Evaluation of root morphology of selected rice varieties under anaerobic and aerobic conditions in Sri Lanka

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Keywords: Aerobic condition, anaerobic condition, *Oryza sativa L.*, root morphology.

Introduction

Rice (*Oryza sativa* L.) is the staple food in Sri Lanka. With the increasing population and the changing climatic conditions, there is a need to grow rice with increased yielding potential and tolerance to several biotic and abiotic stresses. Around 99 % of the total paddy production area of the country is cultivated with newly improved varieties, while the remaining area is adopted with low-yielding traditional rice varieties [1]. Since rice is a semi-aquatic plant, it is usually grown under anaerobic conditions as long as water is available. According to recent studies, the annual mean rainfall in Sri Lanka has decreased throughout the country. In 2013, about 35 % of rain-fed rice farmers in Dry and Intermediate zones had given up their cultivation during the *Yala* season compared to the *Maha*, primarily due to insufficient water availability [2]. Further, the rice production of *Yala* 2019 had decreased approximately by 1.5 million metric tons than *Yala* 2018 season, owing to the drought situation and pest damages experienced in the primary rice-producing districts [3].

The root architecture critically influences the yield of the crops, and improved root characteristics help farmers grow crops tolerant to multiple stresses and with high yield. There is an urgent need to identify and develop drought stress adaptable rice genotypes for rain-fed and drought-prone areas. Therefore, the objectives of this study were to screen three locally available rice varieties for their root morphology under aerobic and anaerobic conditions and to identify best-performing varieties with improved root traits to withstand drought.

Methodology

The experiment was carried out at Rice Research Station, Labuduwa, Sri Lanka (6^o 04'N and 80^o 22'E; altitude 17 m above sea level) located at low country wet zone (WL_3) during the period from October to February 2021 in *Maha* season. Fields were established in two methods *viz*; anaerobic and aerobic condition and selected areas were divided into three blocks each comprised of 6.7 m × 7 m were arranged in Randomized Complete Block Design (RCBD) having three replicates. Subsequently, three best-performing varieties recommended for the low country wet zone (BW367, Ld253, and Bw272-6B) were used. Initially, rice seedlings were established in nursery beds prepared according to Department of Agriculture (DOA) recommendations on 11th November 2020, allowing four weeks, then field transplanting was done on 9th December 2020. Subsequently, DOA recommended management practices were performed throughout the growing season. Then data on root morphology were collected 60 days after field planting from randomly selected five plants in each replicate. Here, the number of roots, length (cm), width (cm), and eventually calculated volume (cm^3) by employing displacement techniques [4]. Finally, root dry weight (g) was measured after the oven-dried samples at 80 ^{o}C at the constant weight. Then the collected data of each parameter mentioned here were met the assumption of constant variance and normal distribution of residuals. Then tested their significant differences by employing SPSS statistical software version 26. The hypothesis was tested using one-way

ANOVA with Tukey's post-hoc test at a 5% significant level.

Results and Discussion

The anaerobic field trials revealed that significant differences were observed in rice root length, width, volume and the number of roots ($P<0.05$). In contrast, no significant difference was observed in root dry weight produced per plant irrespective of the treatment (Table 1). Variety Ld253 recorded the highest root length (18.9 cm) than the tested counterparts ($P<0.05$), while Bw367 had the highest root width (5.6 cm). Both of these varieties had conferred with an increased number of roots in Ld253 (114 plant^{-1}) and Bw367 (113 plant^{-1}), respectively. The Bw367 featured significantly increased root volume (71.6 cm^3 plant^{-1}) than the tested counterparts. On the contrary, variety Bw272-6B recorded the lowest for the above root morphological traits. A lengthier and thick root system with a higher number of roots contributes to the rice plant in accessing water and nutrients from deeper layers of soil column [5]. Based on the overall performances Bw367 and Ld253 performed well in terms of rice root morphology under anaerobic conditions.

The aerobic trial revealed that the rice varieties showed significant differences in the number of roots and root volume. Here, variety Ld253 attributed with the highest number of roots (70.5 plant^{-1}) and root volume (30 cm^3 plant^{-1}) while Bw272-6B had displayed the lowest (49.4 and 17.2 cm^{3,} respectively) (Table 2). However, considering the effects, there were no significant variations in root dry matter in both trials irrespective of treatments, speculating that the dry matter partitioning for roots among these varieties seems equal, indicating that the root morphology might adjust according to genetic characteristics to optimize the water and nutrient uptake from the soil.

Table 1. The performance of root characteristics of three rice varieties under anaerobic conditions. The values are means ± standard error (SE); Within a column, means with the same letter are not significantly different at p = 0.05.

Varieties	Root length (cm)	Root width (cm)	Number of roots	Root volume (cm^3)	Root dry weight/plant (g)
Bw367	15.3 ± 0.4^a	5.6 ± 0.5^b	113.3 ± 4.6^b	71.6 ± 8.6^b	2.4 ± 0.5^a
Bw272-6B	16.8 ± 0.3^{ab}	3.7 ± 0.4^a	75.3 ± 3.3^a	20.2 ± 0.8^a	6.9 ± 1.8^a
Ld253	18.9 ± 0.9^b	3.3 ± 0.0^a	113.7 ± 4.2^b	40.5 ± 4.1^a	3.9 ± 0.6^a
P value	*0.015*	*0.010*	*0.001*	*0.002*	0.079

Table 2. The performance of root characteristics of three rice varieties under aerobic conditions. The values are means ± standard error (SE); Within a column, means with the same letter are not significantly different at p = 0.05.

Varieties	Root length (cm)	Root width (cm)	Number of roots	Root volume (cm^3)	Root dry weight/plant (g)
Bw367	11.7 ± 1.6^a	2.3 ± 0.3^a	50.1 ± 6.4^a	23.1 ± 1.9^{ab}	2.6 ± 0.6^a
Bw272-6B	11.1 ± 0.7^a	2.4 ± 0.3^a	49.4 ± 1.1^a	17.2 ± 2.5^a	1.7 ± 0.3^a
Ld253	12.0 ± 1.3^a	2.6 ± 0.2^a	70.5 ± 6.0^b	30.0 ± 2.2^b	2.7 ± 0.6^a
P value	0.869	0.852	*0.043*	*0.019*	0.404

A recent study found that rice varieties with higher root volume exhibit the drought tolerance in upland conditions [6]. Therefore, the present study revealed that rice variety Ld253 could perform well under aerobic and anaerobic conditions compared to other rice varieties.

Conclusion

Proper understanding of root morphology is important for developing new rice varieties that can sustain moisture stress in fields. Our analysis found that the local variety Bw367 performed well in terms of root morphological traits under anaerobic conditions, whereas Ld253 responded well under both aerobic and anaerobic conditions. Further, both varieties can be proposed for advanced plant breeding programs, prioritizing the gene exploration related to root morphology.

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