Preliminary Assessment of ABA Concentration in Roots of Drip Irrigated Peach Trees

E. Xylogiannis[a], A. Sofo, G. Montanaro, A.N. Mininni and B. Dichio
DiCEM/SAFE – Università degli Studi della Basilicata
Potenza
Italy

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Abstract

Abscisic acid (ABA) is a phytohormone able to regulate the stomatal behaviour, transpiration and photosynthesis. ABA synthesis is usually associated to drought conditions. Based on the evidence that drip irrigation wets only 15-20% of soil surface and that ~80% is dry during summer, this study tests the hypothesis that in a well drip irrigated tree the ABA concentration in roots located in the inter-row (non-irrigated) is higher than that measured in roots under the emitter line (irrigated row).

Abscisic acid was determined by a competitive enzyme-linked immunosorbent assay in roots collected from a well irrigated tree (x 3) in summer at row and inter-row positions in a nectarine orchard grown in Southern Italy. Results show that leaf water potential was optimal (~0.3 MPa at pre-dawn). However, ABA concentration was 3.74 pmol g^{-1} FW in roots from inter-row while it was 2.58 pmol g^{-1} FW in that growing along the row. Possible effects of the increased ABA levels at a part of the root-zone on leaf gas exchanges are discussed.

INTRODUCTION

During the last decades, several irrigation methods have been proposed in order to reduce irrigation volume and optimise plant performance. Briefly, the "continuous or Sustained Deficit Irrigation" (SDI) method suggests that a constant fraction of the crop evapotranspiration (ET_C) would be supplied at regular intervals time throughout the season (Fereres and Soriano, 2007).

Plants under "Regulated Deficit Irrigation" (RDI) are usually well irrigated during the early part of the season and purposely drought-stressed at specific developmental stages (usually after harvest) when plants are believed to be less vulnerable to water deficit (Fereres and Soriano, 2007). In addition, with the "Partial Root zone Drying" (PRD) method, irrigation water is supplied only to half of the root-zone (Dry and Loveys, 1998). In this way, trees experience a certain degree of water stress and roots of the non-irrigated soil can produce chemical signals when soil dries which may influence canopy physiology (e.g., gas exchanges) (Davies and Zhang, 1991).

Abscisic acid (ABA), is a phytohormone synthesised by roots of trees facing drought, then it is translocated and accumulated in leaves where it is able to influence (reduce) stomatal conductance (g_s) and thus transpiration (E) (Kriedemann et al., 1972; Davies et al., 1994, 2000; Schachtman and Goodger, 2008).

Drip irrigated trees receiving 100% of ET_c usually are in optimal water condition despite irrigation is supplied only along the row where irrigation line sits (Dichio et al., 2011). However, during summer in well drip irrigated orchards, the soil moisture at the inter-row alley progressively dries reaching low water contents (close to the wilting point). Under these conditions, even if plant water status is optimal, it is hypothesised that in roots located at the inter-row (non-irrigated part of the soil) ABA concentration is higher than in those located at the row (irrigated part of the soil).

To test this hypothesis, in a drip irrigated nectarine orchard, roots from row and inter-row of well irrigated trees were sampled during summer for ABA determination.

[a] Corresponding author; E-mail: evangelos.xilogiannis@unibas.it.

MATERIALS AND METHODS

Plant Material and Experimental Site

The experiment took place at end-June 2012, in a 4-year old nectarine orchard (1.5 x 4 m, cv. 'Big Bang' grafted on GF677) grown in Metaponto (Southern Italy) (40°23'58.13"N, 16°45'43.50"E). The area has a typical Mediterranean climate with dry and warm summer and 400-500 mm of annual rainfall. Trees were drip irrigated (16 L h^{-1} per tree) at a 3-5 days interval time and irrigation volume was calculated according to reference evapotranspiration recorded by a local weather station. Crop coefficient was applied according to Dichio et al. (2007) and 100% of ETc was supplied. As usual, drip irrigation wets only the soil under the emitter line (i.e., approximately 15-20% total soil surface), while the rest ~80% is rain-fed. Average soil pH was 7.5 and the soil texture (upper 20 cm soil layer) was 70.6% sand, 16.2% loam and 13.1% clay.

Gas Exchanges, Leaf Water Potential and Soil Parameters

Leaf gas exchanges were measured in three plants using an open-flow portable system (LI-6400; Li-Cor Inc., NE, USA) equipped with a leaf chamber fluorometer operated at 500 µmol s^{-1} flow rate. The measurements of gas exchange were carried out at early morning (9:00-10:00 am) on mature leaves (five per plant). Soil temperature (0-15 cm depth) was measured on midday using the Li-Cor 6400-09 soil chamber equipped with the 6000-09TC Li-Cor temperature probe.

Midday leaf water potential measured on the same day (0:45-1:30 pm) using the Scholander pressure chamber (Scholander et al., 1965). For the stem water potential leaves were covered with aluminium for approximately one hour before the measurements.

Immediately after the gas exchanges measurements, soil samples (upper 20 cm soil layer) were taken from three plants at row and inter-row position to determine soil moisture (w:w%). Samples were immediately weighed (FW) and dried at 110°C for 48 h in a ventilated oven and weighed again (DW). The w:w% water content was calculated as 100×(FW-DW)/DW.

Root Sampling and ABA Determination

Simultaneously to soil sampling, roots (1.5-3 mm diameter) from row and inter-row positions were collected (0-20 cm depth) from three plants. Immediately, they were gently cleaned from the soil, enveloped in aluminum foil and promptly transported in a poly-styrene box covered with ice to the laboratory for storage at -80°C. Finally, ABA contents were calculated according to Sofo et al. (2011).

RESULTS AND DISCUSSION

Irrigation schedule was adequate to maintain the trees at optimal water status. Thus, pre-dawn leaf water potential was about -0.33 MPa while midday leaf water potential (LWP) was around -1.63 MPa. Early morning gas exchanges measurements further confirm that plants were well irrigated (Dichio et al., 2007). Transpiration was on average 3.5 mmol m^{-2} s^{-1}, photosynthesis (A) was ~9 µmol m^{-2} s^{-1} and g_s was ~ 0.14 mol s^{-1}. Soil moisture at the inter-row position was significantly ~40% lower than that measured under the emitter line (row position) (Fig. 1) being close to 4.9%. Correspondingly, higher midday soil temperature was observed at the inter-row position compared to the row one (Fig. 1).

Drought-induced increases in ABA concentrations have been recognised in leaves of peach trees from long time (Xiloyannis et al., 1980), while information on possible variability of ABA within the root system are still poor. In the present study, the concentration of ABA in roots varied depending on sampling position (row, inter-row) and soil parameters (moisture, temperature). According to our initial hypothesis, in roots sampled from the dried soil (inter-row) ABA concentration was 45% significantly higher (up to 3.74 pmol g^{-1} FW) than those located under the emitters (row) (Fig. 2). This result is difficult to discuss because existing information on this specific topic is very limited.

Plant hormones are responsible for the transformation of signals produced in dry conditions into changes in the expression of genes useful for the plant to adapt in hostile environments (Hare et al., 1997). Thus, it would be of high importance to understand in which parts of the plant ABA is mainly produced.

In this experiment, despite a roughly good plant water status (pre-dawn leaf water potential) values of g_s and in turn transpiration recorded may in some way be influenced by the elevated ABA concentration as reported by Davies et al. (2000). Hence, it could be hypothesised that under drip irrigation, even though trees are well irrigated, g_s and carbon gain (water use efficiency) is affected by ABA-related signals produced by the roots located at the non-irrigated inter-row. More investigation is required to test it.

Further research regarding the generation and pathway of a chemical signal in plants growing in dry soil would help to further improve our knowledge on tree physiological responses to a water-limited environment.

CONCLUSIONS

Our results prove that in drip irrigated trees root ABA concentration varies within the same root-zone according to soil moisture and temperature. Drip well irrigated trees are usually considered as non-stressed trees due to their optimal leaf water potential, however our data suggest that in these trees, an ABA increase could possibly affect gas exchange and g_s.

Consequently, the increase in ABA production in drought-stressed roots could allow plants to achieve a better compromise between stomatal closure, water loss by evapo-transpiration, and irrigation water saving, increasing orchard and plant water use efficiency (Davies et al., 2000).

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Literature Cited

Davies, W.J. and Zhang, J. 1991. Root signals and the regulation of growth and development of plants in drying soil. Annu. Rev. Plant Physiol. Plant Mol. Biol. 42:55-76.

Davies, W.J., Tardieu, F. and Trejo, C.L. 1994. How do chemical signals work in plants that grow in drying soil? Plant Physiol. 104(2):309-314.

Davies, W.J., Bacon, M.A., Thompson, D.S., Sobeih, W. and Rodríguez, L.G. 2000. Regulation of leaf and fruit growth in plants growing in drying soil: exploitation of the plants' chemical signalling system and hydraulic architecture to increase the efficiency of water use in agriculture. J Exp. Bot. 51(352):1949-1949.

Dichio, B., Xiloyannis, C., Sofo, A. and Montanaro, G. 2007. Effects of post-harvest regulated deficit irrigation on carbohydrate and nitrogen partitioning, yield quality and vegetative growth of peach trees. Plant and Soil 290:127-137.

Dichio, B., Montanaro, G. and Xiloyannis, C. 2011. Integration of the regulated deficit irrigation strategy in a sustainable orchard management system. Acta Hort. 889:221-226.

Dry, P.R. and Loveys, B.R. 1998. Factors influencing grapevine vigour and the potential for control with partial root zone drying. Aust. J. Grape Wine Res. 4:140-148.

Fereres, E. and Soriano, M.A. 2007. Deficit irrigation for reducing agricultural water use. Journal of Experimental Botany 58(2):147-159.

Hare, P.D., Cress, W.A. and Van Staden, J. 1997. The involvement of cytokinins in plant responses to environmental stress. Plant Growth Regulation 23:79-103.

Kriedemann, P.E., Loveys, B.R., Fuller, G.L. and Leopold, A.C. 1972. Abscisic acid and stomatal regulation. Plant Physiol. 49:842-47.

Loveys, B.R. and During, H. 1984. Diurnal changes in water relations and abscisic acid in field-grown *Vitis vinifera* cultivars. II. Abscisic acid changes under semi-arid conditions. New Phytol. 97:37-47.
Schachtman, D.P. and Goodger, J.Q.D. 2008. Chemical root to shoot signalling under drought. Trends in Plant Science 13(6):281-287.
Scholander, P.F., Hammel, H.T., Bradstreet, E.D. and Hemmingsen, E.A. 1965. Sap pressure in vascular plants. Science 148:339-346.
Sofo, A., Scopa, A., Manfra, M., De Nisco, M., Tenore, G., Troisi, J., Di Fiori, R. and Novellino, E. 2011. *Trichoderma harzianum* strain T-22 induces changes in phytohormone levels in cherry rootstocks (*Prunus cerasus* × *P. canescens*). Plant Growth Regulation 65:421-425.
Wallace, J.S. 2000. Increasing agricultural water use efficiency to meet future food production. Agriculture, Ecosystems and Environment 82:105-119.
Xiloyannis, C., Uriu, K. and Martin, G.C. 1980. Seasonal and diurnal variations in abscisic acid, water potential, and diffusive resistance in leaves from irrigated and non-irrigated peach trees. Journal of the American Society of Horticultural Science 105:412-415.

Figures

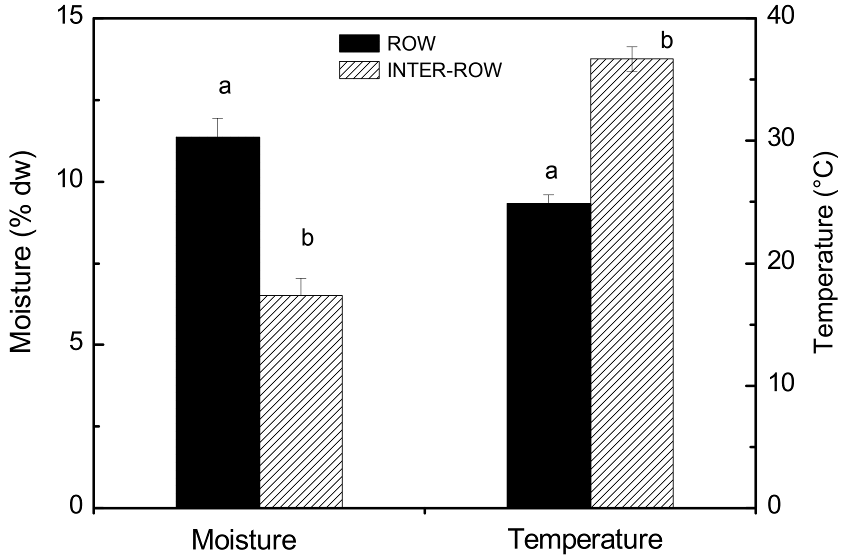

Fig. 1. Soil moisture (w:w%) and midday temperature (°C) measured at row and inter-row position of the drip irrigated peach orchard. Different letters indicate a statistically significant difference (*n*=3, P<0.05). Bars represent standard error.

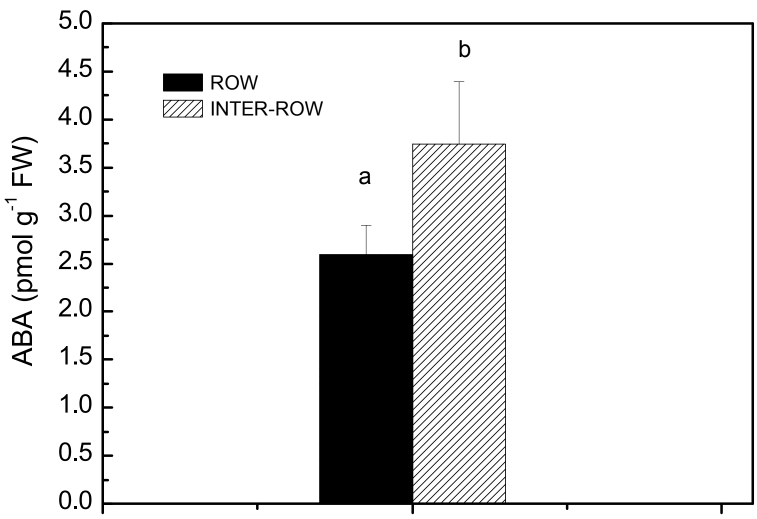

Fig. 2. ABA concentration (pmol g^{-1} fresh weight) detected in roots (20 cm soil depth) at the row and inter-row position in a drip irrigated nectarine orchard. Different letters indicate a statistically significant difference (*n*=3, P<0.05). Bars represent standard error.