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GROWTH AND WATER RELATIONS OF ROSELLE GROWN ON BRIS SOIL UNDER PARTIAL ROOT ZONE DRYING

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ABSTRACT

Twenty-four roselle plants were grown on BRIS soil in a greenhouse to evaluate the effects of partial rootzone drying (PRD) technique on the growth, water relation and its quality. PRD is one of the deficit irrigation methods applied in order to face global water scarcity by alternating left and right roots to be irrigated within certain period of time. Four treatments were compared *viz*. i) Control (100% full irrigation, CI), ii) 20% PRD (80% irrigation), iii) 40% PRD (60% irrigation) and iv) 60% PRD (40% irrigation) with three replications. No significant differences were recorded for volumetric soil water content (θ) of the roselle plants under different PRD treatments throughout 84 days experimental period. Plants subjected to 60% PRD showed a significant reduction in stem water potential (Ψ_{stem}) as compared to control plants on Day 56. While all plants subjected to PRD experienced mild water stress, they suffered no serious damaging effects in terms of calyx fresh weight, calyx number or total anthocyanins as compared to control plants. In fact, plants in the 20% PRD treatment tended to have higher total anthocyanins than control plants, resulting in better postharvest quality. This study shows that it is possible to reduce 20% irrigation water without serious adverse effects on the growth, yield, and postharvest quality of roselle.

Key words: PRD, postharvest quality, *Hibiscus sabdariffa* L., water potential

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is cultivated for its succulent calyces, leaves, and young shoots which are eaten either raw or as cooked vegetables. The red colour of the roselle calyx is determined by the type and concentration of vacuole-based phenolic compounds, mainly anthocyanins, which have been reported to reduce chronic diseases including cancers, cardiovascular diseases, asthma, and type II diabetes (Boyer and Liu, 2004). The anthocyanins are very strong antioxidants; they act as anti-oxidative, anti-mutagenic, anti-microbial and anti-carcinogenic agents (Awad *et al*., 2000). Several studies have revealed that water deficit in fruit crops consistently increased anthocyanin concentration without affecting other fruit quality attributes (Wan Zaliha and Singh, 2010a; 2010b; Ojeda *et al*., 2000; Grimplet *et al*., 2007). Whether this also holds true for the red pigment in roselle calyx under water deficit conditions is hitherto unknown.

Roselle can be planted in most types of soils, including Beach Ridges Interspersed with Swales (BRIS) soil. This is a widely known problematic soil containing 82 to 99% sand particles. The soil has a low cation exchange capacity (CEC) of 9.53 mq/100 g with a pH of 4.3 to 4.4 (Chen, 1985), has low water-holding capacity, and is poor in nutrients (Shamshuddin, 1990). Thus, it is useful to determine how much water is sufficient for roselle plants growing on BRIS soil without their growth, yield, and postharvest performance being affected. Considering that the demand for the earth's finite water supply is increasing worldwide, parsimonious irrigation management systems that remain effective would contribute to the conservation of water. Therefore, there is an urgent need to identify and adopt effective irrigation management series for roselle planted on BRIS soil.

The partial root drying technique (PRD) is a relatively new irrigation technique where water is applied to one half of the rootzone at each irrigation operation, while the other half is left to dry to a predetermined level of soil moisture. After a certain period of time the 'wet' and 'dry' zones are alternated, allowing the former 'wet' zone to dry while the 'dry' zone is irrigated (Dry *et al*., 2000). During PRD, the dehydrated rootzone is expected to stimulate the secretion of the root-to-shoot chemical signal, abscissic acid (ABA). Abscissic

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acid triggers the closing of stomata, which then reduces stomatal conductance, transpiration, shoot growth to maintain plant water potential. Water deficit management techniques such as PRD not only sustain many crops grown under irrigation constraints, but they can further improve the quality of various fruit crops (Wan Zaliha, 2009).

This study was aimed at evaluating the effects of PRD on the plant water relations, yield, and growth of the roselle plant on BRIS soils, and to evaluate the quality of the roselle calyces that were obtained.

MATERIALS AND METHODS

Twenty-four roselle plants of the variety Terengganu (UMKL-1) were grown in a greenhouse at the School of Science and Food Technology, Universiti Malaysia Terengganu. BRIS soil was supplied by the Department of Commodities Centre, Rhu Tapai, Setiu; roselle seeds were obtained from the Department of Agriculture, Kuala Berang, Terengganu. Twenty-four lysimeters were constructed from polyvinyl chloride (PVC) cylinders and set up on a wooden rack as described by Alias *et al*. (2013). All lysimeters were then divided into two parts using plastic cardboards placed vertically. Each lysimeter was filled with 30 kg BRIS soil into which two-week-old seedlings were then transferred. Other than irrigation water which varied with the experimental treatment, all the plants received similar cultural practices, including applications of fertilizers, pesticides, and fungicides.

The experiment was laid out following a Randomized Complete Block Design (RCBD) with four different regimes of irrigation: i) control (100%I, full irrigation), ii) 20% PRD (80% irrigation), iii) 40% PRD (60% irrigation), and iv) 60% PRD (40% irrigation) with three replications. Two plants represented one experimental unit. Drippers set to a flow rate of 8L·h were used for irrigation that was applied twice a day at 0830-0900 hours and 1630-1700 hours. The irrigation treatments were applied alternately (wet and dry) at 7-day intervals over 84 days after transplanting. The amount of irrigation for control was 2.15 L per day, applied based on evapotranspiration calculation: Etc=ETo x Kc; where ETc=crop evapotranspiration, ETo=reference crop evapotranspiration and Kc= crop coefficient. Average Kc was taken as 1.2 from a generalized Kc chart by Doorenbos & Pruitt (1977). Average ETo was 1.99 mm/day (Niazuddin, 2007). The ETo was calculated from Penman-Monteith equation according to Allen *et al*. (1998). The preharvest parameters were volumetric soil water content (θ), stem water potential (Ψ_{stem}), leaf area index (LAI), plant height, and stem diameter. Postharvest parameters were calyx fresh weight and total anthocyanin concentration (Wan Zaliha, 2009). The experimental data collected were subjected to an analysis of variance (ANOVA) using GLM (General Linear Models) procedures and further separated by LSD for least significance at $P \leq 0.05$ (SAS Institute Inc., 1999).

RESULTS AND DISCUSSION

Water stress has wide ranging effects on plant growth, anatomy, morphology, physiology, and biochemistry (Hsiao, 1973). In the present study, water-stressed roselle plants experienced mild to moderate water stress as shown in Fig. 1 and 2. The volumetric soil water content (θ) and stem water potential (Ψ_{stem}) fluctuated throughout the 84 days of the experiment. All the PRD treatments had Ψ_{stem} and θ readings generally similar to those of control plants. While Hsiao (1973) noted that PRD treatments tended to impose a mild stress on plants by lowering Ψ_{stem} to below 0.50 MPa, the readings in the present study were mainly between -0.10 MPa to -0.43 MPa throughout the 84 days of observation, with the exception of days 63 and 77 when readings reached -0.50 MPa and -0.57 MPa respectively. These fluctuations in Ψ_{stem} might be associated with the rainy season as the experiment was conducted in mid November 2012 until January 2013. Even though the experiment was conducted in the greenhouse, but the cold air surroundings might be affected the values of Ψ_{stem}. In addition, the decreasing Ψ_{stem} mainly for the 40% PRD and 60% PRD treatments might be attributed to the dry part of the rhizosphere which limited the plants' ability to meet the transpiration demand due to a lowering of root hydraulic conductivity and water deficit in the root zone (Lafolie *et al*., 1999).

No significant differences were found among the different irrigation regimes with respect to the leaf area index (LAI), growth performance (plant height and stem diameter) or the post-harvest quality of the flower calyces, although the 40% PRD and 60% PRD treatments resulted in lower mean LAI readings correlating with water shortage (Fig. 3, 4, 5 and 6). However, the 20% PRD treated plants tended to be more robust compared with plants in the other treatments (Fig. 4). Nur Razlin *et al*. (2013) reported no apparent deleterious effects on the growth of roselle plants cultivated on BRIS soil, a finding that is in agreement with that of Babatunde and Mofoke (2006). The fresh weight of the roselle calyces was affected by the imposed water deficit (Fig. 6 and 7), in agreement with similar observations by Babatunde and Mofoke (2006) and El-Boraie *et al*. (2009). However, in the present study, plants subjected to 20% PRD showed only an 18.54%

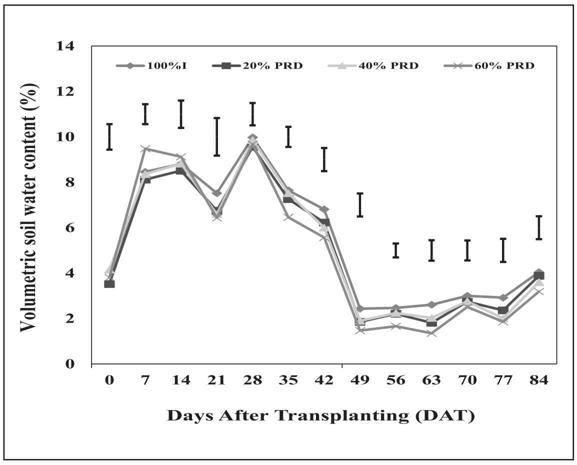

Fig. 1. Effects of PRD on the volumetric soil water content of roselle grown on BRIS soil. Vertical bars represent $LSD_{0.05}$.

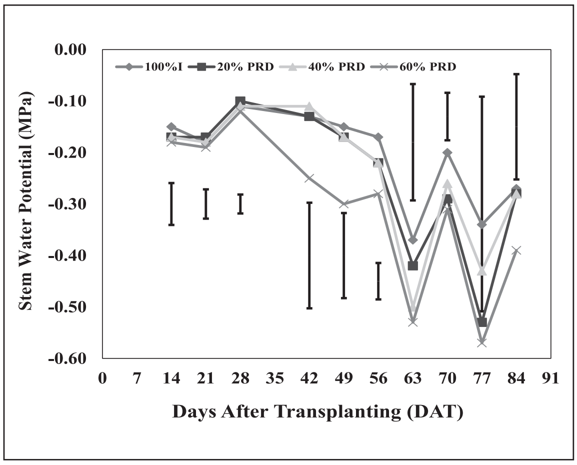

Fig. 2. Effects of PRD on the stem water potential of roselle grown on BRIS soil. Vertical bars represent $LSD_{0.05}$.

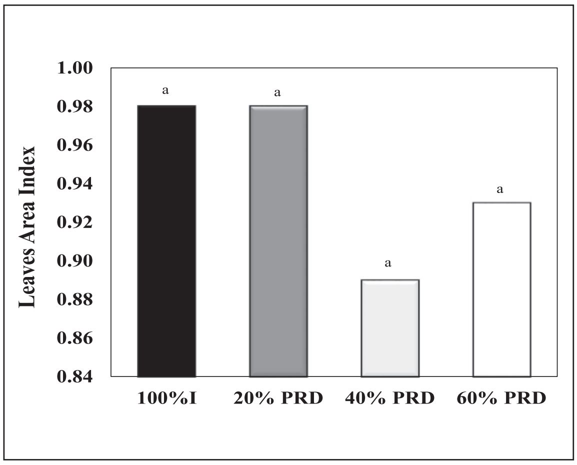

Fig. 3. Effects of PRD on the leaf area index of roselle grown on BRIS soil. Means with different letters are significantly different at the 5% level according to LSD test.

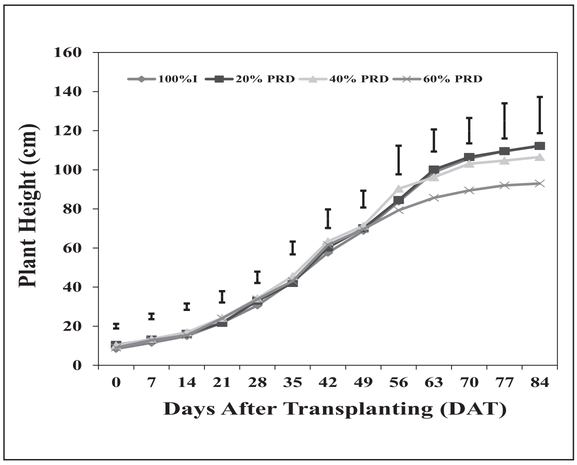

Fig. 4. Effects of PRD on the plant height of roselle grown on BRIS soil. Vertical bars represent $LSD_{0.05}$.

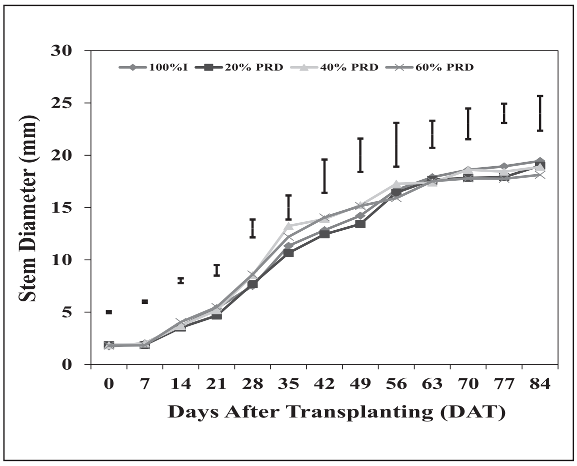

Fig. 5. Effects of PRD on the stem diameter of roselle grown on BRIS soil. Vertical bars represent $LSD_{0.05}$.

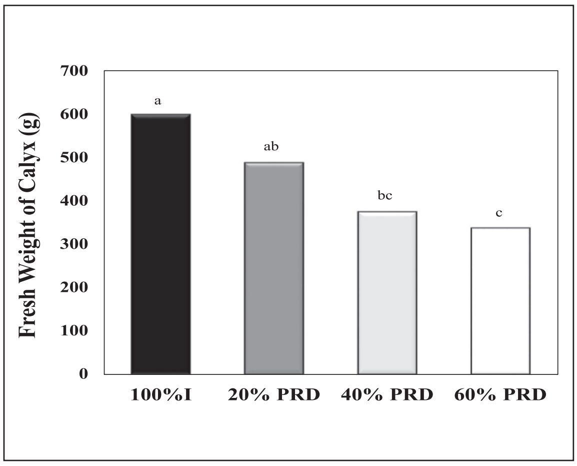

Fig. 6. Effects of PRD on the calyx fresh weight. Means with different letters are significantly different at the 5% level according to LSD test.

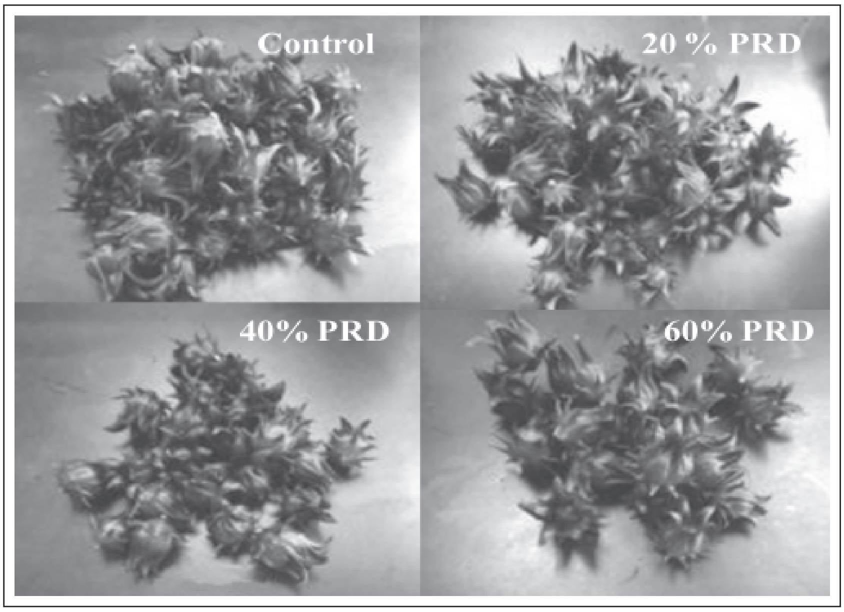

Fig. 7. Yield of roselle.

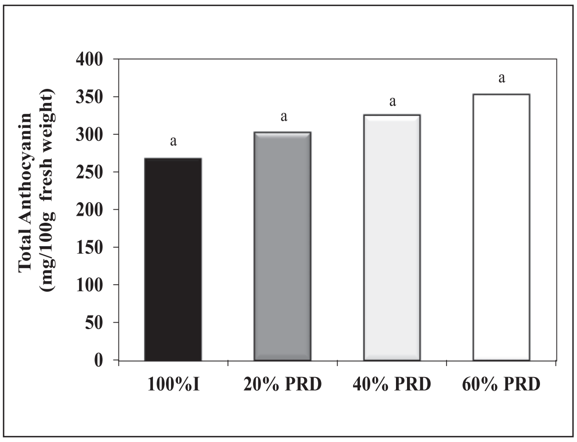

Fig. 8. Effects of PRD on the total anthocyanin of roselle grown on BRIS soil. Means with different letters are significantly different at the 5% level according to LSD test.

reduction in fresh weight from control, a difference that was not statistically significant. On the other hand, plants subjected to 60% PRD had the lowest fresh weight among all treatments. This was the result of water stress that triggered peroxidase activity, which in turn restricted calyx growth. In addition, the slight reduction observed in fruit size with water deficit treatments might be due to the limitation of photosynthetic resources (DeJong and Grossman, 1995) caused by water stress that had been aggravated by lower stomatal conductance (Naor, 1998).

Total anthocyanin concentration was not significantly affected by the PRD applied, but anthocyanin content in calyces from plants on the 60% PRD regime tended to be higher as compared to control plants (Fig. 8). The increase of anthocyanin concentration subjected to water deficit has also been reported for various fruit crops such as grape berry (Ojeda *et al*., 2000; Grimplet *et al*., 2007), olive (Tovar *et al*., 2002) and apple (Wan Zaliha, 2009; Wan Zaliha and Singh, 2010a, 2010b). Possibly, water-deficit imposed in red-skinned apple might similarly trigger the activity of enzymes and anthocyanin-specific genes in the anthocyanin biosynthetic pathway.

CONCLUSION

In conclusion, roselle plants grown on BRIS soil experienced mild to moderate water stress as reflected in various plant water relation parameters (stem water potential and volumetric soil water content). A reduction in 20% irrigation water (20% PRD, 19 m^3/ha or 1.72 L/tree/day) is a recommended option for roselle grown on BRIS soil as it increases water use efficiency and crop profitability without serious unfavourable effects on the growth, yield, and postharvest quality of the flower calyces.

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