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RESEARCH ARTICLE

# CORRELATION OF PLANT HEIGHT AND CROP AGE WITH YIELD POTENTIAL IN SRI LANKAN TRADITIONAL RICE ACCESSIONS OF *Ma wee*: A COMPARATIVE STUDY IN KAMBURUPITIYA WITH SELECTED NEW IMPROVED RICE VARIETIES

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**Abstract**

**Generating knowledge about agronomic and yield characters of *Ma wee* is important for breeding. Therefore, this experiment aimed to determine the selected agronomic characteristics and yield components in accessions 8541 and 8543 ( *Maha Ma wee*) and 4561 ( *Ma wee samba*) varieties in comparison to new improved rice varieties (NIVs) of Bg 38, Bg 300 and Bg 366. Rice varieties were grown in pots in a completely randomized design in the greenhouse with 5 replicates for two consecutive *Maha* seasons of 2021/2022 and 2022/2023 in ecological zone of WL2. Daily daytime temperature (DT) inside the greenhouse and daily photoperiod were recorded during the experimental period. Selected agronomic characteristics and yield components were measured. During 2021/2022, DT varied from 25$^0$C to 30.25$^0$C, while in 2022/23, DT varied from 27.5$^0$C to 33$^0$C. DT during 2022/2023 was significantly higher compared to that of 2021/2022. Days to fifth leaf (DFL), plant height at fifth leaf (HFL), plant height at flowering (HF), number of grains per first panicle (GPP) and effective tiller number at harvest (ETH) varied from 24.00±.40 to 30.4±32, 40.00±1.14 to 60.90±2.75, 95.80±.96 to 235.6±11 and 2.00±.31 to 3.80±.37 during 2021/22 while variations were from 27.00±.70 to 32.60±.40, 39.20±.97 to 73.25±1.60, 81.75±4.11 to 239.00±2.91, 135.25±4.87 to 225.80±3.54 and 2.20±.20 to 3.60±.24 respectively during 2022/2023. DFL was influenced by the season, with significantly higher DFL during the 2022/2023 season having significantly higher DT. In 2021/2022, DFL, HFL, DF, HF and GPP were significantly higher in *Ma wee* accessions in contrast to those of NIVs. Except for Bg 38, which is bred with a traditional rice ancestor, NIVs produced significantly lesser GPP in contrast to *Ma wee* accessions. Although Bg 38 had the highest DF (145±1.15), and produced a higher GPP (213.5±9.97), HF (87.8±1.06) was significantly lower than that of *Ma wee*. Strong correlations were observed for DFL and DF (0.571), DFL and ETH (0.414), DF and GPP (0.599) and, HF and GPP (0.855). Our results suggest that the challenge of incorporating *Ma wee* accessions into breeding programmes for increased yield with an ideal plant structure must overcome the coincidence of high GPP with tall PH and the extended DF efficiently through molecular breeding strategies.**

**Keywords:** Days to flowering, Number of grains per first panicle, *Ma wee,* New improved rice, Correlations between agronomic and yield characters

## INTRODUCTION

More than 90% of global rice production occurs in Asia, where it provides 35-75% of the caloric intake for over 3 billion Asians (Khush 2005). Out of the two rice species significant for human nutrition, *Oryza glaberrima* is cultivated in West Africa, while *Oryza sativa* is indigenous to Asia (Chang and Bardenas 1965). *Oryza sativa* displays an eco-

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logical diversity, resulting in 2 major ecogeographic races named *indica* in tropics and *japonica* in temperate regions and upland tropics (IRRI 2010). Sri Lankan traditional rice (SLTR) collection has been cultivated by Sri Lankan farmers for millennia, as documented in written history (Kahandawala 2011). This collection exhibits a significant morphological diversity, as recorded in the reports of Team of NRC 12-129 (2014), Team of NRC 12-129 (2015 a) and (2015 b) which is crucial in terms of ecological adaptation.

Since the Green Revolution in the 1960s, new improved rice varieties (NIVs) with desirable agronomic characteristics and yield components have been replacing SLTR. NIVs are developed using genotypes primarily from International Rice Research Institute (IRRI) lines. Undesirable characteristics of traditional rice include the short day requirement for flowering initiation, the extended crop age, and tall plant height, leading to lodging. Among SLTR, *Ma wee* varieties play a crucial role as breeding resources for the abiotic stress tolerance and the nutritional and therapeutic properties of grains. The germplasm collection at Plant Genetic Resources Centre, Gannoruwa, Sri Lanka, houses 43 accessions of *Ma wee* varieties named *Ma wee, Sudu mawee, Mawee samba, Maha mawee, Bala mawee, Heen horana mawee, Horana mawee, Kuru mawee, Kuru mawee samba, Sudu kuru mawee* and *Nandu mawee* Team of NRC (12-129, 2015b). Pushpakumari *et al.* (2017), have documented variations in important agronomic characteristics and yield components of above *Ma wee* accessions grown at the Faculty of Agriculture, University of Ruhuna, Sri Lanka.

While NIVs are favoured for their farmer-friendly agronomic characteristics, which are largely derived from the genetic background of exotic germplasm, underutilization of traditional rice may lead to the erosion of valuable genes, such as genes for resistance to biotic and abiotic stresses and nutritional properties. As stated by Wickramasingha and Noda (2008), *Ma wee* varieties have been found to withstand extreme weather conditions.

Flowering time of rice is influenced by exogenous factors, including photoperiod, light quality and temperature, as endogenous factors, mainly genetic background (Song *et al.* 2012). Adjusting the flowering time during breeding can enhance the adaptability of the crop to diverse environments (Kim *et al.* 2008). Vicentini *et al.* (2023) have reviewed the effect of high temperatures on early flowering and the resulting low yield. Based on the natural variation in the flowering time of *japonica* rice, flowering time controlling genes have been studied (Izawa *et al*. 2003).

Ancient local farmers have observed strong photoperiod sensitivity in *Ma wee* varieties, restricting *Ma wee* cultivation to the short day season (*Maha*). During *Maha* season, the day length typically ranges from 11hours and 43 minutes to approximately 11 hours 59 minutes. The photoperiod varies during the months of the *Maha* season, with a decrease in day length from 11 hours and 59 minutes in October to 11 hours and 43 minutes in mid December, followed by an increase to 11 hours and 59 min in March. According to Pushpakumari *et al*. (2017), early planting during the *Maha* season facilitated flowering in all 43 accessions, while delayed planting in *Maha* season resulted in prolonged vegetative growth in 34 accessions. Rathnathunga *et al.* (2016) recorded early flowering of selected *Ma wee* accessions under extremely short day lengths of 8 hours, in contrast to 12 hour day length under greenhouse conditions.

*Ma wee* has the potential for high yield, as documented by Team of NRC 12-129 (2015b). Developing improved *Ma wee* varieties with shorter duration, reduced plant height and higher yield while retaining the genetic background for resilience to environmental stresses and nutritional and therapeutic properties is an important breeding objective. Therefore, this experiment was conducted to determine the Days to Flowering (DF) and associated agronomic characteristics including Days to fifth leaf (DFL), Plant height at fifth leaf (HFL), Plant height at flowering (HF) and selected yield components Number of grains per first panicle (GPP) and Number of effective tillers at harvest (ETH) of selected accessions of *Ma wee* in order to identify promising accessions.

## MATERIALS AND METHODS

Seeds of the accessions of 8541 and 8543 (*Maha Ma wee*) and 4561 (*Ma wee samba*) were obtained from the Plant Genetic Resources Centre, Gannoruwa, Sri Lanka. Seeds of the NIVs of Bg 38, Bg 300 and Bg 366 were received from the Rice Research and Development Institute (RRDI), Bathalagoda, Sri Lanka. Seeds of all rice varieties were germinated and maintained under laboratory conditions for 2 weeks. Two- week- old seedlings were then transplanted into pots and grown during two consecutive *Maha* seasons, of 2021/22 and 2022/23 with 5 replicates. In the 2021/22 season, we grew accessions 4561,8541 and 8543, as well as NIVs Bg300 and Bg366. In the 2022/23, we grew accessions 4561,8541 and 8543, along with NIVs Bg366 and Bg38.This experiment was conducted at the greenhouse located at the Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka, within the agroecological zone WL2 in the low country wet zone (LCWZ). The plants were cultivated in pots filled with paddy field mud, composed of sandy clay loam soil type. The pot dimensions measured 22 cm in diameter and 20 cm in height. One plant per pot was considered as one replicate in a completely randomized design within the greenhouse. Regular irrigation was practiced, and the plants were fertilized according to the Department of Agriculture recommendation for NIVs taking the pot size into account (Urea 140kg/ha, MOP 35 kg/ha, TSP 50 kg/ha). Daily daytime temperature (DT) in the greenhouse and the daily photoperiod were recorded throughout the experimental period. Selected agronomic characteristics including of DFL, HFL, DF, HF and selected yield components of GPP and ETH were measured following the guidelines established by Team of NRC 12-129 (2014) and Team of NRC 12-129 (2015).

### Statistical analysis

The data were analyzed using SPSS software (version 25). A T-test was performed to determine the significant difference between the DT in the two *Maha* seasons of 2020/21 and 2022/23. Analysis of variance, followed by Duncan's multiple range test for mean separation, was performed for the each parameter including DFL, HFL, DF, HF, ETH and GPP separately.

## RESULTS AND DISCUSSION

### Daily photoperiod and temperature variation within and between two *Maha* seasons of 2021/22 and 2022/23

The photoperiod varied during each *Maha* season of 2021/22 and 2022/23 in the same way (Figure 1). The onset of the *Maha* season was characterized by long days of 12 hours and 10 minutes from September 15 to October 08. Day length reduced from the day-neutral condition on October 09 to 11 hours and 43 minutes on December 27. Subsequently, the day length increased from 11 hours and 44 minutes to 11 hours and 54 minutes until February 15 of the following year.

During the *Maha* season 2021/2022, DTs varied from $25^0$C to $30.25^0$C, while they varied from $27.5^0$C to $33^0$C during the 2022/2023 season. According to the T-test, the average DT in 2022/2023 was significantly higher ($p<0.002$).

### Variation of agronomic characteristics and yield components of rice varieties

Variations in agronomic characteristics and yield components during the two *Maha* seasons are given in Table 1 and Table 2. DFL varied from 24.00±.4 to 30.4±.32 and from 27±0.7 to 35.2±.49 during the 2021/2022 and 2022/2023 seasons, respectively. Except for the lowest DFL of 8543 during 2022/2023, traditional rice produced the highest DFL under both seasons. DFL indicates the onset of reproductive phase. According Rathnathunga *et al.* (2017), DFL is affected by temperature and photoperiod. The plants of accession 4561 responded to high temperatures and a short-day photoperiod for the lowest DFL (38.3) in contrast to DFL of 53.7 and 51.7 under day-neutral and long-day conditions respectively. The 4561 plants grown under high temperatures were reported to be responsive to day-neutral conditions with higher HFL stage as

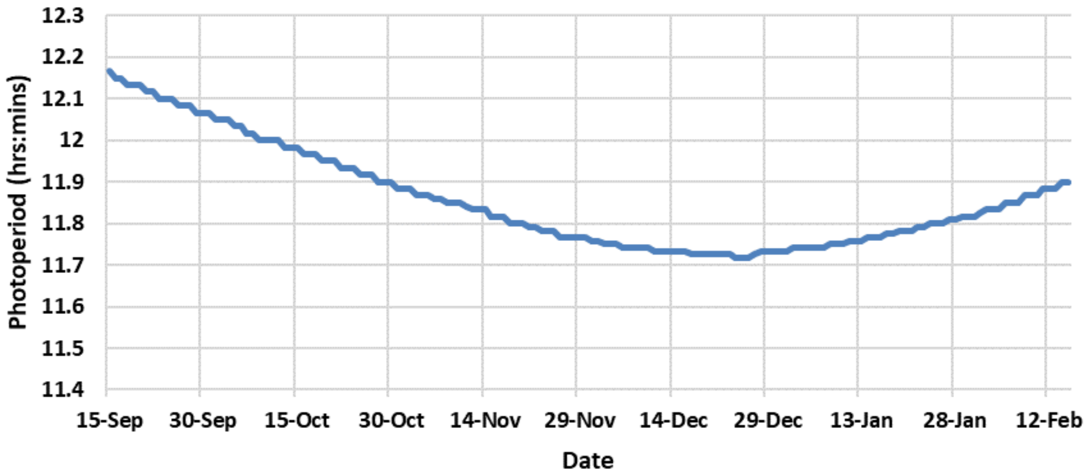


**Figure 1: Variation of photoperiod during *Maha* seasons of 2021/2022 and 2022/2023 at Faculty of Agriculture, University of Ruhuna in WL2**

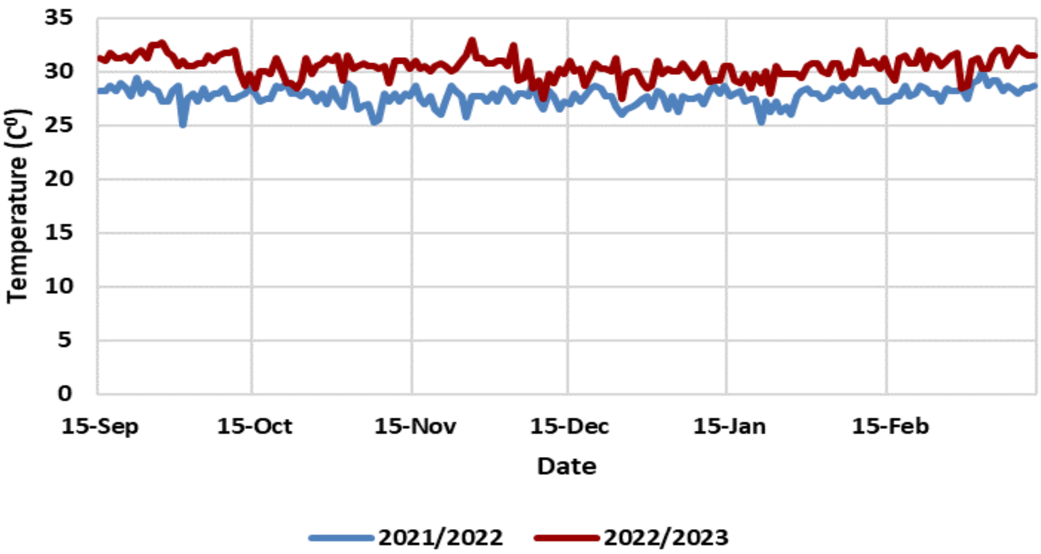


**Figure 2. Variation of day time temperature during *Maha* seasons of 2021/2022 and 2022/2023 in the greenhouse at Faculty of Agriculture, University of Ruhuna in WL2**

well. In this experiment, accession 8541 produced the highest HFL during both *Maha* seasons.

DF varied from 71.6 ±.4 (Bg 300) to 137 ±.47 (8543) during the 2021/2022 season and from 72.25±.85 (Bg 366) to 145±1.15 (Bg 38) during the 2022/2023 season as depicted in Figure 3. *Ma wee* accessions 4561 (124.4±.81) and 8541 (136±1.5) were not different from 8543 (137 ±.47) during 2021/2022. Accessions 8541 (138.75±1.4) and 8543 ( 135.6±1.32) were not different during 2022/2023 in DF (Tables 1 and 2). The highest PH at 2021/2022 (231.4 ±2.33 and 235.6±.11 cm) and 2022/2023 (221.25 ± 4.53 and 239 ± 2.91 cm) seasons were from accessions 8541 and 8543, respectively. The variation in GPP of tested accessions is provided in Table 1, Table 2 and Figure 4. The panicle sizes of the tested accessions varied (Figure 5). The GPP of improved rice was the lowest during 2021/2022 season, with values of 133.75± 2.95 and 159.2±12.6 for Bg 366

**Table 1: Variation of agronomic characteristics and yield components of rice varieties and accessions during *Maha* season 2021/2022**

| Character-istic | Traditional rice accession/ new improved rice variety | | | | |
|---|---|---|---|---|---|
| | Bg 300 | Bg 366 | 4561 | 8541 | 8543 |
| DFL | 24.60±.24 a | 24.00±.40a | 29.60±.67b | 27.60±.24b | 30.4±.32b |
| HFL (cm) | 42.60±.60 a | 40.00±1.14a | 48.60±.67b | 60.90±2.75c | 59.4±.71c |
| DF | 71.60±.40 a | 74.20±.73a | 124.40±.81b | 136.00±1.58b | 137±.47b |
| HF (cm) | 107.20±2.33 b | 95.80±.96a | 144.40±4.34c | 231.40±2.33d | 235.6±11d |
| GPP | 159.20±12.61b | 133.75±2.95a | 269.60±1.5d | 286.40±3.35d | 225±31c |
| ETH | 2.60±.24 b | 2.75±.25b | 3.80±.37c | 2.00±.31a | 3.0±.17bc |

Significantly different values for each characteristic are given in different letters ($p<0.05$)

**Table 2: Variation of agronomic characteristics and yield components of rice varieties and accessions during *Maha* season 2022/2023**

| Character-istic | Traditional rice accession/ new improved rice variety | | | | |
|---|---|---|---|---|---|
| | Bg 366 | Bg 38 | 4561 | 8541 | 8543 |
| DFL | 30.20±66b | 32.60±.40c | 35.20±.49d | 32.00±.57c | 27.00±.70a |
| HFL (cm) | 39.20±.97a | 43.80±.97b | 47.75±.75c | 73.25±1.60e | 64.80±1.02d |
| DF | 72.25±.85a | 145.00±1.15d | 133.00±1.58b | 138.75±1.49c | 135.60±1.32bc |
| HF (cm) | 81.75±4.11a | 87.80±1.06a | 139.40±1.56b | 221.25±4.53c | 239.00±2.91c |
| GPP | 135.25±4.87a | 213.50±9.97b | 219.75±4.85b | 220.00±12.73b | 225.80±3.54b |
| ETH | 3.33±.33b | 3.60±.24b | 2.75±.25b | 3.50±.28b | 2.20±.20a |

Significantly different values for each characteristic are given in different letters ($p<0.05$)

and Bg 300, respectively. Accessions 4561 (269.6±1.5), 8541 (286.4±3.35) and 8543 (225±31) produced higher GPP during 2021/2022. The GPP of Bg 366 (135.25±4.87) was the lowest in 2022/2023 as well. The highest GPP from *Ma wee* accessions 4561 (219.75±4.85), 8541 (220.00±12.73) and 8543 (225.80±3.54) were not different from that of Bg 38 (213.5±9.97). Bg 38 is derived through a cross between the traditional rice selection line *Podi wee* 8 and an introduced variety *Engtech,* based on the personal communication with the former director of RRDI, Dr. Sumith Abeysiriwardhana. According to NRC 12-129 (2015a), *Podi wee* accession 6160 reported a GPP of 237. The ETH was lower in all accessions under potted conditions, ranging from 2±.31 (in 8541) to 3.8± .37 (in 4561) during 2021/2022, and from 2.2 ±.2 (in 8543) to 3.6±.24 (in Bg 38) during 2022/2023. The ETH under transplanted conditions in the field would provide a better estimate of the total yield of the above accessions.

As reviewed by Zhong *et al*. 2023, the number of grains per panicle is one of the main yield components, specifically targeted in rice breeding programmes. The number of grains per panicle is variable in response to environmental factors, such as growing seasonal conditions (Pushpakumari *et al*. 2017). The *Grain Number per Panicle 1 (GNP1)* gene is responsible for the increase in grain number as it affects cytokinin activity in panicle meristem (Wu *et al*. 2016). A panicle with 200 to 250 grains is considered as a large panicle, and a rice plant having such panicles and fewer tiller number in ideal plant structure is a major breeding objective (Khush 2005). Genes associated with grain number have been artificially selected throughout rice breeding history worldwide (Zhong *et al*. 2023).

Correlations between selected agronomic characters were significant (Table 3). DF positively correlated with GPP (0.855) while plant height (HFL and HF) were positively correlated with DF (as 0.610 and 0.599 respectively) at p < 0.01 level. Taller plant height and long age are undesirable agronomic characteristics of *Ma wee* accessions that lead to lodging. However, taller plant structure and prolonged vegetative growth are correlated with grain yield, according to the above results. As mentioned in the review of Zhong *et al*. 2023, there are pleiotropic effects in grain number determining genes with other agronomic characteristics, such as plant height, tiller number and days to flowering, which can often be detected among high-yielding taller Sri Lankan traditional rice under local conditions as well (Rathnathunga *et al*. 2016).

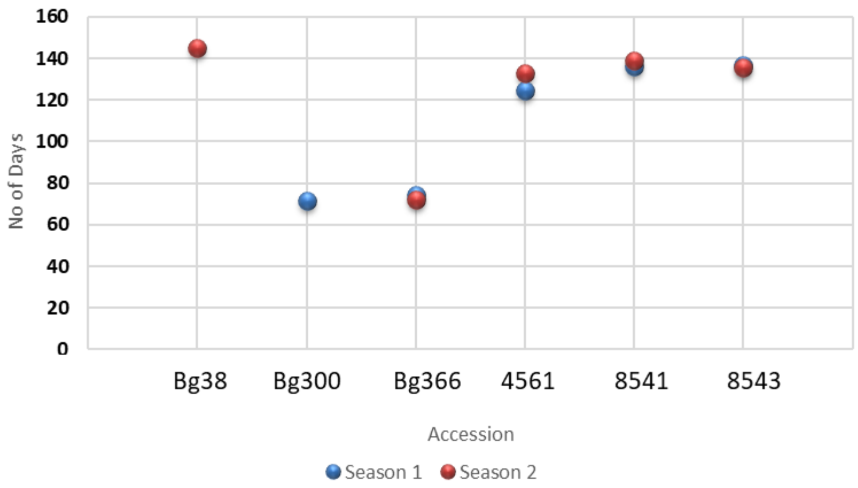


**Figure 3: Variation of days to flowering of traditional rice accessions and improved rice varieties during two *Maha* seasons 2021/22 and 2022/2023 in the greenhouse**

Season 1: *Maha* 2021/2022; Season 2: *Maha* 2022/2023

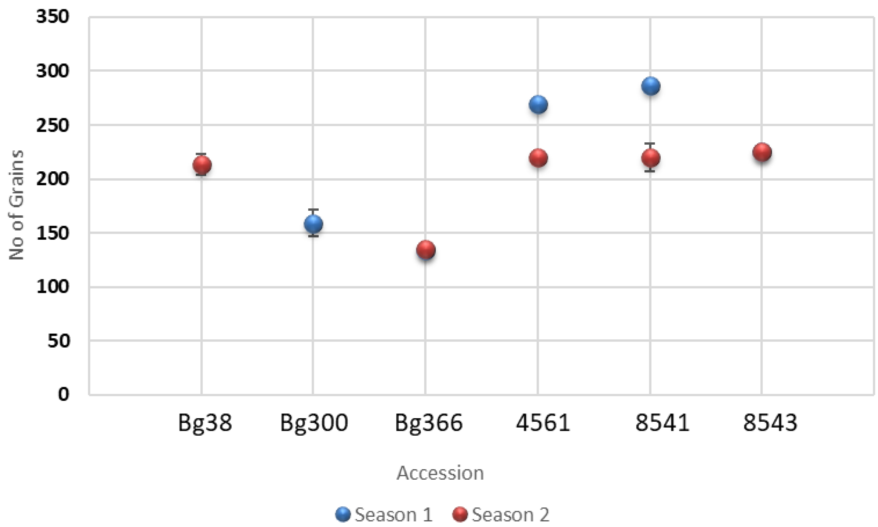


**Figure 4: Variation of number of grains per first panicle of traditional rice accessions and improved rice varieties during two *Maha* seasons 2021/22 and 2022/2023 in the greenhouse**

Season 1: *Maha* 2021/2022; Season 2: *Maha* 2022/2023


**Figure 5: Variation of number of grains per panicle of traditional rice accessions and new improved rice varieties**

**Table 3: Correlations between agronomic characters and yield components of rice varieties**

| | DFL | HFL | DF | HF | GPP | ETH |
|---|---|---|---|---|---|---|
| **DFL** | 1 | 0.043 | 0.571** | -0.132 | 0.328 | 0.414* |
| **HFL** | | 1 | 0.610** | 0.928** | 0.550** | -0.062 |
| **DF** | | | 1 | 0.599** | 0.855** | 0.149 |
| **HF** | | | | 1 | 0.627** | -0.314 |
| **GPP** | | | | | 1 | 0.004 |
| **ETH** | | | | | | 1 |

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level

Breeding for higher grain yields while reducing DF and PH would be a breeding objective to exploit the nutritional properties and abiotic stress tolerance of *Ma wee* in the future.

## CONCLUSION

Tested agronomic characters and yield components varied among *Ma wee* accessions and NIVs during the two *Maha* seasons: DFL varied from 24.00±.4 to 30.4±.32 and 27±0.7 to 35.2±.49 during 2021/2022 and 2022/2023 seasons, respectively. DF varied from 71.6 ±.4 (Bg 300) to 137 ±.47 (accession 8543) during the 2021/2022 season and from 72.25±.85 (Bg 366) to 145±1.15 (Bg 38) during 2022/2023. *Ma wee samba* accession 4561 (124.4±.81) and *Maha Ma wee* accession 8541 (136±1.5) were not different from *Maha Ma wee* accession 8543 (137 ±.47) in DF during 2021/2022. Accessions 8541 (138.75±1.4) and 8543 ( 135.6±1.32) were not different in DF during 2022/2023. The highest PH in 2021/2022 (231.4 ±2.33 and 235.6±.11 cm) and 2022/2023 ( 221.25 ± 4.53 and 239 ± 2.91 cm) seasons were from accessions 8541 and 8543, respectively. The GPP of improved rice was the lowest during 2021/2022 season, with values of 133.75±

2.95 and 159.2±12.6 (Bg 366 and Bg 300 respectively). Accessions 4561 (269.6±1.5), 8541(286.4±3.35) and 8543(225±31) produced higher GPP during 2021/2022. The GPP of Bg 366 (135.25±4.87) was the lowest in 2022/2023 as well. The highest GPP from *Ma wee* accessions 4561 (219.75±4.85), 8541 (220.00±12.73) and 8543 (225.80±3.54) were not different to that of Bg 38 (213.5±9.97). The ETH was less in all accessions under potted condition as 2±.31 (in accession 8541) to 3.8± .37 (in accession 4561) during 2021/2022 and 2.2 ±.2 (in accession 8543) to 3.6±.24 (in Bg 38) during 2022/2023. Strong correlations were detected for DFL and DF (0.571), DFL and ETH (0.414), DF and GPP (0.599) and, HF and GPP (0.855). As grain number controlling genes are pleiotropic, the exploitation of high-yielding trait while expelling tall plant height and higher DF traits from *Ma wee* would be a challenge for breeding high-yielding Sri Lankan traditional rice for farmer friendliness. The use of molecular breeding strategies must be indispensable for above approach.

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**AUTHOR CONTRIBUTION**

HMASBJ carried out the experiment, analyzed the data and drafted the manuscript. DMJBS and EUU contributed the experiment and commented on the manuscript. SG conceived the concept, designed the experiment and edited the manuscript.

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