Ld8-13-4)	70.7[ab]	102.7[b]	4.42 ± 0.24[a]
Ld12 -9-3-1 (SR) (Ld7-17-5-2/ Ld 362)	73.7[a]	102.0[bc]	4.06 ± 0.53[a]
Ld1-5-15 (SR)	73.0[a]	101.0[c]	4.53 ± 0.38[a]
Bg359	66.0[b]	97.7[d]	4.49 ± 0.36[a]
Bg94-1	70.3[ab]	98.3[d]	4.37 ± 0.16[a]
CV	3.74	0.57	14.28
2015 *Yala*			
Ld12-6-22-1-2	75.3[ab]	112.0[b]	3.56 ±0.094[a]
Ld12-6-3-1-1	77.3[a]	112.0[b]	1.76 ±0.33b[c]
Ld12-8-2	76.0[ab]	114.0[a]	2.68 ±0.77[abc]
Ld11-4-3-1-2	75.0[ab]	110.0[c]	3.05 ±0.25[a]
Ld12-25-3-1-1	73.7 [b]	112.0[b]	3.16 ±0.18[a]
Ld12-9-3-1	75.7[ab]	109.0[c]	1.68 ±0.13[c]
Ld371	69.3[c]	110.0[c]	2.82 ±0.20[ab]
Bg359	68.7[c]	110.0[c]	2.76 ±0.30[abc]
Bw372	69.0[c]	105.3[d]	3.12 ±0.53[a]
CV	1.81	0.87	21.5

Values followed by the same letter within a column are not significantly different at the p=0.05 level.

In the line screening test for rice blast, during 2015 *Yala* of RRRDC Bombuwala Ld12-6-22 -1-2, was resistant, while susceptible check variety *Pachchaperumal* was highly susceptible, and the resistant check Tetep was highly resistant. The line Ld12-6-22-1-2 was moderately susceptible for BLB, while Bg358 was susceptible. The line Ld12-6-22-1-2 was moderately resistant for brown plant hopper, while Bg380 was moderately susceptible, and Ptb33 was resistant in RRDI screening studies.

Varietal performances during NCRVT are included in *Supplementary Table 1*. During the 2017 *Yala* NCRVT trials, Ld12-6-22-1-2 recorded better performances than the standard check variety Bg94-1 in the Dry Zone for the long slender category. In 2017/18 *Maha* season, Ld12-6-22-1-2 was superior to the check variety in both Dry and Wet Zones and recorded first rank for both variance component and rank method. During 2018 *Yala*, except for the Wet Zone, the line Ld12-6-22-1-2 performed better. Based on adaptability rankings, Ld12-6-22-1-2 demonstrated superior adaptability compared to Bg94-1 across all three NCRVT seasons.

The results of Varietal Adaptability Trials during the 2019 *Yala* and 2019/20 *Maha* are included in Table 2. According to the variety adaptability trials test in the farmer fields, Ld12-6-22-1-2 was the best performer in both seasons in both evaluations. Ld12-6-22-1-2 recorded more than 10 t/ha in four locations during 2019 *Yala* and 2019/20 *Maha* evaluations in the farmer fields. According to the average yield performance during 2019 *Yala* and 2019/20 *Maha*, a higher average yield was recorded in the *Yala* season in the Dry and Intermediate Zones with enough sunlight and better irrigation, while the Wet Zone reported less average yield due to overcast conditions and heavy rains. *Maha* season is the favourable season in the Wet Zone, with a higher average and maximum yield performance of the varieties.

Maximum yields recorded in Dry and Intermediate Zones in *Maha* in two varieties were higher compared to *Yala* maximums, while average yields were higher in *Yala*. The variations in maximum yield were recorded in different locations, possibly due to microclimatic conditions and farmer operations.

Table 2: Mean grain yield (t/ha) and adaptability rank of Ld12-6-22-1-2 in Varietal Adaptability Trial (VAT), compared to the standard variety Bg94/1 tested in Dry and Intermediate zones and mean grain yield (t/ha) and adaptability rank of Ld12-6-22-1-2, compared to the standard variety Bg 359 in Wet Zone

Season	Variety	Agro- ecological zone					
		Dry and Intermediate Zones			Wet Zone		
		Average yield t/ha	Maximum yield t/ha	Adaptability rank	Average yield t/ha	Maximum yield t/ha	Adaptability rank
2019 *Yala*	Ld 2-6-22-1-2	8.05	10.59 (N)	1	2.36	2.72(W)	1
	Bg94-1	7.78	9.58 (M)	1	-	-	-
	Bg359	-	-	-	2.17	2.61(W)	1
	Bw367	6.69	10.61(G)	2	2.11	2.72(W)	1
2019/20 *Maha*	Ld12-6-22-1-2	6.46	11.03 (B)	1	4.21	7.08 (A)	1
	Bg94-1	5.49	10.19(S)	2	-	-	-
	Bg359	-	-	-	4.01	6.25 (A)	1
	Bw367	5.25	8.5(S)	2	3.47	5.00(A)	2

A=Aranayake (Kegalle) B=Bakamuna (Polonnaruwa) S= Siyambalanduwa N=Nintavur -1(Ampara) M= Manampitiya (Polonnaruwa) G Galenbindunuwewa A- W= Wanduramba(Galle)

The mean grain yield (t/ha) of Ld 12-6-22-1-2 tested line over several locations representing diverse environments in Wet and Dry Zone in Large Scale VAT during 2021 *Yala* and 2021/22 *Maha* exhibited better performance over check variety Bg94-1 (Table 3). According to the NCRVT and VAT results, the line Ld12-6-22-1-2 performed well in both *Yala* and *Maha* seasons in Dry, Intermediate and Wet Zones, resembling the line's potential and wide adaptability.

Table 3: Mean grain yield (t/ha) of Ld12-6-22-1-2 compared to the standard variety Bg94/1 tested over several locations representing diverse environments in Wet and Dry Zone in Large Scale VAT.

Season	Agro Ecological Zone	Yield t//ha		Number of locations tested
		Ld12-6-22-1-2	Bg 94/1	
2021 *Yala*	Dry	6.29	5.74	02
	Intermediate	-	3.34	01
	Wet	3.6	3.04	01
2021/ 2022 *Maha*	Dry	4.27	5.64	05
	Intermediate	4.74	4.58	03
	Wet	4.53	4.01	03

In the process of high-yielding variety development, the exploitation of elite genetic backgrounds of rice lines for high yield has been performed from the Green Revolution to the present. Wide genetic variations were created using the variety Milyang23, a variety developed in a South Korean rice breeding program targeting high yield by hybridizing *Indica* and *Japonica* rice varieties (Chung and Heu, 1991; Anonyms, 2009). Milyang23 is a crucial parental material in improving high-yielding rice varieties. Its high yield potential, disease resistance, and adaptability make it an invaluable asset in rice breeding programs (Mario Marcos State Uuiversity, 2024). Milyang23 carries *Xa21, Xa13* and *Xa4* genes for the BLB resistance (Jiang *et al*., 2020). On the other hand, At362 is one of the most outstanding rice varieties improved in Sri Lanka with high yield potential, wide adaptability, better rice quality and tolerance to major pests and diseases (Department of Agriculture, 2023). The line Ld8-13-4, developed through the At362/ Milyang23 cross, is a superior genetic combination of the two elite varieties. Further enhancement of BLB tolerance and yield was achieved through IR 79200-65-2-2, a significant rice variety with a high-yield and disease-resistance rice cultivation. Its strong resistance to bacterial blight with *Xa21* and *Xa4* genes

and high yield potential make it a crucial component in breeding programs (Mariano Marcos State University, 2024). Hence, the line Ld 12-6-22-1-2 possesses BLB resistance genes from both parental backgrounds. The line Ld 12-6-22-1-2 showed field resistance to BLB and, under inoculated conditions, Moderate Resistance (MR) to Moderately Susceptible level (MS), which was superior to other recommended rice variety, Bg94-1 (Table 3). Considering the other significant pests and diseases, the line Ld12-6-22-1-2 performed better than the recommended variety Bg94-1 with MR/MS for rice gall midge, MR/MS for brown plant hopper, and MS/R for rice blast (*Supplementary Table 2*).

The developed line Ld12-6-22-1-2 was long slender white grains with high yield potential and adaptability, and there were no recommended varieties for the long slender category in 3.5 months age category in Sri Lanka (*Supplementary Table 2*); the variety Bg94-1 is a long medium variety the close resemblance to the candidate variety. Long-grain rice, which includes varieties like Basmati and Jasmine, accounted for more than 63% of the global rice market revenue (Grand View Research, 2024). Hence, the candidate variety can potentially cater the international and local markets. Both tested line Ld12-6-22-1-2, and the recommended variety Bg94-1 reported the same milling qualities with 78% brown rice %, 71% of total milled rice, 55 -65% head grains in raw rice, 71-73% head grains in parboiled rice (*Supplementary Table 2*).

According to the tasting panel evaluations conducted at RRS Ambalantota and RRRDC Bombuwala, a significant difference was observed in the milled rice appearance between Ld12-6-22-1-2 and Bg94-1, based on the mean ranks from the Kruskal-Wallis test. Ld12-6-22-1-2 recorded mean ranks 21.59 and 19.3, for RRS Ambalantota and RDC Bombuwala, respectively. Bg94-1 reported mean ranks 13.41 and 11.7 for the same character. There was no significant difference in ranking by the evaluators for cooked rice appearance and taste for both locations (Table 4).

Zinc and protein contents of Ld12-6-22-1-2 were comparable with recommended rice varieties grown at RRS Labuduwa, and Iron content was comparably high (Figure 1).

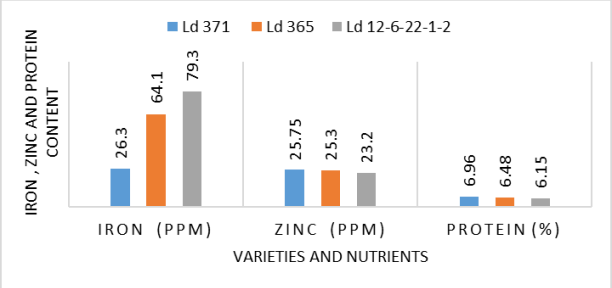

Figure 1: Iron, Zinc and protein content of grains of Ld12-6-22-1-2 and the other recommended varieties grown at RRS, Labuduwa

Table 4: Tasting panel evaluation of Ld12-6-22-1-2 and Bg94-1 at RRS Ambalantota and RRRDC

Station	Criteria	Line/ variety	Raw rice appearance	Cooked rice appearance	Cooked rice aroma	Cooked rice taste
RRS/ Ambalanthota	Mean ranks	Ld12-6-22-1-2	21.59	17.91	16.47	18.97
		Bg94-1	13.41	17.09	18.53	16.03
	Chi-Square		6.669	0.068	0.418	0.855
	Sig.		0.01	0.794	0.518	0.355
RRRDC/ Bombuwala	Mean ranks	Ld12-6-22-1-2	19.3	17.9		16
		Bg94-1	11.7	13.1		15
	Chi-Square		6.41	2.905		0.114
	Sig.		0.011	0.088		0.736
	Kruskal Wallis Test					

Based on yield performance and adaptability ranks in NCRVT and VAT, the candidate line Ld12-6-22-1-2 performed better compared to the Bg94-1 recommended variety with a potential yield of more than 10 t/ha with an acceptable level of tolerance to major rice pests and diseases. Further, no recommended high-yielding, long, slender white rice variety is recommended for the 3.5 -month age category. Therefore, this line would be a potentially high-yielding variety with better consumer preference that has the potential to be cultivated in all the rice-growing areas of Sri Lanka.

CONCLUSIONS

The rice line Ld12-6-22-1-2 ranked first in adaptability during multi-locational trials, with a yield potential of over 10 t/ha. It belongs to the long-slender grain category and has good consumer preference. Based on the results, the line was released as Ld376 by the Department of Agriculture.

AUTHOR CONTRIBUTION

MCM and GAJ designed and carried out the breeding program. JP, UAJR, UHKW, SMCN, SHK, YJP, YMCH, and KKJC carried out different parts of the study. MCM wrote the manuscript.

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REFERENCES

Abeysiriwardena, D.S. de Z. (2000) 'Rice varietal improvement for future challenges', *Rice Congress 2000,* Department of Agriculture, Peradeniya, Sri Lanka, p 87-99.

Abeysiriwardena, D.S. de Z. (2016) 'Yield potential, potential yield and realized yield at farmer level of cereals with special reference to rice (*Oryza sativa L.*)', *Sri Lanka Journal of Food and Agriculture*, 2, p 1-17.

Abeysiriwardena, D.S. de Z., Buss, G.R. and Reese, J. (1991) 'Analysis of multi-environmental yield trials for testing adaptability of crop genotypes', *Tropical Agriculturist*, 147, p 85-97.

Amorim, F.A.C., Costa, V.C., Guedes, W.N., Ivero, P. de Sa, Mayara, C. dos Santos, Erik, G.P. da Silva, Daniel, de C. Lima. (2016) 'Multivariate optimization of method of slurry sampling for determination of iron and zinc in starch samples by flame atomic absorption spectrometry', *Food Analytical Methods*, 9, p 1719-1725.

Anonymous, (2009) 'Improvement in Rice Breeding Technology and System in KOREA', Available at: https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/korea_workshop/lecture7/3ParentalRicelinebreedinginKorea(2009)res.pdf [Accessed 26 March 2025].

Chung, G.S. and Heu, M.H. (1991) 'Improvement of Tongil-Type Rice Cultivars from Indica/ Japonica Hybridization in Korea', In: Bajaj, Y.P.S., ed. *Biotechnology in Agriculture and Forestry,* Vol. 14 Rice. Springer-Verlag Berlin Heidelberg.

Das, G.R. (1982) 'A method of scoring yield status for selecting rice cultivars', *Indian Journal of Agricultural Sciences*, 52(4), p 207-209.

Dhanapala, M.P., Nugaliyadde, L. and Senanayake, D.M.J.B. (2020) 'A rational look at the genetic improvement of rice in Sri Lanka', *Tropical Agriculturist*, 168(1), p 1-12.

Department of Agriculture, (2023) Rice Research and Development Institute, Department of Agriculture, Sri Lanka. Available at: https://doa.gov.lk/rrdi_sub_ambalanthota_history [Accessed 26 March 2025].

Emitiyagoda, G.A.M.S.S., Abeysiriwardena,

D.S. de Z. and Silva, S. (2010) Grain yield and yield variability of rice under high management in different agro-climatic zones in Sri Lanka. *Annals of Sri Lanka Department of Agriculture*, 12, p 63-77.

Grand View Research, (2024) *Rice market size, share & trends analysis report*, Grand View Research, https://www.grandviewresearch.com/industry-analysis/rice-market-report [Accessed 26 March 2025].

Jiang, N., Yan, J., Liang, Y., Shi, Y., He, Z., Wu, Y., Zeng, Q., Liu, X., Peng, J., & Jiang, N. (2020) 'Resistance genes and their interactions with bacterial blight/leaf streak pathogens (*Xanthomonas oryzae*) in rice (*Oryza sativa* L.): an updated review', *Rice*, vol. 13, no. 1, p. 3. Available from: https://doi.org/10.1186/s12284-019-0358-y.

Ikehashi, H. and Fujimaki, H. (1980) 'Modified bulk population method for rice breeding', In: *Innovative approaches to rice breeding: Selected papers from the 1979 International Rice Research Conference,* p 163-182.

International Rice Research Institute, (1996) *Standard Evaluation System for Rice*. Los Baños, Laguna, Philippines.

Mariano Marcos State University, (2024) https://extension.mmsu.edu.ph/news/show/304/presidents [Accessed 26 March 2025].

SAS Institute Inc. (2013) *SAS/STAT® 9.4 User's Guide.* Cary, NC: SAS Institute Inc.

SPSS Inc. (2012) IBM SPSS Software for Windows, version 20.0.

Weerakoon, W.M.W., Jayawardena, S.N., Kahandewela, K.G.D.S., Malaviarachchi, M.A.P.W.K., Wanigasuriya, S.C. and Mithrasena, A.H.G. (2017) 'Meeting challenges to realize potential yield in rice cultivation in Sri Lanka', *Rice Congress 2010*, p 159.

Yuan, L.P. (2017) 'Progress in super-hybrid rice breeding', *Crop Journal*, 5, pp.100-102. doi: 10.1016/j.cj.2017.02.001.

Yuan, L. (1998) 'Hybrid rice development and use: innovative approach and challenges', Paper presented at the *19th session of the IRC*, 7-9 September, Cairo, Egypt.

Supplementary Table 1*: Maturity durations grain yield and adaptability ranks of NCRVT tested rice varieties during 2017 *Yala*, 2017/18 *Maha* and 2018 *Yala

Season	Variety	Maturity duration		Grain yield t/ha		Adaptability ranks							
		DZ	WZ	DZ & IZ	WZ	Ranking method				Variance component method			
						DZ		WT		DZ		WZ	
						All variety rank	Long slender white rank	All variety rank	Long slender white rank	All variety rank	Lomg slender white rank	All variety rank	Long slender white rank
2017 *Yala*	Bg15- 520	104	107	5.04	3.02	5		6		4		4	3
	WAS4-2-3	106	110	4.20	1.33	8		8		6		5	4
	Ld12-6-22-1-2	109	110	6.02	3.43	1	1	5	2	1	1	3	2
	Ld11-7-3-1	106	108	4.81	2.58	6		7		5		3	
	Bw14-509	109	116	5.31	3.59	3		2		3	2	2	
	Bg94-1	103	105	5.22	3.57	4	2	3	1	2		1	1
	Bg360	105	105	4.22	3.53	7		4		6		1	
	Bw367	108	108	5.46	4.05	2		1		1		1	
2017/18 *Maha*	Bg15- 520	104	103	5.14	4.19	3		3		2		1	
	WAS165-B-B-4-2-3	106	103	4.38	3.82	7		4		5		5	
	Ld12-6-22-1-2	107	106	5.37	4.11	2	1	1	1	1	1	3	1
	Ld11-7-3-1	109	111	4.45	4.04	8		5		5		2	
	Bw14-509	110	109	5.25	4.20	1		2		2		2	
	Bg94-1	103	100	4.98	3.49	4	2	6	2	3	2	4	2
	Bg360	108	108	4.50	3.72	6		4		4		5	
	Bw367	110	109	4.82	4.14	5		2		3		1	
2018 *Yala*	Bg15- 520	103	104	5.63	4.58	2		1		1		1	
	WAS165-B-B-4-2-3	104	101	4.16	2.89	8		8		7		4	
	Ld12-6-22-1-2	108	110	5.61	4.07	1	1	5	2	2	1	2	1
	Ld11-7-3-1	107	104	4.58	3.24	7		7		6		4	
	Bw14-509	109	111	5.14	4.42	5		2		4		1	
	Bg94-1	102	102	5.39	3.99	4	2	4	1	2	1	2	1
	Bg360	105	103	4.70	3.66	6		6		5		3	
	Bw367	108	107	5.36	4.08	3		3		3		2	

***Supplementary Table 2*: Reaction to pests and diseases and grain quality assessment of 3.5 months rice varieties during 2017 *Yala*, 2017/18 *Maha* and 2018 *Yala* at RRDI Bathalagoda**

Season	Variety	Reaction to pests and diseases				Grain quality								
		RGM	BPH	BLB	BL	BR%	TMR %	HG% (raw)	HG % (par)	S/S	GT	AC	WB/ WC	TL
2017 *Yala*	Bg15- 520	MS	MR/R[1]	S MS[1]	S	78.4	72.1	54.4	71.3	L/M	H/I	I	WB-2	I
	WAS4-2-3		MR/MS[1]	S MS[1]	MS	77.7	70.8	53.6	70.5	L/S	H	L/I	WB-2	I
	Ld12-6-22-1-2	MS	MR/MR/MS[1]	S MS[1]	MS	78.5	71.3	54.5	71.4	L/S	L	L/I	WB-2/3	I
	Bg94-1	MS	MR/S1	S S[1]	S	78.7	70.9	59.8	72.0	L/M	H/I	H	WB-2/3	I
	Bw367	MS	MS/MR/MS[1]	S S[1]		79.3	74.1	72.6	72.1	S/R	H/I	H	WC-2/3	I
2017/18 *Maha*	Bg15- 520	R/MR	MR/MR[1]	S MS[1]		78.2	73.1	67.4	70.9	L/M	I/H	I	WB-2	I
	Ld12-6-22-1-2	MR	MS/MR[1]	MS MS[1]		79.0	72.6	55.1	73.3	L/S	H/I	L/I	WB-2/3	I
	Bg94-1	MS	MS	S MS[1]		77.3	70.8	64.4	71.2	L/M	I	H	WB-2/3	I
	Bw367	MR/ MS	MR/MS MR[1]	S S[1]		79.5	74.4	71.9	73.6	S/R	H/I	H	WC-2/3	I
2018 *Yala*	Bg15- 520	MR/ MS	MRMR[1]	MS S[1]	HR[1]	78.1	72.1	63.6	68.8	S/R	I/H	I	WC-2	I
	Ld12-6-22-1-2	MR	MR/MR[1]	MS MS[1]	HR[1]	78.8	72.1	65.1	70.6	L/S	L	L	WB-1/2	I
	Bw14-509	MR/ MS	MR MR[1]	MS MS[1]	HR[1]	77.5	72.7	69.8	70.6	I/B,L/M	I	H	WB-3	I
	Bg94-1	MS	MS/MR/MS[1]	MR/MS/ MS[1]	HR[1]	78.5	71.3	65.9	69.9					
	Bw367	MR/ MS	MR/MS/MR[1]	S/S[1]	HR[1]	79.7	74.8	72.4	72.4					

Notes: RGM=Rice Gall Midge BPH = Brown Plant Hopper BLB= Bacterial leaf Blight, BL= Blast, R= resistant, MR= Moderately resistant, MS = Moderately Susceptible, S= Susceptible, BR= Brown Rice, TMR= Total Milled Rice, HG= Head Grain, S/S= Size/shape, GT= Gelatinization temperature(L=55-690 c, I=70-740 c and H=> 750 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 1 Data from RRRDC Bombuwala