Contribution of developmental responses of root system of a rice chromosome segment substitution line to water uptake and shoot dry matter production under transient waterlogged to progressive drying soil conditions

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Introduction

We previously showed that an aerobic rice genotype exhibited greater root system development based on lateral root production than irrigated lowland genotypes under transient stagnant to drought condition in hydroponics due to its faster seminal root elongation, higher branching of lateral roots on the seminal root axis, and greater nodal root production (Suralta et al, 2008). The importance of these traits was reconfirmed under the same transient moisture stress conditions using the selected chromosome segment substitution lines (CSSL) derived from Nipponbare and Kasalath crosses (Suralta et al., 2006). The selected CSSL47 was identified as highly homozygous to Nipponbare in plant growth under non-stressed conditions, but exhibited greater root system development compared with Nipponbare under the transient condition, which however did not result in higher shoot dry matter production (Suralta et al., 2006). Plastic root response of CSSL47 was unique only under transient moisture stresses but not under drought stress (Kanou et al., 2007). We hypothesized that such plastic root responses can be also clearly expressed under soil condition and could contribute to shoot growth with longer duration of transient moisture stresses. This study therefore aimed to examine and confirm plastic developmental responses of root system of a selected CSSL47 to longer duration of transient waterlogged to progressively drying soil conditions and compare with those of Nipponbare to analyze the contribution of such root responses to water uptake and dry matter production.

Materials and methods

The seedlings of CSSL47 and recurrent parent Nipponbare were grown in PVC boxes (40cm x 25 cm x 2 cm) filled with sandy loam soil for 38 days; the first 14 days under initial waterlogged conditions, then either continuously waterlogged or transferred to progressive soil drying for another 24 days. Under the progressive soil drying condition, the soil was allowed to dry and maintained at 30, 25 and 20% soil moisture content (SMC). Two samplings were done; at 14 days after initial waterlogging and at 38 days after progressive soil drying. Plant growth and water use was regularly recorded. Before and after imposition of progressive soil drying, transpiration and photosynthesis were measured. The experiment was laid out in a completely randomized design with 3 replications.

Results and discussion

Under continuously waterlogged condition, shoot dry weight, total root length, photosynthesis, transpiration, water use and water use efficiency were not significantly different between CSSL47 and Nipponbare (Figs. 1-3) indicating high similarity of their genetic control for those traits under the condition. After initial waterlogging, progressive soil drying at higher constant SMC (30%) did not induce significant differences between genotypes in any of the above traits. However, at lower constant SMC of 25 and 20%, CSSL47 showed significantly higher shoot dry weight than Nipponbare by 35 and 20%, respectively (Fig. 1). The total root length of CSSL47 was also significantly higher by 25% than Nipponbare at both 25 and 20% constant SMC (Fig. 1). Leaf photosynthesis and transpiration in CSSL47 were also significantly higher than in Nipponbare during progressive soil drying with 25 and 20% constant SMC (Fig. 2). Furthermore, under progressive soil drying period, water use of CSSL47 was significantly higher by 35 and 25% than Nipponbare at 25 and 20% constant SMC, respectively (Fig. 3). In contrast, water use efficiency did not significantly differ between the two genotypes at any of the treatments (Fig. 3). Regression analysis showed that 67% of the variations in shoot dry weight under different soil moisture conditions were due to the variations in water use but not water use efficiency (Fig. 4). These facts confirmed earlier results of short-duration hydroponics and also indicate that the substituted chromosome segments from Kasalath into Nipponbare in CSSL47 brought about promoted root growth under transient waterlogged to progressive drying soil condition, which enhanced water uptake, thus sustaining higher photosynthesis for continued plant growth particularly at lower levels of soil moisture.
Fig. 1. Shoot dry weight and total root length of CSSL47 (■) and Nipponbare (□) grown under continuously waterlogged (CWL) and progressive soil drying with different constant SMC. ns: not significant; **: significantly different at P<0.01 between genotypes under each soil moisture level.

Fig. 2. Leaf photosynthesis and transpiration of CSSL47 (■) and Nipponbare (□) grown under continuously waterlogged (CWL) and progressive soil drying with different constant SMC. ns: not significant; ** and *: significantly different at P<0.01 and P<0.05, respectively, between genotypes under each soil moisture level.

Fig. 3. Water use and water use efficiency of CSSL47 (■) and Nipponbare (□) grown under continuously waterlogged (CWL) and progressive soil drying with different constant SMC. ns: not significant; ** and *: significantly different at P<0.01 and P<0.05, respectively, between genotypes under each soil moisture level.

Fig. 4. Regression analysis on the relationship of water use and water use efficiency with shoot dry weight of CSSL47 (■) and Nipponbare (□). ns: not significant; **: significant at P<0.05.


Acknowledgment: CSSL seeds were provided by Rice Genome Research Center, National Institute of Agrobiological Sciences, Tsukuba, Japan.