

Corporal punishment for carrots (making bad carrots good!)



Introduction

In Nova Scotia, carrots (*Daucus carota* L.) are an important part of the agricultural sector. After processing, carrots generate more than 12 million dollars for the food production industry. Drought in recent years has resulted in crop losses from 20 to 80% for Nova Scotian farmers. Enhancing the ability of plants to deal with drought will be of great benefit to the agricultural industry.

When plants are exposed to drought they are stressed. Plants have innate stress tolerance mechanisms; it is up to us, as innovators, to enhance this tolerance. One innate mechanism is the production of stress hormones, these hormones will affect changes in the plant to resist stress. To tolerate drought, these changes optimizing photofunctions and water use efficiency. Many stresses, some more benign than drought, will trigger the release of these hormones, including physical damage or disturbance inducing Thigmomorphogenesis (TM). If a plant was subjected to one of those "less stressful stresses" before drought, perhaps the plant would have enough circulating stress hormones to better tolerate subsequent drought. TM or physically disturbing plants could act as a trigger for the stress defence mechanisms.

It was the goal of this project to develop a treatment, for plants, that increased plant defences to drought. This treatment involved brushing the carrot tops with a wooden rod, causing physical disturbance. The brushing treatment would act as a trigger for the plant to tolerate the subsequent drought treatment.

Objective

- To evaluate the effects of brushing treatment on drought tolerance by measuring physiological parameters affected by drought stress.
- To determine optimal brushing frequency that triggers for drought tolerance mechanisms

Materials and Methods

This experiment consisted of two treatments. The first treatment was brushing the tops of the carrots. Following this, the second treatment was imposing drought by withholding water. There were five brushing treatment groups (0, 1, 10, 50 and 100 brushes per day for one week) and four drought treatment groups (0, 2, 4 and 8 days of drought). The whole experiment was replicated three times requiring sixty pots of carrots. Carrots, variety 'oranza', were grown in a greenhouse, in six inch diameter pots containing promix¹. The carrots were sown in a row within the pot, and thinned out, after emergence, to ten carrots per pot. The experiment was organized as a randomized complete block design.

The brushing treatment began three weeks after seedling emergence, and lasted for one week. The act of brushing consisted of gently passing a wooden rod (1" diameter) horizontally over the tops of the carrots, perpendicular to the carrot rows and growing axis (fig. 5). The brushes were as uniform as possible, hitting the plant at mid-height. The drought treatment began after the week of brushing, with each of the brushing treatment groups being subdivided into four drought treatment groups.

Measurements were taken before and after each treatment. The variables monitored included: growth, net photosynthesis (Pn), stomatal conductance (Cs), instantaneous transpiration (Ti), relative water content (RWC), xylem pressure potential (XPP) and membrane injury index (MI). Growth was measured using a ruler. An LCA4 portable photosynthesis and transpiration measurement system² was used to measure Pn, Cs and Ti (fig. 6). To determine the RWC, of carrot leaves, a scale was used to measure the weight of fresh, turgid and dry leaves. A conductivity and TDS meter³ was used to measure conductivity and therefore determine the MI. Xylem pressure potential was measured using a model 600 pressure chamber instrument⁴.

The data was analyzed using the SAS statistics package. The proc GLM procedure was used to test the data. Interactions between the two factors were discovered for some of the responses, so an LSmeans was performed.

Results

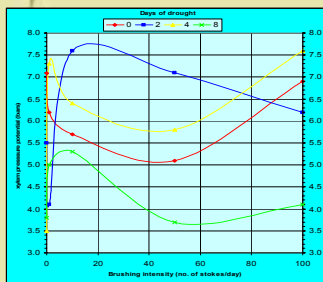


Fig. 1 Trends in the effect of brushing on xylem pressure potential of carrot seedlings under drought.

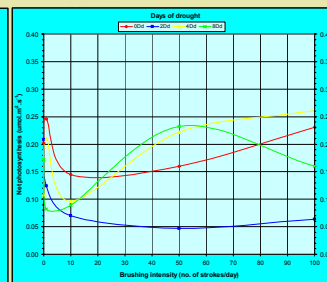


Fig. 2 Trends in the effect of brushing on net photosynthesis of carrot seedlings under drought

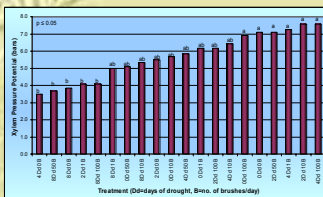


Fig. 3 The effects of brushing on xylem pressure potential of carrot seedlings under drought

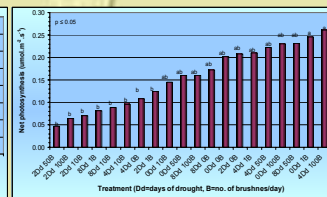


Fig. 4 The effects of brushing on net photosynthesis of carrot seedlings under drought

In carrots, subjected to two days drought, net photosynthesis declined significantly in the groups at a brushing frequency (BF) of 1, 10, 50 and 100 times per day (fig. 4). In carrots, subjected to eight days drought, net photosynthesis declined significantly in the groups with BF 1 and 10 times per day. Xylem pressure potential was maintained at a low value, after eight days of drought, in the groups with BF 50 and 100 times per day (fig.3). This was significantly lower when compared to control plants that were not subject to drought. Similar effect was noticed in the plants receiving one brush per day that were subjected to two days of drought.

Other data, not included, indicated that all brushing treatments maintained membrane injury index at a low value (high stability) after eight days of drought. Plant height was also increased in the groups receiving 100 brushes per day when compared to the groups that received 50 brushes per day. Brushing reduced stomatal conductance in plants subjected to eight and two days of drought, when compared to unbrushed controls.



Fig. 5 Brushing the carrots



Fig. 6 Taking measurements with the LCA4

Discussion

The reduction in net photosynthesis (Pn) in plants under drought was expected. Such a reduction in Pn can be attributed to a reduction in Cs, Rubisco activity, PEP carboxylase and electron transfer. ABA, ethylene (ETH) and Jasmonic acid (JA), the stress hormones that accumulate under drought can lead to photodysfunction. Another expected result was the reduction in stomatal conductance, a necessary consequence of drought. Abscisic acid and JA, can close stomata, which will in fact lead to water conservation. Since TM also induce ethylene and mechanical or physical damage can trigger JA, ABA and ETH, it is postulated that physical disturbance may protect plants against drought through triggering stress induced hormones. If the brushing treatment triggered these effects prior to drought, then carrots will be better protected against declining soil moisture.

A low xylem pressure potential was a desirable effect. A plant suffering from water deficit will require more pressure to force water out of the xylem. A low xylem pressure potential after eight days of drought indicates that 50 or 100 brushes per day has a positive effect on the carrots water status. A low membrane damage was also a good sign. Brushed plants maintained higher membrane stability (low MI) indicating that brushing triggered a protective mechanism stabilizing membrane integrity. The overall increase in plant height for the 100 brushes per day group was an unexpected result. It was expected that brushing would reduce plant growth by triggering inhibitors such as ABA, ETH and JA however, brushed plants continued to grow which may perhaps be due to high WUE and membrane protection.

This experiment indicates that their may be some merit to the brushing technique, and that more investigation is required. Brushing the carrots was simple and did not require much time. No one brushing treatment was proven superior to the others, although in many cases at least one brush was better than none. This experiment would be complemented by a protein analysis of the carrots, before and after the treatments, to determine if there are indeed circulating stress hormones after the brushing treatment. Also of benefit would have been one more drought group where the plants would have been subject to drought until death. This would have indicated whether or not the brushing treatment extended the maximum period of drought tolerated by the carrots.

Nevertheless it appears that one can "make bad carrots good, with a stick". In reality, this could be developed into a technique for small scale farmers as well as larger producers. For small farms some kind of hand tool could be used. For the larger farms some form of machine could be designed to drag behind your tractor. The hand tool version (even a stick) would be universally applicable around the world, regardless of the local economy.

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Thank you

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- Jim Burke

1) Plant Products co., Ontario; 2) ADC Bioscientific Ltd., Hoddesdon, UK; 3) Oakton Instruments, Vernon Hills, Illinois, USA; 4) PMS Instrument co., Corvallis, Oregon, USA.