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Utilizing chromosome segment substitution lines (CSSLs) to evaluate developmental plasticity of root systems in hardpan penetration and deep rooting triggered by soil moisture fluctuations in rice

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Abstract

Water availability in rainfed lowlands (RFL) is strongly affected by climate change. In RFL, rice plants are exposed to soil moisture fluctuations (SMF) but rarely to simple progressive drought as widely believed. Typical RFL field is characterized by a about 5-cm thick high bulk density hardpan layer underneath the cultivated layer at about 20 cm depth that impedes deep root development. Root system has the ability to develop in response to changes in SMF, known as phenotypic plasticity. We hypothesized that genotypes that can adapt to RFL have root plasticity. The roots can sharply respond to re-wetting after drought period and thus penetrate the hardpan layer when the hardpan is wet and so becomes relatively soft, and thus access water under the hardpan. This study aimed to identify CSSLs derived from a cross between Sasanishiki and Habataki which adapted to such RFL conditions. We used 39 CSSLs together with the parent Sasanishiki, which were grown in hydroponics and pot under transient soil moisture stresses (drought and then rewatering), and compared with continuously well-watered (WW) (control) up to 14 days after sowing (DAS), and 20 DAS, respectively. Based on the results of hydroponics and pot experiments, we selected a few lines, which were grown in the soil-filled rootbox with artificial hardpan layer and without artificial hardpan. For the rootbox without artificial hardpan, plants were grown under WW and transient soil moisture stresses for 49 DAS. While the rootbox with artificial hardpan, the plants were grown under WW (control) and SMF (WW up to 21 DAS, 1st drought (22-36 DAS), rewatering (37-44 DAS), and followed by 2nd drought (45-58 DAS)). Among the 39 CSSLs, only CSSL439 (SL39) consistently showed significantly higher shoot dry weight (SDW) than Sasanishiki under transient soil moisture stress conditions as well as SMF conditions in all the experiments. Furthermore, under WW, SL39 consistently showed no significant differences from Sasanishiki in shoot and root growth in most of traits examined. SL39 showed significantly greater total root length (TRL) than Sasanishiki under transient soil moisture stress, which is considered as phenotypic plasticity in response to rewatering after drought period. Such plastic root development was the key trait that effectively contributed to root elongation and branching during the rewatering period and consequently enhanced the root to penetrate hardpan layer when the soil penetration resistance at hardpan layer reduced. In addition, using the rootbox with artificial hardpan layer (1.7 g cm^{-3}, heavily compacted), SL39 showed greater root system development than Sasanishiki under SMF, which was expressed in its significantly higher TRL, total nodal RL, and total lateral RL at hardpan layer as well as at below the hardpan layer. These results prove that SL39 has plasticity that enables its root systems to penetrate hardpan layer in response to rewatering. Under SMF, such root plasticity contributed to its higher *gs* and *Pn*.

Keywords: Rice, soil moisture fluctuations, hardpan penetration, deep root development

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