Grower Summary

PE 015

Inducing compact growth and improved shelf life in herbs by mimicking drought signals

Final 2014

DISCLAIMER

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

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Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

HDC is a division of the Agriculture and Horticulture Development Board.

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Further information

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GROWER SUMMARY

Headline

High salinity treatments were found to be effective in reducing petiole length in flat leaf parsley and coriander. The sodium chloride treatments did not significantly reduce leaf area.

Background

Low light levels induce growth of longer, weaker stems and petioles in plants including culinary herbs (etiolation). Such plants show reduced shelf life and may fail to meet buyer specifications and customer expectations.

Under drought or high salinity conditions, plants respond by reducing growth via systems involving alkalinisation of xylem sap, hormone signalling via abscisic acid (ABA) and ethylene and other physical and physiological changes such as stomatal closure (Wilkinson and Davies, 2010).

Previous work on a wide range of species has indicated that supplying high pH artificial xylem sap or application of high pH solutions to the substrate can lead to reduced growth rates (Bacon *et al.,* 1998; Fung and Wong, 2001; Kaya *et al.,* 2002; Shi and Sheng, 2005; Aronsson *et al.,* 2009; Afshari *et al.,* 2011; Kang *et al.,* 2011; Kering and Kaps, 2011; Kettlewell *et al.,* 2012; Zhao *et al.,* 2013). This reduction in growth rate can lead to reduced plant height (Afshari *et al.,* 2011; Zhao *et al.,* 2013). High salinity has also been reported to reduce plant growth in a number of species (Shi and Sheng, 2005; Pitann *et al.,* 2009; Afshari *et al.,* 2011; Wang *et al.,* 2011; Babu *et al.,* 2012; Habibi and Amiri, 2013; Hajiaghaei-Kamrani *et al.,* 2013; Huckle and Mulholland, 2013; Hussain *et al.,* 2013). For example, when chervil seedlings were grown *in vitro* in sodium chloride solutions of up to 240 mM, the height of seedlings, along with hypocotyl and root length, was reduced by over 80% compared to control plants (Liopa-Tsakalidi and Barouchas, 2011).

Plant responses to drought and salinity appear to use an overlapping set of signals. For example, in broad bean (*Vicia faba*), apoplastic pH increased in response to treatment with potassium chloride or sodium chloride (Felle and Hanstein, 2002). In addition, both high salinity and drought conditions can result in an increase in ABA concentration in some species (Hartung *et al.,* 1988; Cramer, 1994; He and Cramer, 1996; Montero et al., 1998; Stoll *et al.,* 2000; Bahrun *et al.,* 2002; Christmann *et al.,* 2005; Babu *et al.,* 2012). Sunflower seedlings show reduced growth and leaf area at both higher salinity and pH (Shi and Sheng, 2005). When both stresses were combined together, the effect was much larger. This background led to this project where the effect of high pH and high salinity treatments on herb growth was investigated.

Summary

High pH and high salinity treatments were applied to four species of culinary herbs in an attempt to induce natural drought and salinity responses whilst still maintaining water provision.

The species investigated were: flat leaf parsley (*Petroselinum crispum* var. *neapolitanum*), coriander (*Coriandrum sativum*), basil (*Ocimum basilicum*) and mint (*Mentha sp.*). Two preliminary experiments (Experiments 1 and 2) were carried out to optimise the experimental design. These two experiments were performed with a minimum daytime temperature of 15°C and minimum night temperature of 5°C. The treatments in Experiment 1 were: foliar sprays of potassium bicarbonate ($KHCO_3$) from pH8 to 12, a 3 second soil drench of $KHCO_3$ at pH12 and both a foliar spray and 3 second soil drench of 0.24M sodium chloride (NaCl) with the water spray control being treatment 2. No significant effects on stem or petiole elongation or overall biomass differences were observed in these preliminary experiments. From the results, the experimental design was modified and was performed at minimum day and night temperatures of 18°C, with weekly treatments for up to four weeks before harvest.

In Experiment 3, $KHCO_3$ foliar sprays at pH8 and pH12, a $KHCO_3$ 3second soil drench at pH12 and a 0.24M NaCl 3 second soil drench were applied weekly. Again there was a water spray control. The optimisation of the experiment design appeared to be successful as several statistically significant results were observed in this experiment. The greatest effects were found with the 0.24M NaCl salt drench treatment. This treatment led to an average reduction in parsley 1st petiole length of 16% after 4 weeks and 11% for coriander after 2 weeks versus the water spray control. Parsley plants treated with the foliar spray of $KHCO_3$ at pH12 also showed reduced length of 1st petioles by 14% versus the water spray control after 4 weeks. The 0.24M NaCl drench, $KHCO_3$ pH12 spray and drench also led to a significant reduction in overall plant biomass for parsley only (an average reduction of 32%, 21% and 18% in wet weight, respectively, after 4 weeks versus the water spray control). Interestingly, the NaCl drench also showed an increase in the per cent dry weight of mint plants versus the water spray control by 15% after 4 weeks. The $KHCO_3$ treatments did not significantly affect coriander elongation or biomass in this experiment.

After Experiment 3 it was decided to proceed with flat leaf parsley and coriander as these species had shown the largest responses to the treatments and more reliable and consistent growth than mint and basil.

Experiment 4 investigated the possibility of combining the high pH and high salinity treatments for an additive effect on plant elongation. The treatments used were a 0.24M NaCl foliar spray, $KHCO_3$ pH12 foliar spray either once or twice weekly, 0.24M NaCl soil drench either once or twice weekly and a combined 0.24M NaCl soil drench and $KHCO_3$ pH12 foliar spray. A water spray and water soil drench were used as controls. Treatments were applied for four weeks with additional lighting being provided.

For coriander, the NaCl drench once and twice weekly reduced petiole 2 length by 15% and 19% respectively (versus water drench once per week) and reduced petiole 3 length by 21% and 28%, respectively (versus water drench once per week). No significant effects on coriander elongation were noted when $KHCO_3$ sprays were applied alone. For parsley, NaCl drench twice weekly reduced petiole 2 and 3 length by 13% and 22%, respectively (versus water drench once per week). For coriander, the twice weekly NaCl drench led to 31% and 42% reductions in wet and dry weight, respectively (versus once weekly water drench). No significant effects on overall biomass were noted for parsley. The use of additional lighting may have reduced the effectiveness of the treatments in this experiment as two treatments per week were needed to obtain a significant reduction in petiole elongation. Also, some mild leaf tip scorching of coriander plants was noted, particularly for those treated twice weekly with NaCl, which could also result from the increased lighting and any resultant temperature increase. No additive effect from combining the high salinity and high pH treatments was detected as the high pH treatments appear largely ineffective in this experiment.

As the high salinity treatments appeared to be the most effective, Experiment 5 used variation in treatment frequency, duration and NaCl concentration to further investigate the effects of salt application on parsley and coriander. Soil drench treatments of either 0.24M or 0.12M NaCl supplied once or twice weekly for 5 second or 10 second durations were used. For parsley, no significant effects on petiole elongation were found. However, for coriander, the 0.24M NaCl 5s once weekly treatment significantly reduced the length of petiole 1 by 9%, the 0.12M NaCl 5s twice weekly treatment reduced the lengths of petioles 3 and 4 by 11% and 12%, respectively, while the 0.12M NaCl 10s twice weekly treatment significantly reduced the lengths of petioles 1 to 4 by 9%, 12%, 17% and 19%, respectively (in each case versus the corresponding water control).

For both parsley and coriander plants we could detect no significant difference in leaf area or colour of the third leaf in this experiment. However, leaf scorching and yellowing was noted on some coriander plants in this experiment, particularly when using the 0.12M NaCl 10s twice weekly treatment. The high light levels and day temperatures in this experiment, which was carried out in March and April could explain the reduced effectiveness of the treatments and increased severity of phytotoxicity, Interestingly, after a three day period of drying, the soil moisture content of salt-treated plants was significantly higher than for water control plants, suggesting a reduced water uptake rate by these plants, possibly involving reduced transpiration owing to stomatal closure in response to salt application. This effect should be considered when determining the relative water requirements of salt-treated and control plants.

Experiment 6 was designed to investigate the deterioration of salt- and water-treated plants during cold storage. The plants were treated as in experiment 5 and so some leaf damage (leaf scorching, yellowing) was noted for some salt-treated plants prior to storage. Plants were scored for leaf damage before and after 14 days storage at 4°C and the change in score calculated. In addition, plants were given a general appearance score based on colour and firmness after storage.

For parsley, significant differences were detected between the treatments in the ‘before’ and ‘general’ scores, with salt-treated plants appearing to have higher scores, indicating lower condition plants. For coriander, all four scores (‘before’, ‘after’, ‘change’ and ‘general’) showed significant differences between the treatments. Salt-treated plants appeared to have higher ‘before’, ‘after’ and ‘general’ scores than water-treated plants, indicating a worse plant condition. The ‘change’ score, indicating the difference in the condition of the plant from before to after storage, however, appeared to be lower for the salt-treated plants, suggesting a smaller change in condition during storage than for water-treated plants. These results may indicate that salt-treated plants deteriorate less quickly during storage than water-treated plants or that for salt-treated plants most deterioration had occurred prior to storage. It should be noted that the condition of coriander plants in this experiment was worse than noted in previous experiments, perhaps due to ambient light levels.

In the final experiment, Experiment 7, parsley plants were grown hydroponically in pots containing perlite partially submerged in an aerated commercially available nutrient solution. Treatments used were a once weekly foliar spray of $KHCO_3$ at pH 12, a once weekly exchange of the nutrient solution for 0.24M NaCl for 4 hours and a combination of both treatments. The NaCl treatment once again gave the largest reduction in elongation, decreasing the length of petioles 2 and 3 by 10% and 19%, respectively and reducing overall biomass by 39% versus the nutrient solution control. Again, the $KHCO_3$ pH 12 spray did not significantly affect elongation or biomass. Leaf area, colour and electrolyte leakage were unaffected by the treatments. Petiole firmness was also unaffected.

In summary, soil drenches of 0.24M NaCl 5s once weekly, 0.12M NaCl 5s twice weekly and 0.12M NaCl 10s twice weekly significantly reduced petiole elongation, particularly of coriander plants by 10-20% compared to control plants. No significant effects were found on leaf area or colour. The overall biomass of plants was reduced at times by the NaCl treatments but less consistently than elongation. Despite previously published data, we found no additive effects by combining high pH and high salinity treatments, likely due to the relative ineffectiveness of the high pH treatments. Further, in a hydroponics experiment, parsley leaf electrolyte leakage was unaffected by NaCl treatment, suggesting leaf quality was unchanged by the treatments. The firmness of petioles was similarly unaffected. However, given the reduction of petiole length, petioles could ultimately resist bending more than in untreated plants. NaCl treatment may also reduce plant quality deterioration during storage.

The effectiveness and phytotoxicity of the treatments appeared to depend on environmental conditions and treatment regime. Phytotoxicity was very low or absent in winter months but increased into spring. For example, increased phytotoxicity and reduced treatment efficacy was noted for Experiment 5 carried out in March-April compared to Experiment 3 performed in November-December. Given that the provision of artificial lighting in Experiment 4 also appeared to reduce treatment effectiveness, it is likely that ambient light levels and temperature are responsible for the differences seen. In addition, phytotoxicity also increased with higher frequency, higher duration NaCl treatments, particularly for the 0.12M NaCl 10s twice weekly treatment.

Financial Benefits

Provision of electrical lighting for large scale commercial glasshouses is very expensive. Using saline solutions to combat etiolation appears to represent a promising low cost alternative.

Action Points

- Despite the promise shown with these methods, there is insufficient evidence of benefits without the risk of phytotoxicity to make practical recommendations at this stage.