AHDB HORTICULTURE

Grower Summary

PE 023

Hormetic UV-C Treatments for Control of Plant Diseases on Protected Edibles

Final 2017

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Further information

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Project number:	PE 023
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Report:	Final report, August 2017
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GROWER SUMMARY

Headline

- Post-harvest treatments of tomato fruit with a high intensity, pulsed polychromatic light source (HIPPL), rich in UV-C, show disease control against *Botrytis cinerea* and delayed ripening through delayed colour and texture changes.
- Treatment time is reduced by 97.3% for the HIPPL source in comparison to a conventional low intensity UV-C (LIUV) source.
- Post-harvest HIPPL and LIUV treatments of tomato fruit control disease against *Penicillium expansum* on ripe tomatoes.
- The molecular mechanisms underpinning HIPPL and LIUV hormesis on tomato fruit are extremely similar. Disease control is achieved through induced resistance. Down-regulation of genes involved in ethylene biosynthesis enzyme (*ACO1*) and polygalacturonase is observed. Increased expression of jasmonic acid (*OPR3*) and salicylic acid (*P4*) biosynthesis enzymes and markers are observed. Up-regulation of a pathogenesis related proteins (*CHI9* and GLUB) is also observed.
- Post-harvest HIPPL and LIUV treatments of tomato fruit elicit a local response when fruit are treated from either the blossom end, calyx or side. Full surface exposure is, therefore, required.
- The HIPPL induced resistance and delayed ripening on tomato fruit is not solely due to UV-C. UV-C emissions, however, account for approx. 50 % of the observed induced resistance and delayed ripening.
- Pre-harvest HIPPL and LIUV treatments showed the potential to control *Botrytis cinerea* on lettuce (cv. Temira) in a lighting and temperature controlled environment; reducing disease progression by 21.4 and 21.0 %, respectively.
- LIUV treatment of tomato seeds decreased disease progression and disease incidence of *B. cinerea* on flowering plants by approx. 10 %.
- Biostimulation of seedling growth is observed following LIUV treatment of tomato seeds. Biostimulation is observed for both roots and shoots. Root growth, however, is stimulated to a greater extent.

Background

Hormesis is a dose-response phenomenon where low doses of a stressor bring about a positive response in the organism undergoing treatment. The benefits of UV-C hormesis have been known for nearly 30 years. A broad range of benefits are observed from increased nutritional content to disease resistance and reduced chlorophyll degradation. To date, the majority of studies have been performed using conventional low pressure, low intensity UV-C (LIUV) sources on post-harvest produce. Commercial application of these treatments has, in part, been prevented due to the lengthy exposure times that are required: conventional treatments of tomato fruit take in excess of six minutes. High intensity, pulsed polychromatic light sources (HIPPL), rich in UV-C, however, have been developed which hold the potential of drastically reducing treatment times and making such treatments a commercial possibility. However, it is necessary to demonstrate that such sources have the ability to induce disease resistance and delayed ripening on tomato fruit through post-harvest treatments.

Recently, exposure of foliage to UV has been shown to induce resistance against downy mildew and grey mould on *Arabidopsis thaliana*. The horticultural application of such treatments, however, have not been explored. We, therefore, aim to research pre-harvest LIUV and HIPPL treatments to induce resistance on both tomato and lettuce crops. Utilisation of such treatments in commercial situations may allow an alternative to traditional chemical-based disease control and provide a residue-free alternative to other inducers of disease resistance.

Summary

Objective 1 - Validation of the High Intensity Pulsed Polychromatic Light Source as an Inducer of Hormesis on Tomato Fruit

Tomato fruit of the cv. Mecano were treated at both the mature green and ripe stage. An established LIUV treatment was performed alongside a number of HIPPL treatments. This was to allow a comparison of the sources' ability to induce both disease resistance against *Botrytis cinerea* and *Penicillium expansum,* and delay ripening. Both LIUV and HIPPL sources successfully controlled disease, to comparable levels, against *B. cinerea* on mature green fruit following artificial inoculation. Disease progression on ripe fruit, for *B. cinerea* and *P. expansum*, was inhibited to a greater extent by the HIPPL source. Furthermore, ripening as measured through both colour change and texture, was delayed by the HIPPL source to comparative levels to that observed for the LIUV source.

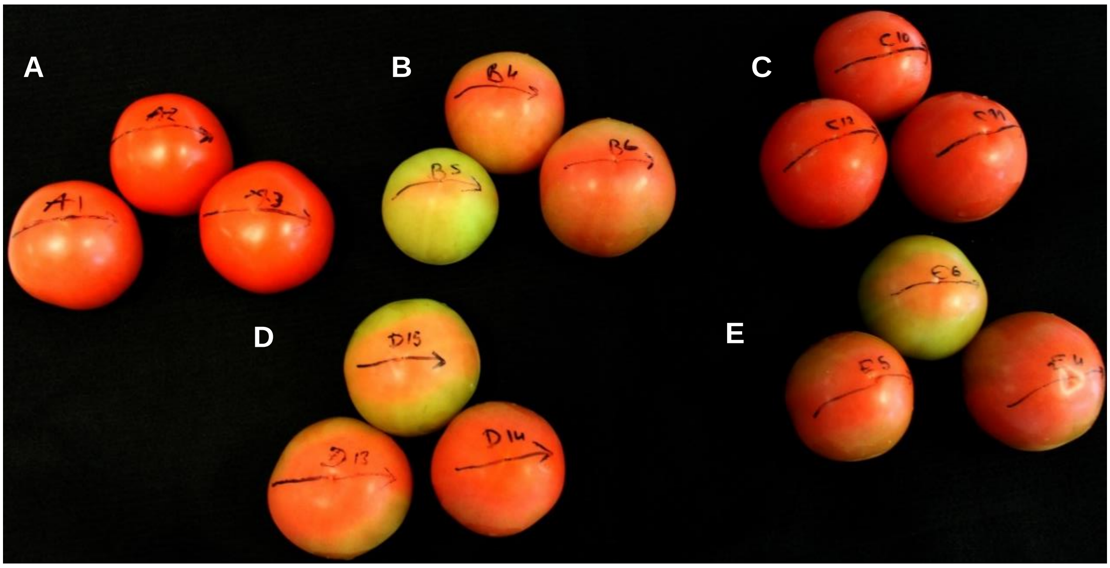
Both ripe and mature green fruit showed optimal HIPPL treatments of 16 pulses giving a total treatment time of 10 seconds yielding a 97.3 % reduction in treatment time in comparison to the LIUV treatment. The ability to induce resistance to *B. cinerea* at both the mature green and ripe stages shows that post-harvest HIPPL treatment could be adopted by growers who harvest at differing fruit maturities. The majority of previously published research was focused on fruit at the mature green stage.

Objective 2 – Comparing the Molecular Mechanisms Underpinning LIUV and HIPPL Hormesis on Tomato Fruit

Utilising quantitative PCR we have found that the molecular mechanisms leading to induced resistance and delayed ripening for both the LIUV and HIPPL source are extremely similar. Both sources show an upregulation of both salicylic acid and jasmonic acid biosynthesis enzymes or markers. Furthermore, 24 hours after treatment a transient peak in ethylene biosynthesis enzyme *AC01* is observed. At 10 days after treatment and 12 hours after inoculation with *B. cinerea,* however*,* a reduction in *ACO1* is seen. The upregulation of pathogenesis related (PR) proteins, involved in the plant's defence response, is observed for both LIUV and HIPPL treatments. Interestingly upregulation of PR protein transcripts, associated with defence against biotrophic and necrotrophic pathogens and plant pests, was observed. This may indicate that LIUV and HIPPL treatments can protect against a wide range of pathogens and pests. Finally, polygalacturonase was downregulated and changes to secondary metabolism were observed. These include downregulation of flavonols and upregulation of carotene-hydroxylase and phenylalanine ammonia lyase.

Objective 3 - Assessing the Importance of Direct Tissue Exposure and Fruit Orientation during LIUV and HIPPL Treatment

Multiple treatment orientations were attempted including treatments from the side, blossom end and calyx. Both the LIUV and HIPPL induced disease resistance and delayed ripening are local responses in tomato fruit. Fruit would, therefore, require full surface exposure.



A representative sample from the fruits treated post-harvest showing: **A)** Control fruit. **B)** Conventional treatment with the low intensity UV-C (LIUV) source. **C)** An 8 pulse high-intensity, pulsed polychromatic light (HIPPL) treatment. **D)** A 16 pulse HIPPL treatment and **E)** A 24 pulse HIPPL treatment. Black lines on the fruit run parallel to the direction of UV source exposure which highlights the dependency of full surface exposure for delayed ripening. (Scott *et al.,* 2017)

Objective 4 - Assessing the Importance of UV-C, B and A and visible light within the High Intensity Pulsed Polychromatic Light Source, for Inducing the Hormetic Effects Observed on Tomato Fruit cv. Mecano

HIPPL treatments were performed with or without UV-C filtering glass. Disease resistance and colour progression was delayed both with and without UV-C. Disease resistance and delayed ripening without the presence of UV-C, however, were reduced by approximately 50 %. This indicated that although UV-C is not essential to maintain such short treatment times, UV-C is required to achieve the full benefits of treatment.

Objective 5 – Pre-harvest Foliar LIUV and HIPPL Treatments of Lettuce

Foliar LIUV and HIPPL treatments of lettuce were performed on two commercial butterhead varieties, Amica and Temira, grown in a temperature-controlled glasshouse with assimilation lighting during the winter months. Damage assessments and disease control bioassays were carried out at the 3-5 true leaf and early, mid and late head formation developmental stages. No conclusions could be drawn from the data.

Objective 6- Low-Dose Foliar LIUV and HIPPL Treatments of Lettuce

To avoid any unwanted damage to crops, low dose LIUV and HIPPL treatments, which were shown to not be damaging at any point during the year were tested. Unfortunately, both single and multiple applications of such low dose treatments were prone to variation. It was, therefore, decided that experiments should be performed in a controlled environment.

Objective 7- LIUV and HIPPL Treatments of Lettuce in a Controlled Environment

Lettuce plants of the cvs. Amica and Temira were grown in a light and temperature controlled environment with no natural lighting. Plants were grown to the 8-true leaf stage and then treated with either HIPPL or LIUV. Plants were assessed for damage and then inoculated with *B. cinerea* using a leaf disc bioassay on the second day following treatment. Amica plants were more susceptible to damage from both the LIUV and HIPPL source. Only Temira showed statistically significant levels of disease control with the 0.64 kJ/m^2 LIUV and a 48-pulse HIPPL treatments reducing disease progression by 21.0 and 21.4 %, respectively. Further investigation is required.

Objective 8- LIUV Seed Treatments of Tomato to Control B. cinerea

Seeds were treated with either 0, 2, 4 or 6 kJ/m^2 LIUV. Inoculations were performed on the plant through the application of a calibrated spore solution onto a petiole stub. All treatments reduce disease progression on flowering plants. The 4 kJ/m^2, however, was shown to be the most successful and statistically significant with a reduction in both disease incidence and progression of approx. 10 %.

Objective 9-Effects of LIUV Tomato Seed Treatment on Germination and Early Seedling Growth

To determine any potential detrimental effects of UV-C, germination and early plant development and growth were monitored. The 4 kJ/m^2 treatment was used along with two higher treatments of 8 and 12 kJ/m. Interestingly, we observed biostimulation of seedling growth following the 8 kJ/m treatment. Germination speed and synchronicity was increased along with a significant increase in root, hypocotyl, and cotyledon dry mass. Furthermore, no differences were observed in root or hypocotyl length indicating an increase in volume. A significant increase in root mass fraction was also observed for the 8 kJ/m^2 treatment indicating that root growth is stimulated to a greater extent than that of shoot growth. This may lead to increased efficiency in water and nutrient uptake, further investigation is required. Moreover, biostimulation of root growth does not appear to negatively impact the shoots where a significant increase in dry mass was also observed.

Financial Benefits

Calculation of financial benefits is not possible at this time.

Action Points

There are no immediate action points.