PHYSIOLOGICAL RESPONSES OF CARROT SEEDLINGS EXPOSED TO DROUGHT

ABSTRACT #1.13

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INTRODUCTION

Drought is considered a meteorlogical and/or environmental event, defined somewhat loosely as the absence of precipitation for a period of time long enough to result in a depletion of soil moisture sufficient to damage plants. Drought is a recurring natural phenomenon, having drastic implications on agriculture. Despite scientific advancements to predict the onset and modify its impact, drought remains the single most dominant factor threatening world food security, and the condition and stability of the land resource from which food is derived (McWilliam, 1986).

The study of drought and drought tolerance has become a focus in agricultural research as a result of severe crop losses felt by farmers within the region, crippling the economy. Carrot crops, that occupy the second largest horticultural acreage in Nova Scotia, also experienced severe drought consecutively over the 1997-1999 seasons. Because the majority of Canadian carrot crops are primarily grown under rainfed conditions, drought is therefore considered a major environmental threat to production. Identifying the physiological mechanisms and adjustments in carrots under drought as well as the threshold water potential at which physiological dysfunction begins to occur, would provide an understanding and help in developing acclimation and/or adaptation strategies to protect this crop in the event of unexpected drought(s).

MATERIALS and METHODS

Oranza variety carrots (*Daucus carota* var. sativus L.) were grown in 4"x 6" pots of 175g dry weight Pro-mix BX premixed growing medium (Premier, Riviere-du-loupe, Canada). Carrot seedlings were allowed to grow for three weeks after emergence was observed. The pots were arranged randomly in a controlled environmental growth chamber (PGW, Conviron Ltd, Winnipeg, Manitoba, Canada) maintained at 20±1/10±1 ºC day and night temperature with a 16 hour photoperiod, and a photon flux density of approximately 200 µmole m^{-2} s^{-1} . Relative humidity was maintained at approximately 60-70% for the duration of the experiment. Each pot received 250ml of water daily to maintain field capacity and 100ml of a 15-15-30 water-soluble fertilizer weekly until the three weeks prior to drought imposition. There were ten seedlings per pot and five replications per treatment.

Drought was imposed naturally by withholding water. There were four drought treatments (2-days, 4-days, 8-days and 10-days water withheld) which corresponded soil water potential (Table 1). Appropriate control was also run. Treatments were fixed based on a preliminary study which determined an approximate maximum threshold external water potential that caused turgor loss. Growth and physiological measurements were made on the 10^{th} day after drought imposition.

Moisture level of the rooting media was obtained through measurement of the soil water potential using a Watermark sensor (gypsum block) (Watermark, USA). Xylem pressure potential was measured on a whole plant, using an Scholander-type pressure chamber. Leaf area was measured using a Licor leaf area meter, LI 2000 (Licor instruments, USA) and expressed as cm^2. Photosynthesis (Pn), stomatal conductance (Cs), transpiration (Tl), water use efficiency (WUE) were measured on the second leaf, with a LI-6200 Portable Photosynthetic System (Li-cor. Inc., Lincoln, USA). WUE was calculated as the instantaneous ratio of Pn/Tl.

Table 1: Pattern of Decline in Soil Water Potential

DAYS IN DROUGHT	Ψ_{ext} (MPa)
0 - DAYS	0
2 - DAYS	-0.25
4 - DAYS	-0.30
8 - DAYS	-0.36
10 - DAYS	-0.69

RESULTS

Figure 1: Xylem Pressure Potential

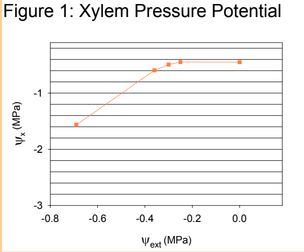


Figure 2: Leaf Area

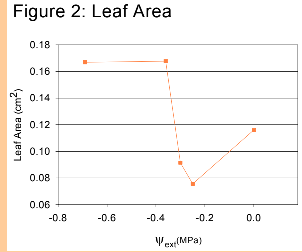


Figure 3: Plant Elongation

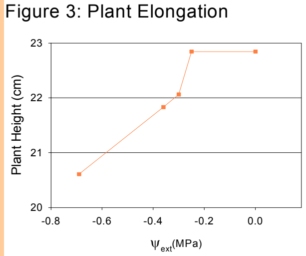


Figure 4: Tissue Capacitance

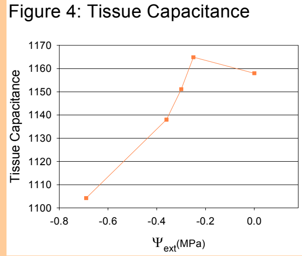


Figure 5: Leaf Transpiration

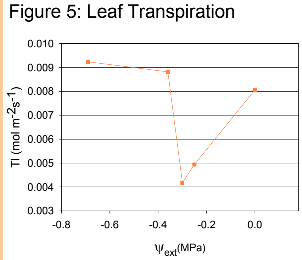
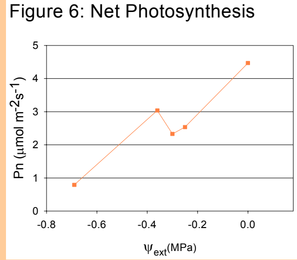


Figure 6: Net Photosynthesis



DISCUSSION

An ANOVA was performed using SAS software, applying a 5% significance level ($P < 0.05$). Withholding water for 10d reduced both soil water potential as well as xylem pressure potential significantly (Fig. 1). Both, Pn and WUE declined significantly as water stress progressed. The threshold was observed to be below Ψ_{ext}-0.36 MPa. Plant elongation was also declined below Ψ_{ext} –0.36 MPa. Although leaf expansion declined initially, continued to expand despite declining external water potential, indicating a net leaf area adjustment, perhaps to compensate for the decline in Pn. Continued expansion of the leaf area however lead to an enhanced transpiratory water loss which lowered the xylem pressure potential well below the external water potential. Although the Tl declined initially, continued to increase despite a decline in Ψ_{ext} indicating a lack of stomatal control thus, predisposing the plants to a severe internal water stress as seen from the rapid decline in xylem pressure potential.

A further examination of the membrane integrity showed that water stress caused a significant decline in tissue capacitance. Again, the threshold Ψ_{ext} was observed to be at or above -0.36MPa. This decline suggests that there was an alteration of membranes to a physical adjustment of membrane structures and/or its composition.

Sustained leaf expansion despite a decline in xylem pressure potential indicates that the carrot seedlings would have regulated turgor. However, the continued decline in plant elongation together with a decline in external water potential suggests that extension growth is more vulnerable to drought and these two processes are differentially controlled. The decline in Pn with an increase in Tl showed that carrot seedlings have low water use efficiency.

CONCLUSIONS

In conclusion, up until a threshold point is reached (~-0.36MPa Ψ_{ext}) carrots initially apply a water conservation mechanism. Drought caused a significant decline in extension growth, while leaf area expansion continued despite severity of stress. Continued expansion resulted in an increase in Tl and the declining Pn reduced the WUE. Tissue capacitance also declined as drought progressed. Carrot seedlings lacked stomatal control and recorded low WUE. The threshold water potential to cause physiological dysfunction appears to be at or below -0.36MPa (Ψ_{ext}) or -0.59 MPa (Ψ_x).

Acknowledgements

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References:

McWilliam, J.R. (1986) The National and International Importance of Drought and Salinity Effects on Agricultural Production. *Aust. J. Plant Physiol.* **13**, 1-13