

VARIABILITY IN MATURITY DURATION AND YIELD OF SOME POPULAR RICE VARIETIES OVER CLIMATIC ZONE, SEASON AND LOCATION

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ABSTRACT

The maturity durations and yields of rice vary across climatic zones, seasons and locations while the present demarcation of maturity durations for different age groups is not clear. A study was conducted to determine maturity durations and yield potentials of Bg 250, Bg 300, Bg 352, Bg 357, Bg 358, Bg 366, Bg 379-2 and Bg 403 using the data from National Coordinated Rice Variety Testing Programme (NCRVT) from 2000 *Yala* to 2016 *Yala*. Bg 250 was the earliest maturing variety (85 ± 0.7 days) while Bg 300 and Bg 352 had close maturity durations (94 ± 0.3 and 96 ± 0.6 days, respectively). The maturity duration was 2-7 days shorter in Wet zone (WZ) than in the Dry & Intermediate zones (D/IZ). Also, the maturity duration was 1-6 days shorter in *Maha* season than in *Yala* season. The grain yield was 46% higher in the D/IZ compared to the WZ while higher yields were recorded in *Yala* compared to *Maha*. Bg 357, which recorded the highest yield (5.5 ± 0.11 t/ha) performed better in all agro-climatic zones. The mean yields of Bg 366, Bg 403 and Bg 379-2 were also above 5 t/ha. Among the NCRVT locations, Murunkan gave the highest yield followed by Ambalantota. Based on this study, the length of maturity duration is used as an alternative method to categorize rice varieties. The five age groups; ultra-short (below 90 days), short (90-99 days), medium (100-109 days) long (110- 135 days) and extra long (above 135 days) are suggested for future grouping of rice varieties.

Key words: Age groups, Maturity duration, Rice, Yield.

INTRODUCTION

The rice varieties are categorized into five different age groups as 2½, 3, 3½, 4- 4½ and 5-6 months based on the length of maturity duration. However, it has been reported that the maturity duration and the yield of the varieties vary time to time depending on prevailing biotic and abiotic factors of the climatic zone, seasons and location in which they are grown. According

to Rani and Maragatham (2013), temperature has a considerable effect on growth and yield of rice by affecting its phenology, physiology and yield components. Water stress during the vegetative and booting stages can delay heading, filled grain % and yield (Sikuku, 2010). Some pest problems may lead to lengthen maturity duration (eg: thrips) in late planted crops, especially in December. Therefore, varieties of the same age group also exhibit wide variability in maturity duration as well as yield. Field problems related to earliness or delay in flowering and maturity period are also reported in some seasons. Therefore, it is imperative to identify the exact maturity duration of popular rice varieties cultivated by farmers.

In the present varietal categorization of rice, the age groups are divided into groups approximately by two weeks intervals but the exact maturity periods are not clearly demarcated. Presently, age group of a new rice line is determined by having a known control/reference variety in the breeding and yield testing plots. Breeders are comparing the individual plants with the reference variety during the selection process. This may have led to irregularities in maturity duration of varieties as the reference variety may not respond similar to the selected lines in different environments. Therefore, when new rice lines are tested in yield trials, a line with longer maturity duration of a particular age group has higher chance to be selected since its yield potential may be higher than the early maturing ones of the same group. Conversely, if a line is not fixed to the preferred age group it may be withdrawn from further testing even if it has some other preferable characters. To overcome these drawbacks, it is needed to demarcate accurate maturity duration of existing rice varieties and group them accordingly. Therefore, this study was conducted to assess the maturity durations and yields of popular rice varieties belonged to different age groups and to propose an alternative method for rice variety categorization.

MATERIALS AND METHODS

Source of data

The data from National Coordinated Rice Variety Testing programme (NCRVT) were used since it is the most reliable source for this purpose having assured level of uniformity and available over a long period of time. NCRVT is conducted over diverse agro-ecological environments to evaluate new breeding lines against existing recommended variety. At present, trials under NCRVT are conducted in 12 research stations both in *Yala* and *Maha* seasons representing major rice growing areas of the country. In these trials, direct wet seeding is done at the recommended seed rate and the crop is maintained under irrigated (D/IZ) or in rainfed conditions (WZ). All other management practices are done as recommended by the Department of Agriculture (DOA). The data including days to 50 % heading, days to maturity (maturity of 85% of the grains in a panicle) and yield of popular rice varieties grown under different age groups

Variety selection

Considering the data availability, eight popular rice varieties *i.e.* Bg 250 (2½ months), Bg 300 (3 months), Bg 352, Bg 357, Bg 358, Bg 366 (3½ months), Bg 379-2 and Bg 403 (4-4½ months) were selected for this study. Data on days to 50 % heading, days to maturity (maturity duration) and yields from 2000 *Yala* to 2016 *Yala* (17 years) in 11 NCRVT locations viz. Aralaganwila, Ambalantota, Giradurukotte Mahailuppallama, Muruncan, Paranthan, Samanthurai and Vauniya in the Dry zone (DZ), Batalagoda in the Intermediate zone (IZ), and Labuduwa and Bombuwala in the Wet zone (WZ) were retrieved from the NCRVT reports maintained at the Rice Research and Development Institute (RRDI), Batalagoda.

Data analysis

The maturity periods and their frequencies of occurrence were plotted for each variety. The data were subjected to univariate analysis using SAS 9.1 computer package and the mean, medium, mode, inter-quartile range (IQR), minimum and maximum value of the maturity duration were calculated for each variety, separately. The average maturity duration and average yield were

also calculated for different climatic zones, seasons and locations. Relationship between maturity period and yield was determined using regression analysis.

RESULTS AND DISCUSSION

Variations in maturity duration among varieties

A wide variation on maturity duration among varieties in different age groups were recorded and the number of observations recorded. Mean, median, mode, IQR, minimum and maximum values recorded for maturity duration of each variety are given in Table 1. Bg 250 was the variety to mature earliest within a mean of 85 ± 0.7 days with IQR of 81-88. Its maturity duration distributed with a mode of 81 and 85 days (Table 1 & Figure 1A). The mean, median and the mode of the maturity duration of Bg 300 were same (94 days) while IQR was 91-97 days (Table 1) which is on average about 9 days longer than that of Bg 250. However, maturity of Bg 300 extended in a wide range of duration from 84 to 106 days (Figure 1B). These data indicate the possibility of occurring too short or too long maturity durations depending on the prevailing weather or soil conditions of the location.

Among the four varieties under $3\frac{1}{2}$ months age group, Bg 352 was the earliest maturing variety (96 ± 0.6 days), more close to the maturity duration of Bg 300 while mode and the median were same as the mean (Table 1). Further, the difference of maturity periods of Bg 250 and Bg 352 was only 11 days on average, though they are categorized as $2\frac{1}{2}$ and $3\frac{1}{2}$ months, respectively, implying that there is 30 days difference in maturity duration between these 2 varieties. The maturity duration of Bg 352 extended from 85 to 107 days which was approximately a period of 3 weeks (Figure 1C). Bg 366 matured in 100 ± 0.7 days while Bg 358 and Bg 357 recorded the same maturity duration of 103 ± 0.4 days (Table 3). Durations of maturity of Bg 366, Bg 358 and Bg 357 were extended by 19, 21 and 25 days, respectively (Figure 1D, 1E & 1F).

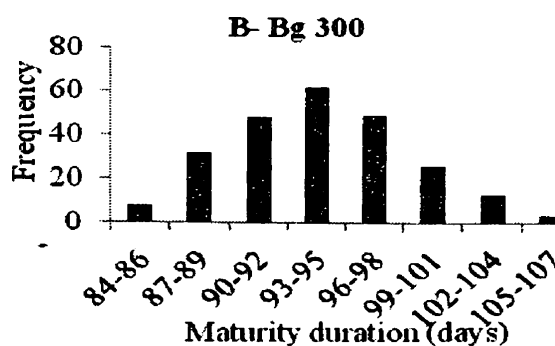
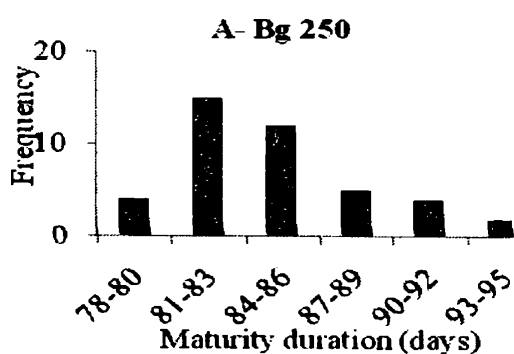
The maturity durations of Bg 403 and Bg 379-2 were almost the same (112 ± 0.7 and 114 ± 0.6 days, respectively) while IQR varied from 107-117 and

109-119 days, respectively. Accordingly, both varieties matured in less than 4 months duration. However, their maturity periods extended approximately by 4 weeks (Figure 1G & 1H). It was also observed that IQR of 4-4½ months varieties extended longer (10 days) compared to the varieties in other age groups (6-8 days). Accumulation of heat units or growing degree days (GDD) determine the time of flowering and maturity and in rice a sharp decrease in days to heading occurs when temperature drops from 24 °C to 21 °C while a rise of temperature by 1 °C above 24 °C shortens the number of days to heading by about 2 days (Parthasarathi *et al.* 2013). Therefore, deviations in minimum and maximum temperatures in year to year, season to season or location to location or due to different sowing dates of the season may causes variation in GDD and thus affect the maturity duration of a particular variety.

Table 1. Number of seasons tested during 2000 Yala -2016 Yala, mean, median, mode, IQR, minimum and maximum value for maturity duration (days) of rice varieties.

Age group (months)	Variety	Number of seasons tested*	Mean ±SE	Median	Mode	IQR	Minimum – Maximum
2½	Bg 250	44	85±0.7	84	81,85	81-88	78-98
3	Bg 300	238	94±0.3	94	94	91-97	84-106
3½	Bg 352	65	96±0.6	96	96	93-100	85-107
	Bg 366	63	100±0.7	100	99	96-104	90-109
	Bg 358	166	103±0.4	103	103	99-107	91-112
	Bg 357	152	103±0.4	103	99	99-106	92-117
4-4½	Bg 403	87	112±0.7	113	116	107-117	98-124
	Bg 379-2	118	114±0.6	114	113	109-119	98-126

Note: * Varied among varieties as these varieties used for standard checks and used only if the particular age group that they belonging was tested during the season.



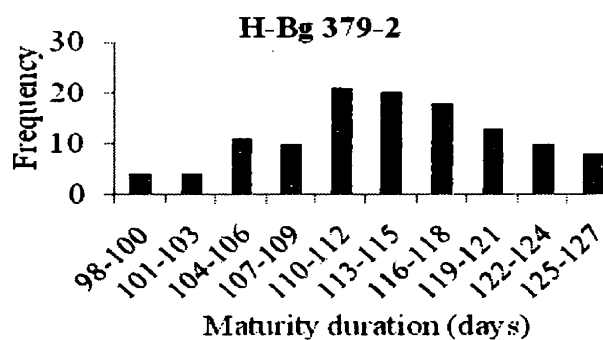
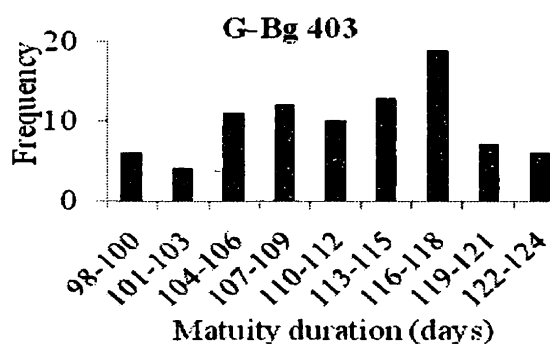
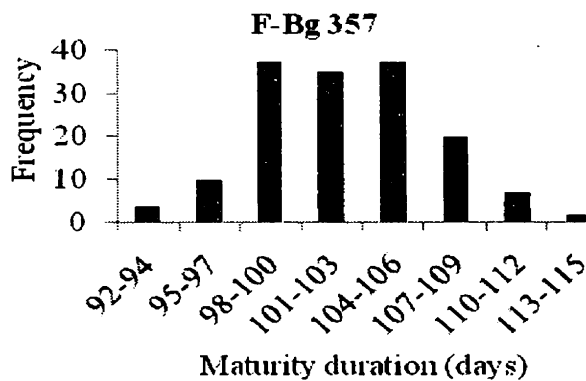
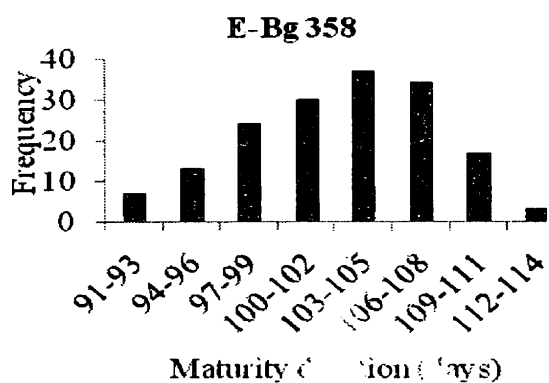
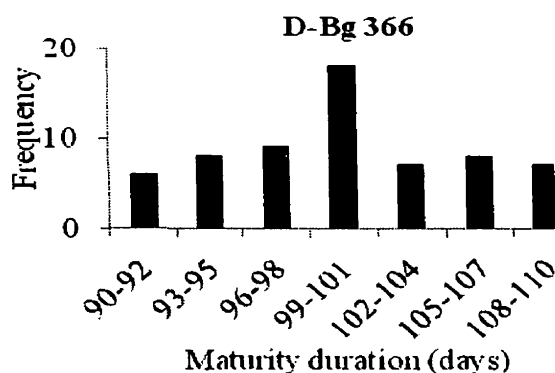
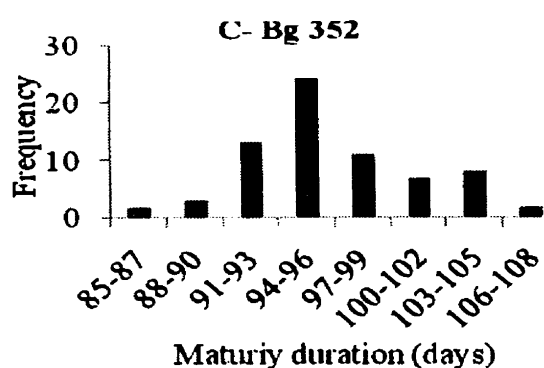


Figure 1. Frequency distribution of maturity durations of test varieties.

Note: A. Bg 250, B.Bg 300, C.Bg 352, D.Bg 366, E.Bg 358, F.Bg 357, G.Bg 403 and H.Bg 379-2

Variation of maturity duration between D/IZ and WZ

The maturity reached 2-7 days earlier in all varieties in the WZ than that of the D/IZ, except Bg 352 (Figure 2A) which was attributed by shorter heading durations (Figure 2B). The highest difference in duration for 50 % heading (7 days) and maturity (7 days) between the D/IZ and the WZ was observed in Bg 379-2. GDD over the growing season are very important to determine the maturity duration and final yield of a variety since they both impact the plants photosynthetic mechanism to operate maximum capacity (Parthasarathi *et al.*, 2013) and the differences in GDD between the climatic zones may be one of the reasons for this variation. Therefore, need of studying the correlation between temperature and the maturity duration in different locations is highlighted.

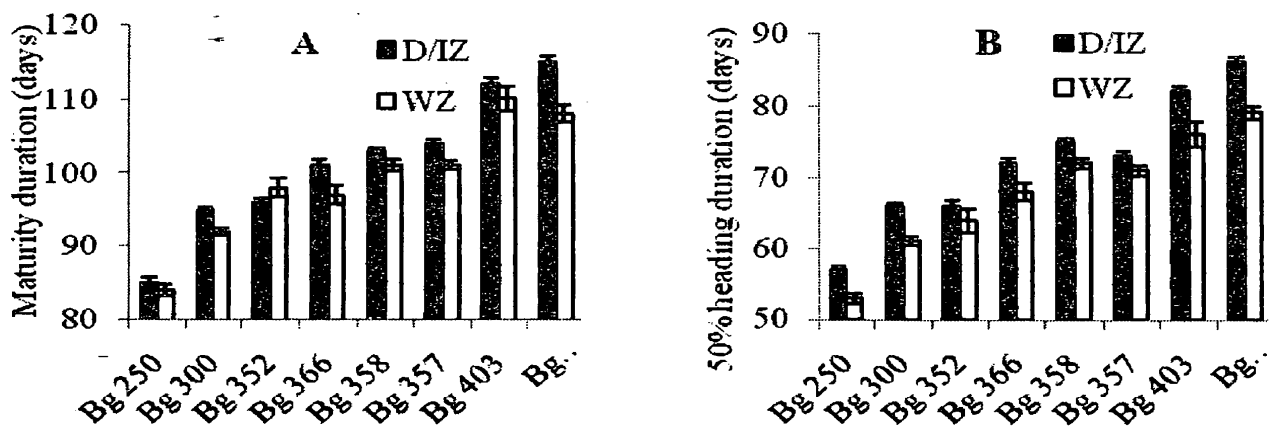


Figure 2. Mean values for A. Duration for maturity and B. Duration for 50% heading of different varieties in the D/IZ and the WZ. Vertical bars indicate \pm standard error.

Seasonal variation in maturity durations

The earliness of 50 % heading and maturity duration was observed in *Maha* than in *Yala* in both the D/IZ and the WZ but was more prominent in D/IZ (Figure 3A, 3B, 4A & 4B). All varieties (except Bg 250 and Bg 300) matured 1-6 days earlier in *Maha* than in *Yala*. The highest difference between *Maha* and *Yala* was observed in Bg 403 and Bg 379-2 in the WZ. Vegara and Chang (1985) reported that short days during the seedling stage accelerated the heading in some rice varieties. This may be one of the reasons for early heading in *Maha* where day lengths are short during December and January which coincides with the vegetative periods of most of varieties cultivated in the WZ.

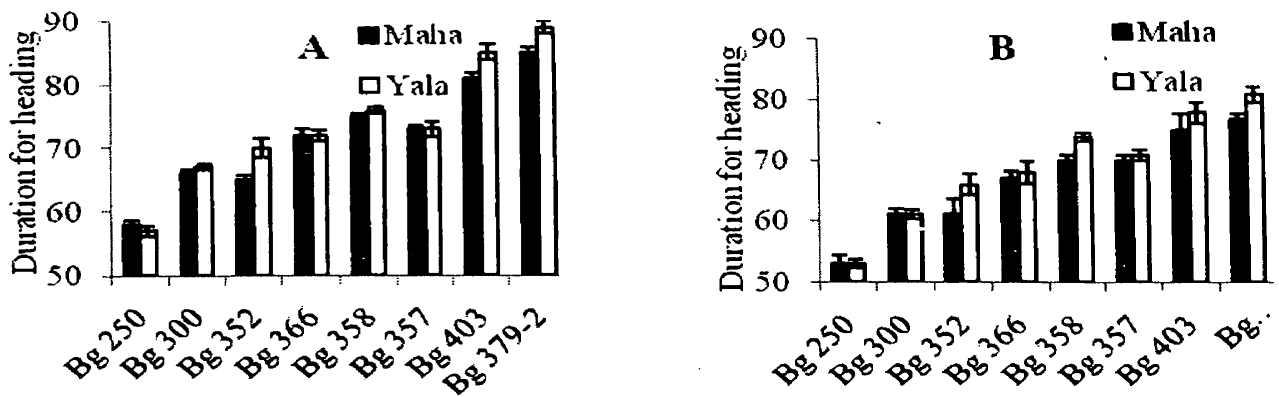


Figure 3. Variation in days 50% heading of varieties in *Yala* and *Maha* A. D/IZ; B. WZ. Vertical bars indicate \pm standard error.

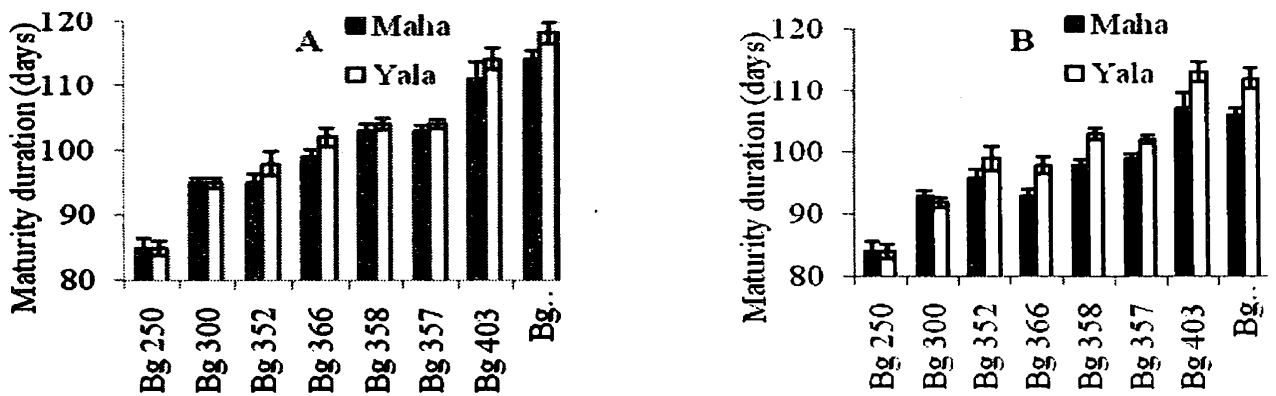


Figure 4. Variation in maturity duration of varieties in *Yala* and *Maha* in A. D/IZ; B. WZ. Vertical bars indicate \pm standard error.

Variations of maturity duration at different locations

Comparatively, shorter maturity durations for all varieties were observed in Bombuwala and Labuduwa in the WZ, and Vauniya and Murunkan in the D/IZ (Table 2). The shortest maturity durations for Bg 250 (81 ± 0.0 days) and Bg 300 (90 ± 1.0 days) were recorded at Murunkan. Giradurukootte also had early maturity for Bg 250 (83 ± 0.5 days) and Bg 352 (94 ± 5.5 days). All varieties except Bg 403 and Bg 379-2 recorded short maturity durations at Samanthurai. Maturity durations of Aralaganwila, Ambalantota, Batalagoda and Paranthan were comparatively same. Late maturities were observed at Mahailuppallama and that was more prominent for varieties of Bg 300, Bg 352 and Bg 366. Three day delay in maturity duration for Bg 300 and Bg 366 and 7 day delay for Bg 352 was observed at Mahailuppallama compared to Batalagoda.

Table 2. Mean \pm standard error maturity duration (days) of rice varieties at different locations.

Location	Bg 250	Bg 300	Bg 352	Bg 366	Bg 358	Bg 357	Bg 403	Bg 379-2
Aralaganwila	84 \pm 2.0	96 \pm 1.1	96 \pm 1.9	103 \pm 2.4	105 \pm 1.3	104 \pm 1.1	112 \pm 2.4	117 \pm 1.9
Ambalantota	88 \pm 1.6	94 \pm 0.6	95 \pm 1.2	101 \pm 1.8	104 \pm 1.0	105 \pm 0.9	116 \pm 1.6	117 \pm 1.5
Batalagoda	87 \pm 2.2	96 \pm 0.7	94 \pm 1.4	102 \pm 2.0	104 \pm 0.9	103 \pm 0.8	115 \pm 1.5	116 \pm 1.5
Giradurukootte	83 \pm 0.5	98 \pm 1.3	94 \pm 5.5	103 \pm 2.7	107 \pm 1.7	106 \pm 3.0	108 \pm 2.6	110 \pm 1.3
Mahailuppallama	87 \pm 3.0	99 \pm 1.1	101 \pm 1.8	105 \pm 1.4	106 \pm 1.2	105 \pm 1.5	115 \pm 2.4	117 \pm 1.7
Murunkan	81 \pm 0.0	90 \pm 1.0	95 \pm 1.1	99 \pm 2.8	102 \pm 1.1	99 \pm 0.7	108 \pm 3.1	113 \pm 1.9
Paranthan	86 \pm 3.1	94 \pm 0.8	97 \pm 2.1	99 \pm 0.8	105 \pm 1.0	103 \pm 1.2	112 \pm 1.8	119 \pm 2.9
Samanthurai	84 \pm 1.7	92 \pm 1.1	94 \pm 2.0	98 \pm 0.7	101 \pm 1.4	102 \pm 0.9	116 \pm 2.1	115 \pm 1.3
Vauniya	83 \pm 2.5	94 \pm 1.3	98 \pm 1.7	96 \pm 1.4	101 \pm 1.6	103 \pm 2.3	106 \pm 0.9	111 \pm 2.5
Bombuwala	84 \pm 1.0	92 \pm 0.7	98 \pm 1.6	97 \pm 2.3	100 \pm 1.1	101 \pm 0.9	110 \pm 1.9	109 \pm 1.8
Labuduwa	84 \pm 1.6	93 \pm 0.9	98 \pm 2.3	97 \pm 2.3	101 \pm 1.0	101 \pm 0.6	110 \pm 1.9	109 \pm 1.8

An alternative method for varietal categorization of rice

Based on the IQR of maturity durations, five alternative age groups are proposed to minimize the drawbacks of present categorization and future use (Table 3). Accordingly, the varieties matured below 90 days of duration can be grouped as ultra-short, 90-99 days as short, 100-109 days as medium, and 110-135 days as long. The varieties mature above 135 days can be grouped as extra-long which may also include photo-sensitive/date fixed types also. The range of length of maturity duration of ultra-short, short and medium age groups are 10 days while it is approximately 25 days for long age varieties.

Table 3. Maturity durations and suggested names for different age groups of rice.

Age group (months)	Variety represented	Maturity period (days)	Suggested name
2½	Bg 250	Below 89	Ultra-short
3	Bg 300, Bg 352	90-99	Short
3½	Bg 357, Bg 358, Bg 366	100-109	Medium
4-4½	Bg 379-2, Bg 403	110-135	Long
5-6	-	Above 135	Extra-long

Variation of grain yields in different varieties

Figure 5 illustrates the average yield of the varieties over 17 years period irrespective of different climatic zones, seasons and locations. Accordingly, Bg 250 recorded the lowest yield (4.5 ± 0.16 t/ha) while Bg 352 and Bg 358 also recorded lower yields below 5 t/ha. Bg 352, which covers about 20 % of the total cultivated extent, has low average yield compared to Bg 300 though its maturity duration is almost the same. This suggests the need of expanding the cultivated extent with varieties having high yield potentials in order to increase the national average yield of the country. Among the varieties, Bg 357 recorded the highest yield (5.5 ± 0.11 t/ha) and therefore it was identified as one of the varieties that should be promoted for cultivation. Average yields of Bg 366, Bg 403 and Bg 379-2 were also above 5 t/ha and can be considered for the cultivation in areas with assured water supply during the growing period.

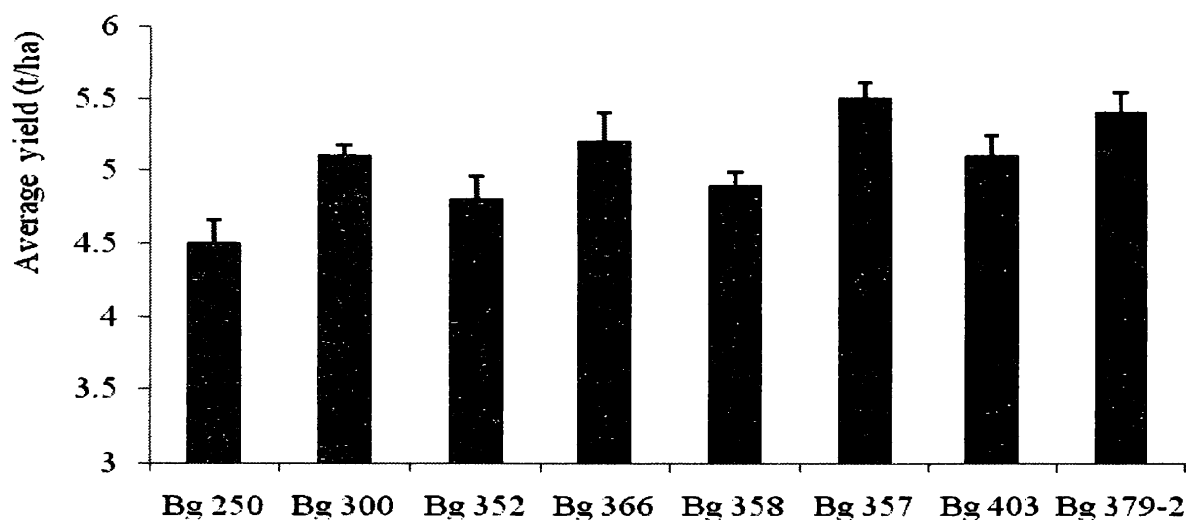


Figure 5. Average yields of different varieties.

Note: Vertical bars indicate \pm standard error.

Variation of grain yields between D/IZ & WZ

The yields of all varieties in the D/IZ were higher than the yields in the WZ (Figure 6). The average yields of the varieties over D/IZ and WZ were 5.4 t/ha and 3.7 t/ha, respectively, which corresponds to 46 % higher yield in D/IZ compared to WZ. Except Bg 250, all varieties gave above 5 t/ha in the D/IZ with Bg 366, Bg 357 and Bg 379-2 recording the highest yield. Ramasamy

and Mosatashi (1986) reported that the DZ of Sri Lanka receives higher solar radiation throughout the year compared to the WZ while the WZ receives comparatively low solar radiation between April and December when most of its rainfall is received during these months. The rice production in the WZ is also affected by soil acidity accompanied by other soil problems such as iron and aluminium toxicity and nutrient deficiencies (Chandrasiri and Pathirana, 1995). Bg 357 and Bg 379-2 recorded more than 4 t/ha in the WZ while Bg 352 and Bg 366 recorded the lowest yields (3.2 t/ha) indicating that some varieties those give higher yields in the D/IZ do not perform similarly in the WZ. Thus, regional release and cultivation of rice varieties more adapted to the area is very much important.

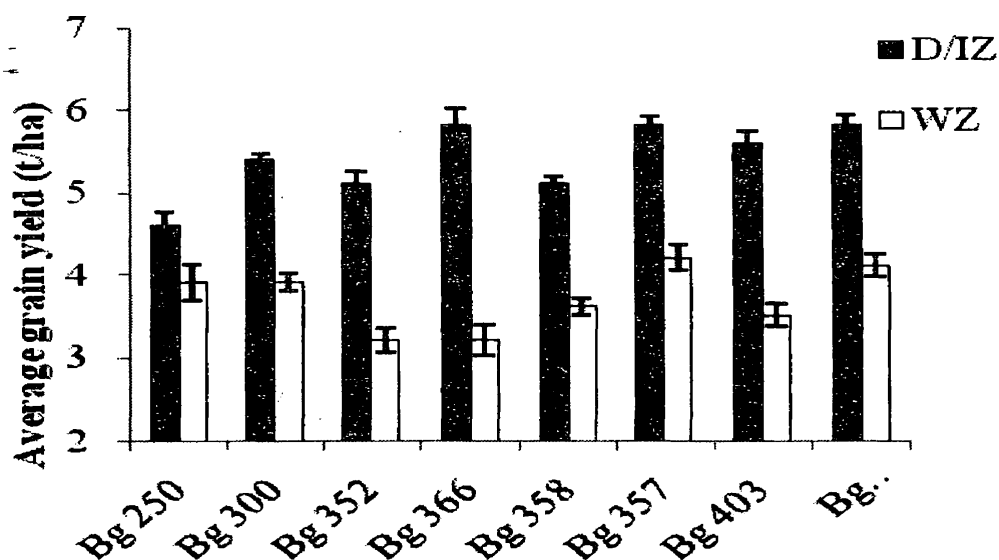


Figure 6. Average grain yields of different varieties in D/IZ and WZ. Vertical bars indicate \pm standard error.

Seasonal variation in yields

The yields of many varieties in *Yala* in D/IZ were comparatively higher than in *Maha*, (Fig. 7A). Bg 366 and Bg 357 recorded 6.1 ± 0.29 and 6.2 ± 0.16 t/ha of average yield in *Yala* compared to 5.4 ± 0.23 and 5.6 ± 0.18 t/ha, respectively in *Maha* in the D/IZ. In contrast, Bg 250 which recorded higher yield in *Maha* compared to *Yala* in the D/IZ, had higher yield in *Yala* compared to *Maha* in the WZ (Fig. 7B). Similarly, Bg 300, Bg 366, Bg 358 and Bg 379-2 which performed better in *Yala* in D/IZ had higher yields in

Maha in WZ. This is possible because *Maha* season in the WZ is favourable for crop production since it is associated with less cloudiness and with higher solar radiation compared to the *Yala* which coincides with the southwest monsoon which sets over the country in late May or early June. The average yields in *Yala* and *Maha* seasons were 5.5 t/ha and 5.3 t/ha, respectively in the D/IZ and 3.8 and 3.7 t/ha in the WZ. *Yala* is considered as the minor season in D/IZ, where less than 50 % of the area is cultivated especially in minor irrigation and rainfed areas owing to water shortages (Chandrasiri *et al.*, 2015). However, *Yala* season which having higher solar radiation throughout the cropping season in the D/IZ is favourable for higher rice productivity if irrigation and other crop management practices can be optimized. Therefore, efficient water management strategies should be adopted in *Yala* season to enhance the rice production of the country.

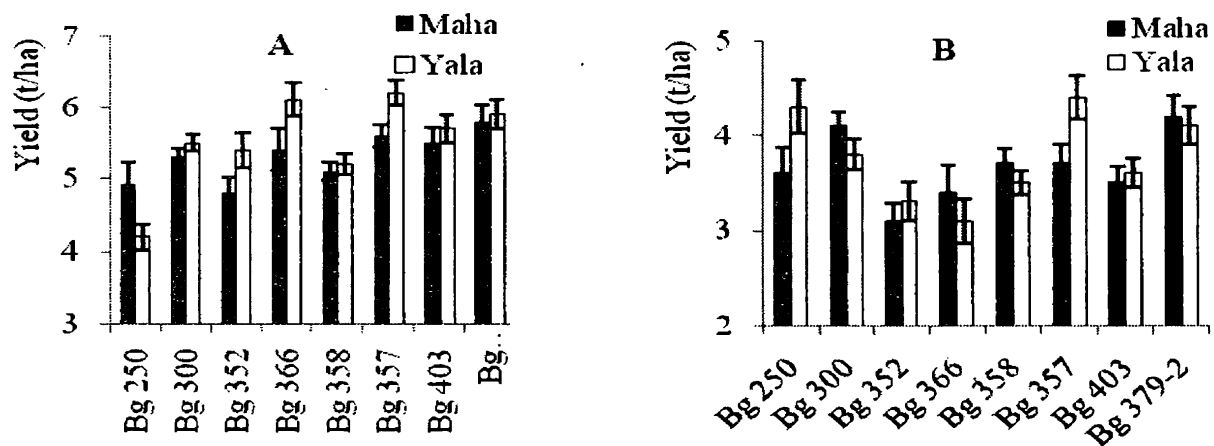


Figure 7. Average yields of varieties in *Maha* and *Yala*.

Note: A. D/IZ, B. WZ. Vertical bars indicate \pm standard error.

Variations of grain yields in different locations

The average grain yields recorded for many test varieties in Giradurukootte, Paranthan, Samathurai and Vauniya were more or less similar to the yields of Batalagoda. Therefore Batalagoda was selected to represent those locations while the data of Bombuwala represented the yields of Labuduwa as illustrated in Figure 8. Accordingly, all varieties recorded lower yields in Bombuwala. Bg 352 and Bg 366 also reported lower yields at Mahailuppallama. All varieties except Bg 366 gave the highest yields in Murunkan; the average yields of Bg 403 and Bg 379-2 were over 8 t/ha, while

Bg 357 recorded over 7 t/ha. The yields at Ambalantota were also high compared to other locations. Higher yields in Murunkan and Ambalantota may be attributed to favourable soil properties present in these locations. Soils in the locations having poor yields are needed to be improved by adopting suitable soil enhancement activities.

Relationship between maturity period and grain yield

Figure 9 illustrates the relationship between maturity duration and yield of Bg 300 in the D/IZ and the WZ. Accordingly, yield did not increase even if maturity period extended and this was same for all other varieties. Conversely, a significant positive relationship ($R^2=0.6$) between average maturity duration of varieties and yield was observed in the D/IZ (Figure 10A), but this relationship was not observed in the WZ (Figure 10B). This suggests that the yield increase due to increasing of age group can be exploited in D/IZ under irrigated condition. However, this strategy seems to be not possible in the WZ.

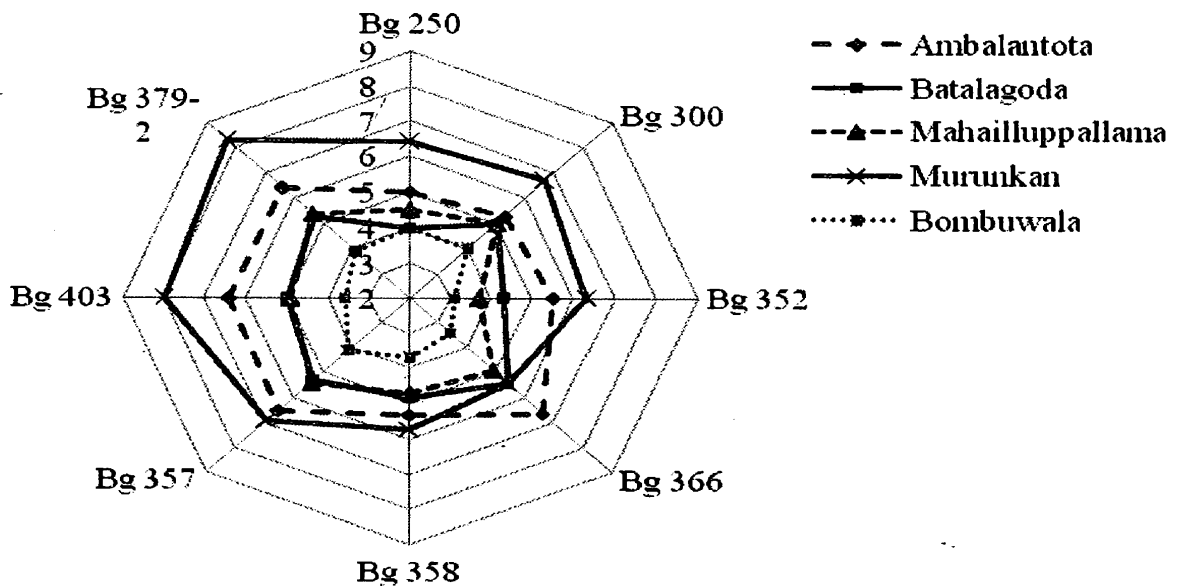


Figure 8. Average grain yields (t/ha) of rice varieties over locations.

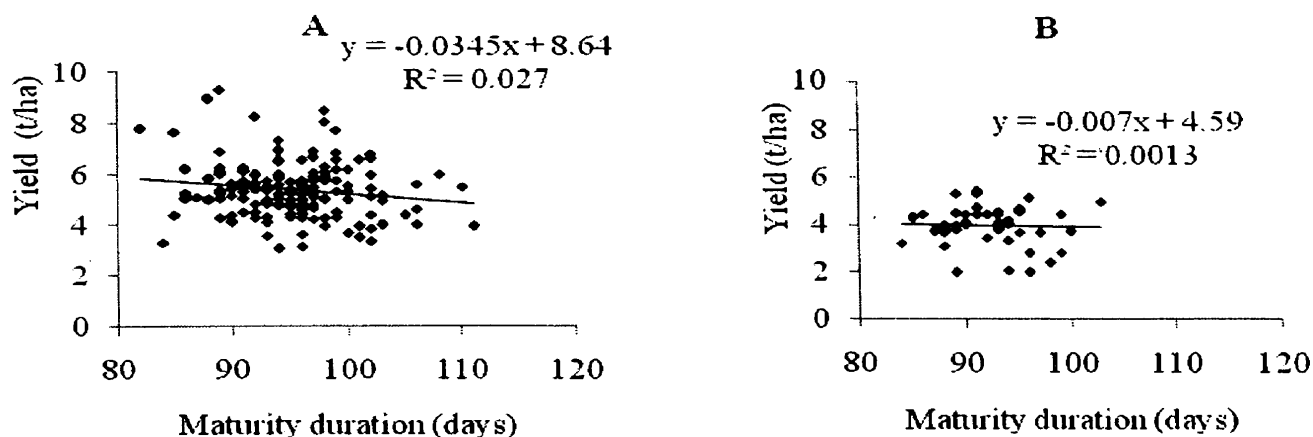


Figure 9. Relationship between average grain yield and average maturity duration of Bg 300 in A. D/IZ and B. WZ.

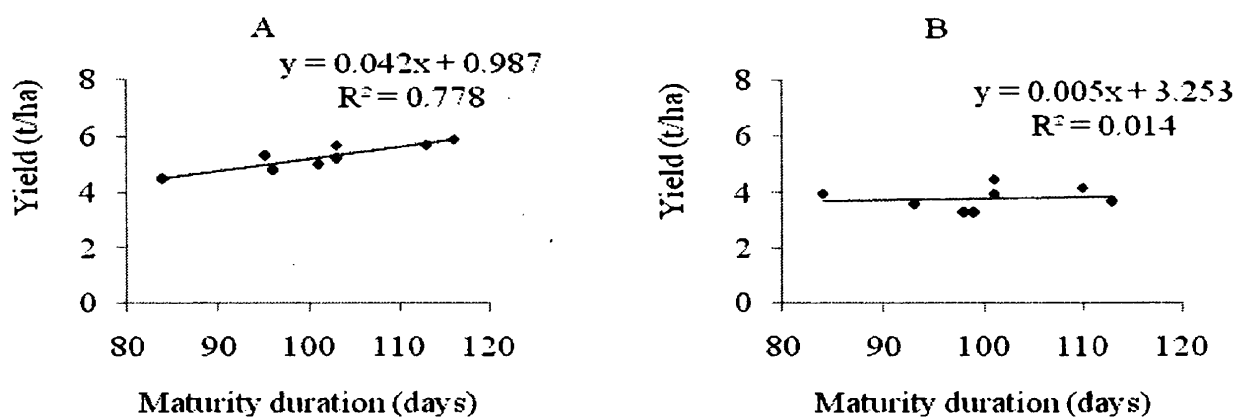


Figure 10. Relationship between average grain yield and average maturity duration of varieties in A. D/IZ and B. WZ.

CONCLUSIONS

The maturity durations and yields of tested varieties vary depending on climatic zone, season and location. Bg 250 matures within 85 ± 0.7 days, only 9 days earlier than Bg 300, though it is categorized under $2\frac{1}{2}$ months maturity group. Bg 300 and Bg 352 show close maturity periods of 94 ± 0.3 and 96 ± 0.6 days, respectively, even if they belong to two different age groups. The maturity of all tested varieties reaches 2-7 days earlier in the WZ compared to the D/IZ. Similarly, maturity occurs 1-6 days earlier in *Maha* compared to *Yala* season. All of the varieties mature early in Bombuwala and Labuduwa in the WZ, and Vauniya and Murunkan in the D/IZ. Bg 357 gives the highest average grain yield (5.5 ± 0.11 t/ha) while the average yields of Bg 366, Bg 403

and Bg 379-2 are above 5 t/ha. The average yields recorded in D/IZ are 46% higher than that of the WZ. Bg 357 performs better in both D/IZ and WZ. The yields are also high in *Yala* season compared to *Maha* season. Murunkan followed by Ambalantota shows the highest yield potential among the test locations. Based on the length on maturity duration, the varieties can be demarcated into five different groups to come up with new categorization of age groups; ultra-short (below 90 days), short (90-99 days), medium (100-109 days), long (110-135 days) and extra-long (above 135 days).

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