CONTRIBUTION OF GROWTH AND PHYSIOLOGICAL CHARACTERISTICS IN YIELD OF FIELD GROWN RICE VARIETIES IN LOW COUNTRY DRY ZONE

S.L.R. Begum[1], E. Pavithira[1], and A.N.M. Mubarak[1]
[1] Department of Biosystems Technology, Faculty of Technology, South Eastern University of Sri Lanka
imara@seu.ac.lk

ABSTRACT: *A field experiment was conducted during the season of Maha 2017 at the AgroTech Park, South Eastern University of Sri Lanka which is located in Malwatha, Ampara district of Sri Lanka to evaluate the leaf stomatal characteristics and its influence on above ground biomass and grain yield of new improved rice cultivars namely AT 362 and BG 94-1. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replicates. Parameters on stomatal conductance, growth characters namely plant height, number of productive tillers, unproductive tillers and yield contributing characters such as panicle length, panicle weight and straw weight were recorded. The data obtained were analyzed with paired t-test using STATA software and further correlation and regression were tested using SPSS. It has been found that stomatal conductance, plant height and panicle weight were varied significantly (P<0.05) among the tested varieties. However, productive tillers, unproductive tillers, straw weight and panicle length were not significantly different (P>0.05) among treatments. At harvesting, the maximum plant height (64.25 cm) was notified in AT 362 and the lowest (56.58 cm) was found in BG 94-1. During reproductive stages, panicle weight was strongly and positively correlated (r = 0.999) with parameters of stomatal conductance, plant height, productive tillers, panicle length and above ground dry matter (AGDM). It indicates that about 99.8% variation in panicle weight could be explained by the variation in evaluated characteristics. Further, linear regression for above ground dry matter and stomatal conductance showed a non-significant (p>0.05) positive correlation (r = 0.687). The value of R^2 (0.473) indicates that about 47.3% variation in stomatal conductance could be explained by the variation in AGDM. Meanwhile, AT 362 significantly performed better than the variety BG 94-1 for growth and yield characters namely panicle length (19 cm), panicle weight (291.5 gm^{-2}) and straw weight (251.3 gm^{-2}). Thus, the results of various characters studied in the experiment depict that crop yield would be improved further by altering stomatal properties and ultimately impact the photosynthetic capacity.*

Keywords: AT 362, Bg 94-1, growth parameters, stomatal conductance, yield parameters.

1. INTRODUCTION

Rice is the single most crop that occupies 34 % of the total cultivated lands in Sri Lanka (Department of Agriculture, 2010). Annual per capita consumption of rice is 100 kg, and at present, national average rice yield is 4.5 t ha^{-1}. Given the nutritional and high caloric value, rice has become the staple food in the country. At present, the gap between the potential yield and farmer realize yield is still high in most of rice ecosystems. This variation is due to ecological factors, bio-physical factors, management practices, cultural and socio-economic factors etc. However, this gap can be minimized through improving the genetic potential of rice varieties and improved management practices in the areas of soil, fertilizer, pest, weed and water management (FAO, 2004).

The sustainability of rice production depends on the development of new rice cultivars with high yield and stable performance across diverse environments (Akter, 2014). Farmers in Sri Lanka generally choose varieties based on the maturity period, thus the maturity period is used as an indicator to identify the dominant varieties. The genotype and environment interaction can cause differences in grain yield performance and stability of a genotype developed in different environments (Colombari Filho *et al*., 2013). According to that, some popular varieties are grown widely across districts that represent different environmental conditions, indicating their wide adaptability. The top three varieties namely Bg 300, Bg 352, and Bg 358 which grown in 23 districts account for around half of the total rice area in the country. High yield, short maturity, good adaptability and good grain quality are the main reasons for their popularity. Generally, the improved rice varieties released in Sri Lanka come from RRDI (Jayawardena *et al*., 2010). Acceptability of new improved varieties (NIV) gradually increases over other germplasms among farmers due to higher yield potential. Amongst the number of varieties released, Bg 94-1 (white nadu) with yield potentials of 10 t/ha and AT 362 are most popular among farmers (Parakrama Waidyanatha, 2014).

Grain yield in rice is a complex trait and highly dependent on agronomic and reproductive characters. Agronomic and morphological characters are usually used as an initial tool to distinguish between varieties (Sadimantara et *al*., 2014). In order to improve yield, any crop depends on its photosynthetic capacity, and on how plants allocate carbohydrates for growth and development. Rice yield mainly comes from photosynthate in leaves after heading, which is affected by photosynthetic function decline in leaves. It has been proved that while filling grains of crops demanded a lot of photosynthate, leading to the increase in yield and yield attributing characters (Zhang et *al*., 2001). On the other hand, respiration rates are normally influenced by soil water availability, climatic conditions and plant development stage. Thereby, the balance between respiration and photosynthesis has a direct influence on plant yield. Considering the importance of photosynthetic capacity of leaf on grain yield, it is prerequisite to analyze the morphological and the physiological characteristics of functional leaves to improve grain yield in rice (Yue et *al.,* 2006). It is suggested that high yielding rice could be developed by selecting cultivars with high photosynthesis.

Moreover, stomatal distribution is found to be an important trait of rice cultivars for increasing yield. It plays an important role for two plant processes namely transpiration and photosynthesis. Kanemura *et al*., (2005) reported that stomatal conductance for gas diffusion (g_s) and transpiration is closely associated with leaf photosynthesis in rice. As cited by Horie et *al*., (2006) and Fischer et *al*., (1998), strong indications have been obtained for a major influence of g_s on crop growth rate during reproductive period in some crop species. Therefore, it is expected that crop yield would be improved by manipulating the stomatal functions and gas exchange. It is relative with the statement of Codon *et al*., (2007) that the stomatal aperture-related traits have been used as selection criteria for high yield-potential in bread wheat. Therefore, the present research was undertaken with the aim of exploring the leaf stomatal characteristics and its influence on above ground biomass and grain yield of new improved rice cultivars namely AT 362 and BG 94-1.

2. MATERIALS AND METHODS

Experimental site and soil: This experiment was conducted during the season of Maha 2017 at the AgroTech Park, Malwatta, South Eastern University of Sri Lanka, located in Ampara district of Sri Lanka. The agro ecological zone of the area is DL 2b. Geographically, it is located at latitude of 07° 19′ 17.30″ N and longitude of 81° 43′ 56.19″ E at an elevation of 30 m above mean sea level. The soil of the experimental site is sandy loam. The annual mean temperature reaching 30°C and it receives most of rainfall from Northeast Monsoon.

Experimental design: The experiment was laid out in randomized complete block design with two treatments replicated four times and plot sizes of 5m x 5m. The treatments consisted of two cultivars; AT 362, BG 94-1.

Experimental method: A quadrate of 1m × 1m was thrown into the replicated plots and stomatal conductance was measured on 10 randomly selected plants during pre and post anthesis stages using leaf porometer (SC-1, Decagon Devices). Before taking measurements, it was calibrated every time according to instructions given by manufacturer under a different set of environmental conditions to ensure accurate stomatal conductance measurements. At harvest, qualitative measurements on plant height, panicle length, productive and unproductive tillers were taken from the plants of 1 m^2 area. Further, whole plant samples from an area of 1 m^2 were separated into panicle and straw and kept in hot air oven at 80° C until constant dry weight obtained. From those readings, above ground dry matter (AGDM) and harvest index were calculated.

Statistical analysis: Data were subjected to paired t-test using software package of STATA (version 13) to test the hypothesis (significance between varieties) at probability of 0.05. Further, correlation and regression analysis were carried out to see the relationships among evaluated growth, physiological and yield traits of rice using SPSS (version 16.0).

3. RESULTS

Mean values for growth and yield characteristics of selected culltivars are shown in Table 1, 2. Accordingly, significant differences ($p<0.05$) between tested improved varieties were found in plant height and panicle dry weight. Among the tested varieties, the variety AT 362 showed higher values for productive tillers, plant height, panicle length and panicle weight. On the other hand, higher number of unproductive tillers and straw weight were observed in the variety Bg 94-1. Further, AT 362 displayed significantly higher harvest index (0.54) than Bg 94-1 (0.47) (Figure 1).

Table 5. Varietal differences in growth characteristics

Characteristics	AT 362	Bg 94-1	p value
Productive tillers (No)	85±11.7	79±5.1	p>0.05
Unproductive tillers (No)	4.0±1.5	18±5.0	p>0.05
Plant height (cm)	64.3±1.7	56.6±1.3	p<0.05*

Values are means with ± standard error of mean

Table 2. Varietal differences in straw and panicle characteristics

Characteristics	AT 362	Bg 94-1	p value
Panicle length (cm)	19±0.4	17.9±0.5	p>0.05
Panicle weight (g/m^2)	291.4±31.4	232.3±15.6	p<0.05*
Straw weight (g/m^2)	251.3±27.7	263.8±25.4	p>0.05

Values are means with ± standard error of mean

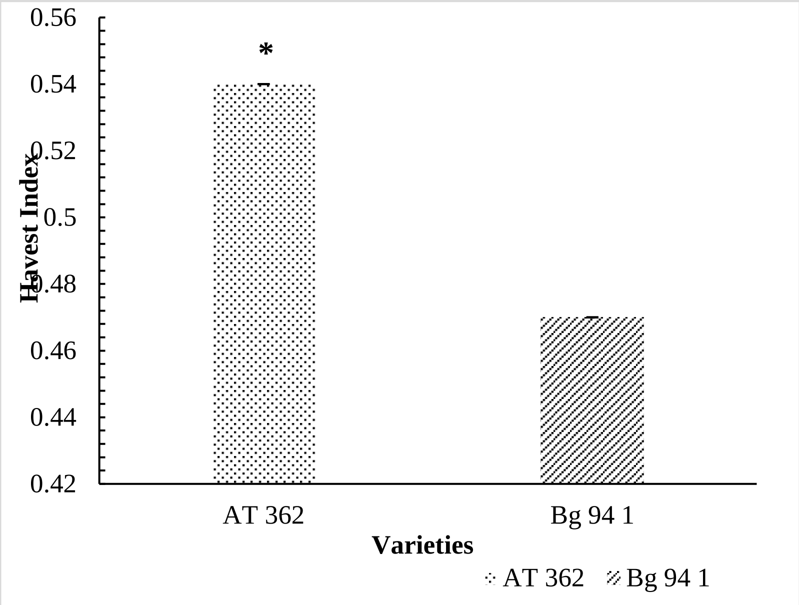

Figure 7: Comparison of Harvest Index between Varieties

Results pertaining to stomatal conductance is shown in Figure 2 and it reveals that the variety Bg 94-1 had higher stomatal conductance during pre-anthesis as well as post anthesis than the variety AT 362. But the magnitude of stomatal conductance was found to decrease during post anthesis in both varieties which showed significant difference among them.

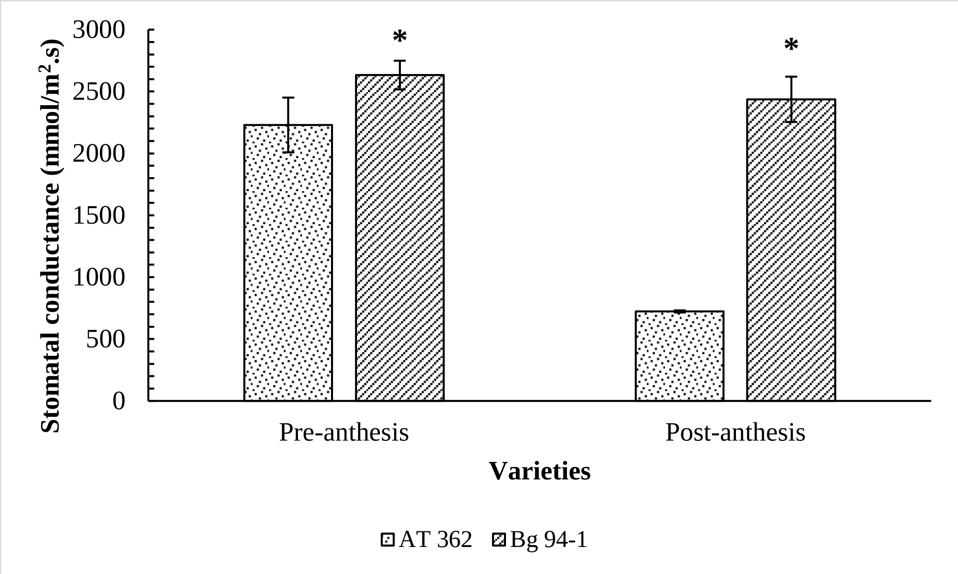

Figure 2. Variation in stomatal conductance among varieties over the growth stage

For correlation analysis, panicle weight and rest of the evaluated characteristics were considered as dependent and independent variables respectively. Results revealed that panicle weight was strongly and positively correlated (r = 0.999) with parameters of stomatal conductance, productive tillers, unproductive tillers, panicle length, plant height and AGDM. The value of R^2 (0.998) indicates that about 99.8% variation in panicle weight could be explained by the variation in yield attributing characteristics. Further, linear regression for AGDM and stomatal conductance showed positive correlations ($p>0.05$) with value of r = 0.687. R^2 (0.473) indicates that about 47.3% variation in stomatal conductance could be explained by the variation in AGDM.

4. DISCUSSION

Photosynthesis is the key physiological process occurs in plants that ultimately determines biomass and final marketable yield of a variety. This process is considerably influenced by morphological, reproductive, genetic characteristics of plants and adopted cultural practices. Varieties tested in the study exhibited significant variations for growth characteristics. The variation observed in varieties might be due to different genetic makeup. Varietal differences in rice for panicle length, productive tillers, panicle and grain weight were reported by several researchers (Ashraf *et al*., 1999; Chowdhury *et al.,* and Idris and Matin, 1990). Of various characteristics, number of productive tillers and panicle length receive more attention on improving yield of rice. Increased number of productive tillers per unit area may have helped in increasing the photosynthetic area for plant. Higher panicle weight obtained in variety AT 362 may be attributed to its growth characteristics of higher number of productive tillers and panicle length. Findings of the study is supported by Behera (1998) who stated that increasing panicle length and the number of fertile spikelets per panicle might have increased grain yield of rice.

Stomatal conductance, a measure of the degree of stomatal opening which is influenced by several environmental factors such as wind speed, temperature and relative humidity thus allows gas exchange between cell and atmosphere and it is used as an indicator of photosynthesis. Significant variation observed in varieties might be due to genotypical differences of improved rice varieties for stomatal aperture in terms of number, length, breadth etc. Ohsumi *et al* (2007) reported the variation in stomatal conductance in 64 accessions of rice germplasm and three high yielding cultivars in which high yielding cultivars had higher stomatal conductance (0.55 $molm^{-2}s^{-1}$) than land races (0.46 $molm^{-2}s^{-1}$). However, with the time throughout the reproductive period, both varieties showed significant decreased in stomatal conductance and it might be due to the climatic condition prevails (Kusumi *et al*., 2012; Willmer and Fricker, 1996).

Under favourable conditions photosynthetic capacity of plants are expected to increase with the increase in stomatal conductance as it enhances gas exchange. Findings of our study was opposite to this phenomena and higher yield was not obtained by the variety Bg 94-1 which had higher stomatal conductance. This might be suspected to a genetic characteristic of particular variety; poor sink source relationship which means translocation of photosynthates is limited by lower sink capacity of grains (small size grains). Ahmadi et *al*., (2009) revealed that source and sink manipulation might be regulated by plant physiological processes such as net photosynthesis and features as stomatal conductance and minimizing transpiration rate. However, the direction and magnitude of the regulation varies with time and cultivar. The grain growth of rice mainly depends on formation, translocation, partitioning and accumulation of photosynthates during the grain filling. Therefore, both photosynthetic activity of leaves (source) and storage ability of grains after anthesis (sink) are the causal factors limiting the grain yield. Conversely, lower grain weight in Bg 94-1 may be due to smaller spikelet size and majority of photosynthates might retained in other vegetative parts of rice like straw, culm that resulted higher straw weight in Bg 94-1 (Table 2).

On the other hand, yield reduction on variety Bg 94-1 might be attributed to stress caused by higher transpiration rate associated to higher stomatal conductance during vegetative, flowering and grain filling stages. The reduction in leaf water potential adversely affects the reproductive growth and canopy expansion, leading to significant yield loss. Also, if the plants keep open the stomata during night too, it leads to depletion of assimilated photosynthates via increased maintenance and dark respiration thus give lower yield. Findings of the study are also agreement with Anjun et *al*., (2011) who stated that water stress adversely affects plant physiological performance through reduction in gas exchange in particular stomatal conductance, photosynthetic pigments and overall crop water relations.

From the findings of stomatal conductance, it is evident that higher yield of variety AT 362 is not due to stomatal opening alone but it is due to some other yield contributing components. And therefore, to know what are the characteristics have impact on yield, regression and correlation analysis were performed. As panicle weight shows positive correlation with growth and physiological characteristics leads to lager amount grain weight per unit area. Finding of the study was supported by Gunasekaran et *al*. (2010) and Osman et *al*. (2012) who stated that the tiller number is the most important morphological character in rice which determines the panicle number, and plays a vital role in grain yield. Further, Sabesan *et al*. (2009) also reported that the grain yield is positively associated with plant height and productive tillers per plant.

5. CONCLUSIONS

Regardless of crop, yield is one of the more promising characteristics during selection of variety for commercial cultivation. Cultivated varieties vary in growth and physiology due to environmental and genetical factors thus ultimately result in either high or low yield. The tested varieties that are generally cultivated throughout Sri Lanka (AT 362 and Bg 94-1), showed variation for most of the growth and physiological characteristics. Thereby, above ground biomass and crop yield could be improved further by altering stomatal properties and ultimately impact the photosynthetic capacity. Moreover it suggested that variety AT 362 is advised to cultivate as far as considering increased grain yield and nutritional beneficial of this particular variety. Since this study is only confined to know the influence of stomatal conductance on photosynthetic capacity, it derives the opportunities for future studies to evaluate the relationship between stomatal properties and other physiological processes like respiration.

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