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Screening for Osmotic Stress Responses in Rice Varieties under Drought Condition

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Abstract: Drought is the major abiotic stress factor that limits rice production worldwide. To evaluate the osmotic stress responses in rice varieties under drought condition, a total of 42 high-yielding rice varieties were collected from various research stations of Kerala Agricultural University in India. The experimental setup comprises of initial hydroponic treatments at different osmotic potentials, artificially induced by desired strengths of polyethylene glycol (PEG6000), and followed by the pot planted experiments in the rain-out-zone. The activities of antioxidant enzymes, relative water content, cell membrane stability, photosynthetic pigments, proline content, along with plant growth parameters of the varieties under drought condition were evaluated. Moreover, the standard scores of these rice varieties were assessed under stress and recovery conditions based on the scoring scale of the Standard Evaluation System for rice. Among the 42 rice varieties, we identified 2 rice varieties, Swarnaprabha and Kattamodan, with less leaf rolling, better drought recovery ability as well as relative water content, increased membrane stability index, osmolyte accumulation, and antioxidant enzyme activities pointed towards their degree of tolerance to drought stress. The positive adaptive responses of these rice varieties towards drought stress can be used in the genetic improvement of rice drought resistance breeding program.

Key words: drought resistance; rice; antioxidant enzyme; osmolyte; relative water content

Rice (*Oryza sativa* L.) is the predominant staple food in at least 33 developing countries, providing 27% of dietary energy supply, 20% of dietary protein and 3% of dietary fat (Kennady et al, 2002). It is estimated that the world needs to produce 40% more rice to feed the population by 2025 (FAO, 2002). And it is the major abiotic stress factor that limits rice production worldwide. Drought is particularly more frequent in South and Southeast Asia and Sub-Saharan Africa. India faced severe drought in 2002 and 2009, which ultimately caused a drastic reduction in rice production. In 2002, the total rice production was declined by 21.50 million tons due to drought, whereas, in 2009, rice production was declined by approximately 10.02 million tons (Directorate of Economics Statistics, 2009; Vikram et al, 2011). The ongoing climatic change process is likely to further worsen the scenario in these rice growing areas (Swamy et al, 2012). With erratic rainfall patterns and constant climatic anomaly exhibited in India, especially in Kerala, the identification of more stable and drought resistant rice varieties are of high importance.

Responses to environmental stress in plants are complex and multigenic, and the functions of many induced genes are still a matter of conjuncture (Bray, 2002). Because of this complexity, selection and breeding of drought-tolerant varieties are extremely difficult (Anami et al, 2009; Tirado and Cotter, 2010). To counteract the adverse effect of environmental insults, plants have evolved efficient defense

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mechanisms by manipulating their tolerance potential through integrated molecular and cellular responses (Gill et al, 2016).

For effective selection of high-yielding rice varieties under drought stress, it is necessary to do a proper drought screening, which clearly distinguishes high-yielding but drought-susceptible lines from drought-tolerant lines (Swamy et al, 2012). In general, in the uplands, drought appears in severe form in 7–10 d after withdrawing irrigation, whereas in the lowlands, it takes 18–21 d, and the drought severity in a drought screening should be very close to the drought situation prevailing in that ecological zone (Swamy et al, 2012). According to Hossain (1995), the concept in the current scenario of rice research should change from 'thinking globally and acting globally' to 'thinking locally but acting globally' to address the problems of the unfavorable rice ecosystems. In Kerala, consumers prefer red kernelled type rice varieties, so the special interest of the study is towards the varietal improvement in those varieties. Thus, the aim of the present study was to characterize the rice varieties in Kerala under drought stress condition and to select the best drought resistant donor for the future drought tolerance breeding program.

MATERIALS AND METHODS

Rice materials

A total of 42 high-yielding rice varieties (Table 1) collected from various research stations of Kerala Agricultural University in India were screened, with the drought-tolerant variety Sahbhagi Dhan as the tolerant check (CRRI, 2009–2010) and the high-yielding variety Jyothi as the susceptible check (KAU, 2011).

Experimental design for hydroponic drought treatment

To carry out hydroponic screening for drought tolerance, the dormancy broken viable seeds were imbibed in water for overnight, followed by the surface sterilization using fungicides. The intact seeds were thus incubated at 28 ºC for 48 h to get germination. The germinated seeds were placed in the fabricating seedling float (of acrylic make) with a nylon mesh. These floats with holes to hold each seedling were kept in plastic tubs containing Yoshida nutrient medium. The seedlings of each line were arranged in two sets of floats (one for stress treatment and the other for control). The seedlings in this setup were kept in water at 28 ºC for 3 d. On the 4th day, the seedlings were transferred to grow in Yoshida's nutrient medium solution and grown under open greenhouse conditions for 3 d. Under hydroponic screening, water-deficit stress is artificially induced by desired strengths of polyethylene glycol (PEG), a high molecular weight, non-penetrating inert osmotic substance. The applications of nutrient hydroponic solution were done with a progressive pattern. Under treatments, the plants were grown primarily in half strength Yoshida's nutrient medium solution, containing 15% PEG6000 with osmotic potential (OP) of -2.35 to -2.95 MPa for 5 d at (28 ± 2) ºC. Consequently, the stress level was increased by substituting 15% with 20% PEG6000 at

Table 1. Varieties used in this study.

Variety	Origin	Variety	Origin	Variety	Origin
Sahbhagi Dhan (CK)	IRRI, the Philippines	Revathy	RARS, India	Mattathriveni	RARS, India
Jyothi (CK)	RARS, India	Karishma	RARS, India	Samyuktha	RARS, India
Bhadra	RARS, India	Krishnannjana	RARS, India	Bhagya	RARS, India
Asha	RARS, India	Gouri	RARS, India	Onam	RARS, India
Pavizham	RARS, India	Prathyasa	RARS, India	Sagara	RARS, India
Karthika	RARS, India	Parambuvattan	RARS, India	VTL1	RRS, India
Aruna	RARS, India	Kattamodan	RARS, India	VTL2	RRS, India
Makam	RARS, India	Karuthammodan	RARS, India	VTL3	RRS, India
Remya	RARS, India	Chuvannamodan	RARS, India	VTL4	RRS, India
Kanakam	RARS, India	Swarnaprabha	RARS, India	VTL5R	RRS, India
Renjini	RARS, India	Neeraja	RARS, India	VTL5W	RRS, India
Pavithra	RARS, India	Kanchana	RARS, India	VTL6	RRS, India
Panchami	RARS, India	Aiswarya	RARS, India	VTL7	RRS, India
Remanika	RARS, India	Harsha	RARS, India	VTL8	RRS, India
Uma	RARS, India	Vaishakh	RARS, India		

IRRI, International Rice Research Institute; RARS, Regional Agricultural Research Station, Kerala Agricultural University; RRS, Rice Research Station, Kerala Agricultural University.