Horticultural Fellowship Awards

Interim Report Form

Project title:	Working with the industry to develop the next generation of technical staff for the UK horticulture industry through a Summer Research Programme.
Project number:	CP 87
Project leader:	Dr Jim Monaghan
Report:	Annual report, March 2014
Previous report:	Annual report, May 2012 Annual report, March 2013
Fellowship staff:	Josie Brough (Technical support); Dr Paul Hand (Associate); Prof Dave Pink (Associate); Dr Tom Pope (Associate)
Location of project:	Harper Adams University
Industry Representative:	N/A
Date project commenced:	8 July 2011 (back dated 1 April 2011)
Date project completed (or expected completion date):	31 March 2016

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

[Name]
[Position]
[Organisation]

Signature ..... Date .....

[Name]
[Position]
[Organisation]

Signature ..... Date .....

Report authorised by:

[Name]
[Position]
[Organisation]

Signature ..... Date .....

[Name]
[Position]
[Organisation]

Signature ..... Date .....

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Progress Against Objectives and Annual Milestones

Objectives

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
1. Recruit a minimum of 15 undergraduates from UK Higher Education Institutions to complete applied experiments in horticultural crop production and agronomy.	31/03/2016		
2. Deliver a minimum of 15 small-scale research projects for the industry.	31/03/2016		
3. Publicise the approach and outputs of the programme to the industry, Further Education and Higher Education Institutions.	31/03/2016		
4. Leverage additional funding for follow up projects.	31/03/2016		

Summary of Progress

The third year of the Summer Research Programme (SRP) was successful. Four UK undergraduates were selected; one from Lancaster University, Manchester University and Exeter University and Bangor University. The students undertook four separate research projects at HAU linked to Lowaters Nurseries, Plant Impacts Ltd and G's, and also worked together on a number of on-going crop research experiments at HAU. Each student prepared and gave a presentation of their research to the representatives from HDC. The students also made a number of visits to businesses including strawberry, leafy salad, field vegetable, protected salad and ornamental producers.

More detailed reports of each of the four projects are appended to this report and a brief summary of each project is included here. The experiments are numbered sequentially throughout the fellowship and experiments 7-10 are reported here.

Experiment 7 - Does lettuce variety affect the performance of the generalist aphid pest *Myzus persicae*?

Jonathan Harvey (studying Biology at Lancaster University).

Resistant varieties of lettuce offer an alternative to the use of insecticides to control aphid pests. Indeed, this approach has been successfully used against both the currant-lettuce aphid (*Nasonovia ribisnigri*) and the lettuce root aphid (*Pemphigus bursarius*) (e.g. Dieleman & Eenink, 1980; Ellis *et al*., 1994; van Helden *et al*., 1993). In the case of resistance to *N. ribis-nigri* near-complete and partial resistance was found in *Lactuca virosa* L., a distant wild relative of cultivated lettuce, and transferred to *L. sativa* by interspecific crosses.

In comparison with *N. ribis-nigri* and *P. bursarius* little work has investigated resistance in lettuce varieties or genotypes to *M. persicae*. However, recent work has investigated quantitative partial resistance to this aphid using a lettuce mapping population (Hand, pers. comm.).

Jonathan completed two experiments using commercial lettuce varieties and recorded performance and host-plant preference of *M. persicae* and showed that;

Key findings

- ***Myzus persicae* was capable of infesting all commercial lettuce varieties tested but performed poorly on the variety Navara.**
- **Results were variable and may reflect the initial survival of aphids transferred onto lettuce plants.**
- **No statistically significant differences were recorded between commercial lettuce varieties in terms of aphid performance and host-plant selection.**

Experiment 8 - Can biochar products improve growth and/or quality in HONS?

Kat Hales (studying Biology at Exeter University).

There is increasing evidence that biochar has some beneficial effects when added to soils. Its highly porous structure can retain water and capture some soil nutrients and release them over time to the surrounding substrate. Some work has shown that biochar incorporation on substrates can reducing N leaching and potentially increase N use efficiency (NUE) (Prendergast-Miller *et al*., 2011). Commercial biochar based products are available in the UK for HONS growers. Some of these products also contain additional ingredients such as mycorrhizal fungi, worm cast and seaweed extract. The exact composition and benefit of these additional components is difficult to establish but some benefits have been reported (Koltai, 2010).

Kat grew Lavender, Hebe and Salvia plants in substrate at 0, 5,10 and 20% amendment with either biochar or biochar supplemented with mycorrhizal fungi, worm cast and seaweed extract and concluded that:

Key findings

- **Addition of biochar or biochar supplemented with additional components showed no consistent statistically significant benefits for the species studied**
- **There were some non-significant trends that suggest further work is needed to understand the potential role of biochar based substrate amendment**.

Experiment 9 - Does radish hypocotyl water content affect susceptibility to post-harvest splitting?

Iain Place (studying Biology at University of Manchester).

Hypocotyl splitting in radish (*Raphanus sativus*) is typically characterized by a radial longitudinal fracture which usually occurs pre-harvest or shortly (1-2 days) post-harvest during storage. Splitting in radish is an important problem for growers as levels of splits can be as high as 30% on arrival at the pack house thus exceeding supermarket tolerances of 10%. This leads to batches having to be sorted by hand which is costly. Despite these problems, little is known about the environmental and physiological causes of splitting particularly in European radishes.

Increased hypocotyl water content could enhance the susceptibility of the radish hypocotyl to splitting post-harvest by increasing turgor pressure within the tissue of the hypocotyl. There have been no reported investigations into the effects of hypocotyl water content on splitting susceptibility in European radishes but failure force in carrot parenchyma tissue has been shown to be negatively correlated with tissue turgor and water potential suggesting there may be a relationship between turgor and susceptibility to splitting in other vegetables.

Iain undertook postharvest experiments where he manipulated the water content of radish before exposing them to different forces using materials testing equipment. He showed that:

Key findings

- **There is a negative correlation between hypocotyl water content and the force required to puncture the hypocotyl**
- **Radishes are more susceptible to splitting as a result of dropping at hypocotyl water contents above 96.5%**

Experiment 10 - Can a Calcium foliar spray improve yield or post-harvest quality in strawberries?

Will Johnson (studying Environmental Science at Bangor University)

Crop nutrition is an important preharvest treatment affecting postharvest fruit quality. Calcium (Ca) has a particular role in membrane integrity in plants (Lara et al., 2004). It is known that postharvest application of Ca as a fruit dip can improve strawberry fruit quality (García et al., 1996) suggesting that additional Ca applied prior to harvest may improve postharvest membrane integrity and tissue firmness.

The production of a large number of strawberry fruit allowed the student to study the distribution of sugars (measured as Total Soluble Solids – TSS) within the fruit. Suppliers and retailers are frequently measuring sugar levels of fruit to ensure that specifications are complied with. Sugar levels may differ between areas of the fruit and understanding the relative distribution will allow QC protocols to be developed.

Will compared the effects of three rates of foliar Ca containing spray applied to table-top 60 day strawberry plants on the yield and postharvest quality of fruit. He also studied the distribution of sugars between the top and bottom hemispheres of harvested fruit. Will concluded that:

Key findings

- **Under the conditions studied there was no benefit of additional foliar Ca to fruit yield, sweetness or post-harvest quality.**
- **Sugar accumulation was not uniform between the top and bottom of the fruit with differences as great as 2 °Brix between the top and bottom of fruit.**
- **This response depends on the average °Brix of the fruit and becomes more variable as the average °Brix of the fruit increases.**
- **Growers should ensure that samples used for QC are taken from the length of the fruit and averaged.**

Visits by students

Eight businesses hosted visits by the students: PDM (lettuce), Lower Reule Farm (strawberries), Vitacress (field vegetables), VHB Herbs (Herbs and tomatoes), Walberton and Binstead Nurseries (Ornamentals), Eric Wall Nursery (Tomatoes), Garden Organic - Ryton, Warwick Genebank (Seed collections),

Informal feedback from the students was again very positive. One of the students has applied for a graduate training post in the ornamental sector, one has applied for a PhD in the area of food security. The other two are unclear at this stage what they will do after graduation.

The fellow aims to keep contact with all the SRP students to track later career choices.

Milestones

Annual Milestone	Original Completion Date	Actual Completion Date	Revised Completion Date
1. Select proposed project titles and outlines of work in agreement with Partner businesses and HDC Research Manager.	31/05/2013	31/05/2013	
2. Commence experimental work.	31/05/2013	31/05/2013	
3. Complete mail shots and selected visits to other institutions.	31/05/2013	31/05/2013	
4. Recruit SRP students	30/06/2013	30/06/2013	
5. SRP students start	01/07/2013	08/07/2013	**08/07/2013**
6. SRP students finish	20/09/2013	31/08/2013	**31/08/2013**
7. Research reported to HDC (end November)	31/03/2014	28/03/2014	

Milestones not being reached

N/A

Do remaining milestones look realistic?

Yes

Training undertaken

No training was undertaken by the Fellow in Year 3.

Expertise gained by Trainee

N/A

Other achievements in the last year not originally in the objectives

The Gatsby Summer School for high achieving Plant Scientists targeted at first year UK undergraduates (www.gatsbyplants.leeds.ac.uk) has linked to this programme as an opportunity for applied research experience.

Changes to Project

N/A

Are the current objectives still appropriate for the Fellowship?

No changes proposed

GROWER SUMMARY

The third year of the Summer Research Programme (SRP) was successful. Four UK undergraduates were selected; one from Lancaster University, Manchester University and Exeter University and Bangor University. The students undertook four separate research projects at HAU linked to Lowaters Nurseries, Plant Impacts Ltd and G's, and also worked together on a number of on-going crop research experiments at HAU. Each student prepared and gave a presentation of their research to the representatives from HDC. The students also made a number of visits to businesses including strawberry, leafy salad, field vegetable, protected salad and ornamental producers.

More detailed reports of each of the four projects are appended to this report and a brief summary of each project is included here. The experiments are numbered sequentially throughout the fellowship and experiments 7-10 are reported here.

Headline

N/A

Background

The recent Royal Society report and the Field and Vegetable Task Force report have both highlighted the shortage of applied technical expertise available to the UK horticulture industry. Reduction in government funding for applied horticulture research has led to a marked reduction in the pool of applied researchers available for employment in industry, research and advisory/agronomist roles. In addition the loss of many relevant crops focussed courses and modules from Universities have led to a marked shortage of opportunities for undergraduates to be exposed to, and trained in, applied research in horticulture crop production compared to 10-15 years ago. This limits the number of suitable candidates for technical roles in industry, research studentships, technical roles in universities or institutes, or agronomy and extension businesses.

We have launched a Summer Research Programme (SRP) based at Harper Adams University College (HAUC) and led by Jim Monaghan. The SRP will recruit three UK undergraduate students (and potentially seconded industry employees) each year. These students will then carry out applied agronomy/crop production research projects within the Fresh Produce Research Centre and be supported by other research staff associated with the centre.

Summary

See appendices

Financial Benefits

N/A

Action Points

See appendices

Knowledge and Technology Transfer

A webpage and facebook site has been set up for the SRP and contain videos of each project.

http://www.harper-adams.ac.uk/initiatives/fresh-produce-research-centre/

https://www.facebook.com/HAUFreshProduce

Glossary

N/A

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Eenink, A. H., Dieleman, F. L. (1983) Inheritance of resistance to the leaf aphid Nasonovia ribisnigri in wild lettuce species. *Euphytica*. **32**: 691–695.

Ellis, P. R., Pink, D. A. C., Ramsey, A. D. (1994) Inheritance of resistance to lettuce root aphid in the lettuce cultivars 'Avoncrisp' and 'Lakeland'. *Annals of Applied Biology*. **124**: 141–151.

García J.M., Herrera S., Morilla A. (1996) Effects of postharvest dips in calcium chloride on strawberry. *J. Agric. Food Chem* 44:30–33

van Helden, M., Tjallingii, W. F., Dieleman, F. L. (1993) The resistance of lettuce (*Lactuca sativa* L.) to *Nasonovia ribisnigri*: bionomics of *N. ribisnigri* on near isogenic lettuce lines. *Entomologia Experimentalis et Applicata*. **66**: 53–58.

Koltai, H. (2010) Mycorrhiza in floriculture: difficulties and opportunities. Symbiosis 52:55-63.

Lara I., García P., Vendrell M. (2004) Modifications in cell wall composition after cold storage of calcium-treated strawberry (*Fragaria* × *ananassa* Duch.) fruit. *Postharvest Biology and Technology* 34(3):331–339

Prendergast-Miller, M.T., Duvall, M., Sohi, S.P. (2011) Localisation of nitrate in the rhizosphere of biochar-amended soils. *Soil Biology and Biochemistry* 43(11) 2243–2246

Appendices

A detailed report of the three experiments are appended to this report:

Appendix 7

Experiment 7 - Does lettuce variety affect the performance of the generalist aphid pest *Myzus persicae*?

Appendix 8

Experiment 8 - Can biochar products improve growth and/or quality in HONS?

Appendix 9

Experiment 9 - Does radish hypocotyl water content affect susceptibility to post-harvest splitting?

Appendix 10

Experiment 10 - Can a Calcium foliar spray improve yield or post-harvest quality in strawberries?

Experiment 7 – Does lettuce variety affect the performance of the generalist aphid pest *Myzus persicae*?

7.1. Background

The peach-potato aphid (*Myzus persicae*) is an important agricultural pest affecting a wide range of crops, including oilseed rape, potato, sugar beetle, Brassica crops, ornamentals and lettuce (*Lactuca sativa*). Damage is primarily through the transmission of a wide range of viruses. In lettuce crops these viruses include lettuce mosaic, cucumber mosaic and beet western yellows virus. Crops are also damaged by the presence of aphids and the natural enemies that they attract e.g. hoverfly larvae, which can result in contaminants within the harvested crop.

Winged *M. persicae* typically fly into lettuce crops in May and June. Careful monitoring of crops is required in order to target controls effectively. However, control of this species of aphid is made difficult due to widespread insecticide resistance. Currently in the UK there are high levels of resistance to both carbamate and pyrethroid insecticides. Neonicotinoid insecticides, applied as seed treatments, remain effective in the UK and in 2011 use of thiamethoxam and imidacloprid accounted for 39% and 11% of the seed treatment area in lettuce and endive crops, respectively (Garthwaite *et al*. 2011).

Continued use of neonicotinoid insecticides is under threat. The recent EU ban of clothianidin, imidacloprid and thiamethoxam seed treatments comes into force at the end of 2013 and will run for two years. Although crops such as lettuce are currently exempt as harvesting is completed before the plants flower, the continued debate on the use of this group of insecticides remains of concern to growers. A second threat to the continued use of neonicotinoid insecticides comes from the emergence of *M. persicae* with high levels of resistance to this group of insecticides. Currently these neonicotinoid resistant aphids are found only in parts of southern Europe, however, the concern is that these resistant forms will eventually arrive in the UK.

Resistant varieties of lettuce offer an alternative to the use of insecticides to control aphid pests. Indeed, this approach has been successfully used against both the currant-lettuce aphid (*Nasonovia ribisnigri*) and the lettuce root aphid (*Pemphigus bursarius*) (e.g. Dieleman & Eenink, 1980; Ellis *et al*., 1994; van Helden *et al*., 1993). In the case of resistance to *N. ribis-nigri* near-complete and partial resistance was found in *Lactuca virosa* L., a distant wild relative of cultivated lettuce, and transferred to *L. sativa* by interspecific crosses.

In comparison with *N. ribis-nigri* and *P. bursarius* little work has investigated resistance in lettuce varieties or genotypes to *M. persicae*. However, recent work has investigated quantitative partial resistance to this aphid using a lettuce mapping population (Hand, pers. comm.).

Two experiments were completed using commercial lettuce varieties and recording performance and host-plant preference of *M. persicae*. These experiments were completed to address the research question:

- *Does lettuce variety affect performance of and host plant selection by the generalist aphid pest M. persicae?*

7.2. Materials and methods

The experiments were carried out at Harper Adams University during the summer of 2013. All experiments were managed by Jonathan Harvey who was a Summer Research Placement student from Lancaster University.

This project was developed with G's who were interested in the interaction between aphids and commercial lettuce cultivars. The two research questions were:

7.1.1 Treatments

Five commercial lettuce variety were used in these experiments (Table 7.1). All seeds were supplied untreated.

Table 7.1. Lettuce varieties studied.

	Lettuce variety	Colour	Type	Seed company
1	Helvius	Green	Romaine	Rijk Zwaan
2	Bolero	Red	Red oak leaf	ISI
3	Navara	Red	Multi-leaf	Nunhems
4	Antarctica	Green	Iceberg	Nickersons
5	LS11507	Green	Iceberg	Syngenta

7.1.1. Experimental set up

All experiments were completed using a culture of *M. persicae* maintained at Harper Adams University. The culture was established from a single aphid clone supplied by Rothamsted Research. This clone of *M. persicae* is of a genotype commonly found on crops grown in the UK (genotype O). The 'O' genotype has target site resistance to both carbamate (Modified AcetyCholinEsterase or MACE) and pyrethroid (knockdown resistance or kdr)

insecticides. The culture was maintained in a ventilated glasshouse on Chinese cabbage plants in insect proof cages.

Lettuce plants were grown in a ventilated glasshouse at Harper Adams University. Plants were grown in John Innes No. 2 compost. Seeds were sown directly into small (290 ml) pots. Plants were watered from beneath by standing pots on capillary matting, which was wetted as necessary.

Experiment 1 – aphid performance

Three week old lettuce plants were used in this experiment. Five wingless (apterous) *M. persicae* were carefully transferred, using a fine paintbrush, from a Chinese cabbage leaf to a lettuce plant. A perforated 'bread bag' was then carefully pulled over the plant and secured around the pot using a rubber band. The perforated bag confined the aphids to the plant but also allowed sufficient ventilation. The aphid infested plant was then transferred to a tray lined with capillary matting to allow watering from beneath.

Eleven plants (replicates) of each lettuce variety were prepared in this way. The plants were arranged in a randomised block design.

Trays of plants were transferred to controlled environment cabinets (Sanyo Fitotron) set to a constant 18°C, 60% relative humidity and 16:8 (light:dark) photoperiod. Plants were maintained within the Fitotrons for two weeks, watering plants as necessary. At the end of the two week period the plants were removed from the Fitotrons and the number of aphids on each plant recorded.

Experiment 2 – aphid host-plant selection

Four week old lettuce plants were used in this experiment. A four week old lettuce plant (var. Cook) was placed within the culture of *M. persicae* on Chinese cabbage plants. The lettuce plant was positioned so that it touched aphid infested cabbage leaves. Once the lettuce plant had become heavily infested with aphids (>100 aphids on the lettuce plant) it was removed from the aphid culture and placed in the centre of a large gauze cage (580 x 510 x 620 mm). One plant of each of the five lettuce varieties was then placed in a ring around the aphid infested Cook plant. The position of each variety was selected at random but each plant was positioned so that at least one leaf touched the central aphid infested Cook plant.

Four gauze cages (replicates) were prepared in this way. Once the lettuce plants had been arranged each gauze cage was carefully placed within the 27 m x 10 m x 3 m polytunnel

sited at CERC, Harper Adams University. A temperature and humidity data logger was placed in one of the cages in order to record environmental conditions throughout the experiment.

Plants were maintained within the gauze cages for six days, watering as necessary. At the end of the six day period the plants were removed from the gauze cages and the number of aphids on each plant recorded.

7.1.2. Statistics

All plant measurements were analysed by ANOVA using Genstat 15th Edition.

7.3. Results

7.1.3. Experiment 1 – aphid performance

The average numbers of aphids recorded on lettuce plants two weeks after infesting each plant with five wingless *M. persicae* were 55 (Helvius), 27 (Bolero), 4 (Navara), 33 (Antarctica) and 10 (LS11507) (Figure 7.1). There was no significant difference (F = 2.11, P = n.s.) between numbers of aphids recorded on each lettuce variety.

7.1.4. Experiment 2 – aphid host-plant preference

The average numbers of aphids infesting lettuce plants six days after plants were placed next to a lettuce plant (var. Cook) infested with *M. persicae* were 31 (Helvius), 6 (Bolero), 22 (Navara), 21 (Antarctica) and 14 (LS11507) (Figure 7.2). There was no significant difference (F = 1.30, P = n.s.) between numbers of aphids recorded on each lettuce variety. There was also no significant difference when numbers of aphids recorded on each lettuce variety were considered as a proportion of the total number of dispersing aphids (F = 2.53, P = n.s.).

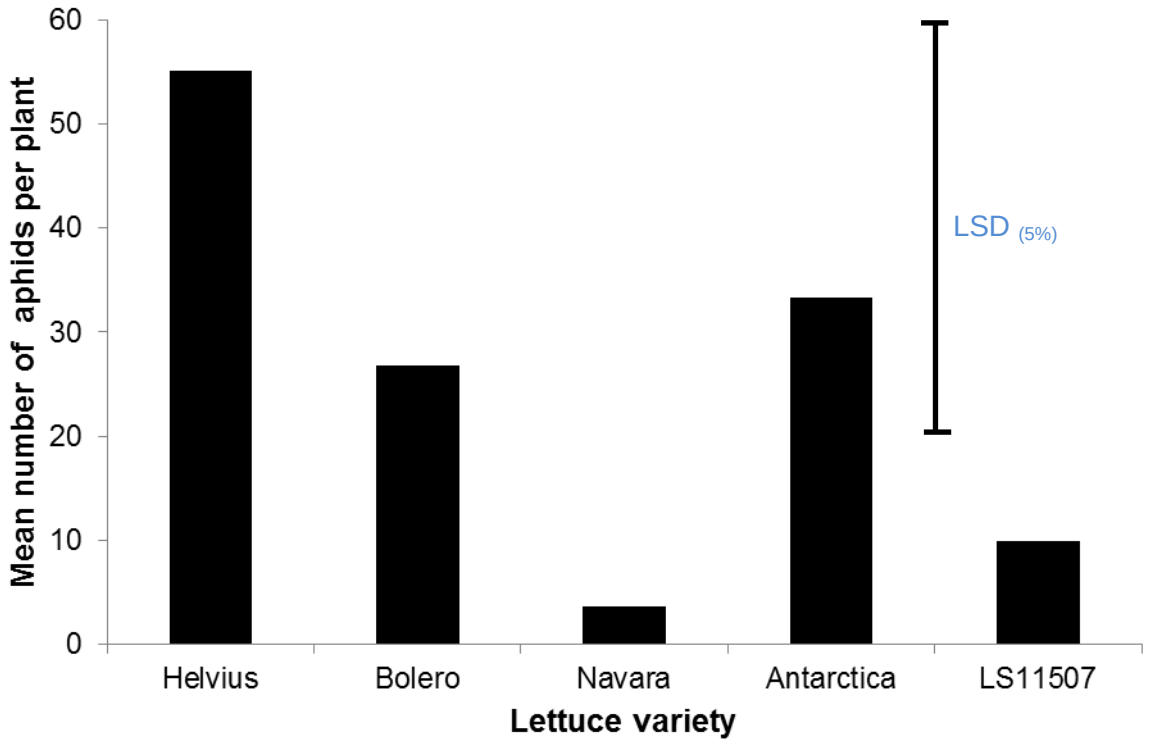

Figure 7.1 *Mean number of aphids recorded on each lettuce variety, recorded two weeks after plants were infested with Myzus persicae. Bar shows LSD(5%).*

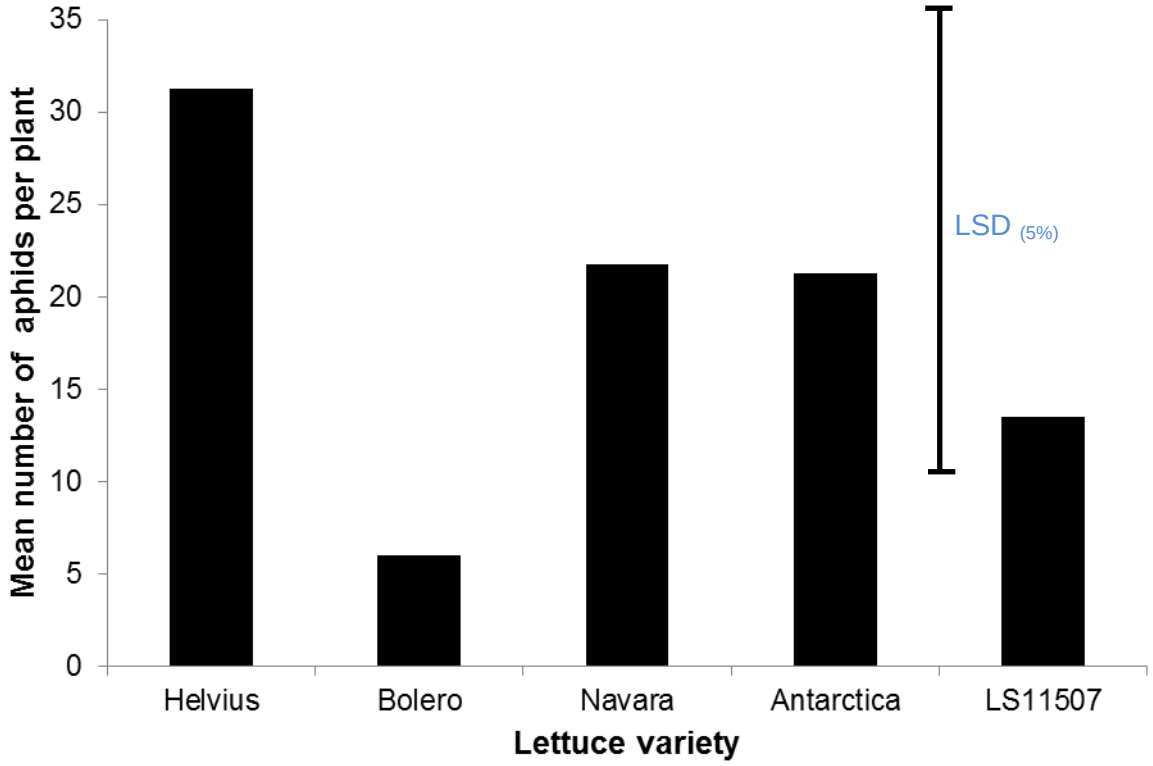

Figure 7.2 *Mean numbers of Myzus persicae infesting each lettuce variety, recorded six days after plants were placed next to an aphid infested lettuce plant (var. Cook). Bar shows LSD(5%).*

Throughout the course of this experiment the temperature within one of the gauze cages placed within the polytunnel fluctuated between a high of 28.7°C and a low of 17.5°C. The mean temperature throughout the experiment was 20.1°C. Relative humidity (RH) fluctuated between a high of 65.9% RH and a low of 48.9% RH. The mean humidity throughout the experiment was 61.7% RH.

7.4. Discussion

Myzus persicae was able to feed and reproduce successfully on all five lettuce varieties used in this study. Results from the experiments completed were characterised by large amounts of variation between replicates, meaning that statistically significant differences between lettuce varieties were not observed. However, the results do show some interesting trends suggesting that the commercial lettuce variety grown may have some effect on aphid performance and host-plant selection.

Experiment 1: rates of reproduction were generally low on all lettuce varieties tested. The highest mean number of aphids recorded two weeks after infesting each plant with five wingless *M. persicae* was 55 on the variety Helvius. Assuming that all five aphids survived being transferred onto each lettuce plant, this is equivalent to less than one nymph being produced per aphid per day. However, numbers of aphids recorded on Helivus plants ranged from 2 to 154 suggesting, either that reproductive rates were extremely variable or, more likely, survival of transferred aphids was variable. More detailed studies recording life tables, and calculation of intrinsic rates of increase, for individual aphids would be required to determine the relative importance of survival and fecundity on aphid performance on each lettuce variety. It is though worth noting that aphids transferred to Navara did not increase in number and variability was low, suggesting that *M. persicae* performed poorly on this host.

Preliminary work investigating mean aphid weight data broadly corresponded to the mean number of aphids recorded on each lettuce variety. For example, aphids feeding on the lettuce variety Helvius were the most numerous (see above) and the heaviest. Similarly, aphids feeding on the lettuce variety Navara were the fewest in number and the lightest. However, these figures will be affected by the relative number of aphids at each stage of development and so further work is required to record weights of standard age cohorts of aphids or individual aphids (e.g. calculation of mean relative growth rates).

Experiment 2: wingless *Myzus persicae* readily moved from an infested lettuce plant to surrounding lettuce plants. The dispersal behaviour by wingless or immature *M. persicae* has previously been described (Hodgson, 1991). In the present study the dispersal of these aphids is likely to have been triggered by crowding. Six days after placing each lettuce variety next to an aphid infested plant, more aphids had moved onto the Helivus plants than any other variety. In contrast, few aphids had moved to the Bolero plants. Although not statistically significant, this result appears to support a preliminary aphid behaviour experiment. In this preliminary study aphids were closely observed after being transferred from a Chinese cabbage leaf to a lettuce leaf. Aphids transferred to a Helivus leaf settled readily and quickly adopted a posture (antennae held back over their body) that indicates feeding behaviour. However, aphids transferred to a Bolero leaf did not settle readily and adopted the feeding posture less frequently. These potential differences could be further investigated using electrical penetration graphs (EPG).

While results from the host-plant selection experiment are interesting and the movement of wingless and immature *M. persicae* may be important in virus transmission, it would be important in future work to also investigate host plant selection of winged (alate) aphids. Visual and olfactory cues are likely to be important in determining host selection in these migrating aphids. Indeed, the red and green varieties selected for use in this study would present very different visual targets.

7.5. Conclusions

- *Myzus persicae* was capable of infesting all commercial lettuce varieties tested but performed poorly on the variety Navara.
- Results were variable and may reflect the initial survival of aphids transferred onto lettuce plants.
- No statistically significant differences were recorded between commercial lettuce varieties in terms of aphid performance and host-plant selection.

7.6. References

Eenink, A. H., Dieleman, F. L. (1983) Inheritance of resistance to the leaf aphid Nasonovia ribisnigri in wild lettuce species. *Euphytica*. **32**: 691–695.

Ellis, P. R., Pink, D. A. C., Ramsey, A. D. (1994) Inheritance of resistance to lettuce root aphid in the lettuce cultivars ‘Avoncrisp’ and ‘Lakeland’. *Annals of Applied Biology*. **124**: 141–151.

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Experiment 8 – Can biochar products improve growth and/or quality in HONS?

8.1. Background

Biochar (charred biomass) is produced by heating biomass in a zero-oxygen environment to temperatures of 250°C or greater, yielding energy-rich gases and liquids which can be used in other processes, and a solid charcoal, or biochar (Downie *et al*., 2009).

Biochar is being studied for two potential uses in UK agriculture and horticulture: a) as a long-term store (sink) for carbon, reducing carbon emissions, and b) as a soil/substrate improver.

There is increasing evidence that biochar has some beneficial effects when added to soils. Its highly porous structure can retain water and capture some soil nutrients and release them over time to the surrounding substrate. Some work has shown that biochar incorporation on substrates can reducing N leaching and potentially increase N use efficiency (NUE) (Prendergast-Miller *et al*., 2011). Commercial biochar based products are available in the UK for HONS growers. Some of these products also contain additional ingredients such as mycorrhizal fungi, worm cast and seaweed extract. The exact composition and benefit of these additional components is difficult to establish but some benefits have been reported (Koltai, 2010).

This project was developed with Lowaters Nursery Ltd who were interested in studying any growth effects of adding biochar or supplementary biochar to the growing substrate of containerised HONS species. The two research questions were:

- *Does biochar addition significantly affect plant growth?*
- *Does supplemented biochar addition significantly affect plant growth?*

8.2. Materials and methods

The experiment was carried out at Harper Adams University during the summer of 2013. The experiment was managed by Kat Hales who was a Summer Research Placement student from Exeter University.

The project was linked to Lowaters Nurseries Ltd.

8.2.1. Treatments

Three container grown species were studied: Lavender (*Lavandula angustifolia* cv Hidcote Blue), Hebe (*Hebe pinguifolia* cv Pagei) and Salvia (*Salvia Patens* cv. Cambridge Blue)

The plants were grown in the following mixes:

1. Peat free base mix
2. 5% Biochar
3. 10 % Biochar
4. 20 % Biochar
5. 5% Supplemented Biochar
6. 10% Supplemented Biochar
7. 20 % Supplemented Biochar

8.2.2. Experiment set up

The experiment was established in a 27 m x 10 m x 3 m polytunnel sited at CERC, Harper Adams University, supplied with mains power and irrigation water. The lower edges and ends of the tunnels were fitted with black butterfly netting to allow for ventilation but prevent entry of airborne pests and the outside perimeter of the tunnel was further protected by a 50 cm mesh electric fence. An overhead sprinkler system was installed with 2 sprinklers per ornamental area prior to laying out the experiment. The water output was measured from each sprinkler to achieve an even coverage then this was adjusted once the plants were *in situ*.

The experimental mixes were prepared in bulk prior to potting up the plants. The base mix was a peat free substrate supplied by Lowaters Nursery containing controlled release fertiliser. The base was measured onto the floor and the correct volume added of either biochar (Grochar, Carbon Gold Ltd) or supplemented biochar (Carbon Gold Soil Improver, Carbon Gold Ltd). The substrate was well mixed manually using a spade. Each bulk mix was made separately. Six 9 cm liners (Hebe and Lavender) or plugs (Salvia) per treatment were potted 2 May 2013 by adding a small amount of compost to the base of a 3 litre pot (Hebe and Lavender) or 2 litre pot (Salvia). The young plant was placed in the centre of the pot substrate mix was gradually added, the pot was then filled to a level of within 5 cm of the top. The guard plants were planted in the same way using surplus substrate.

After potting up all pots were labelled then thoroughly water with a lance and arranged in pot thick rows in the polytunnel on a double layer of Geotex membrane placed on bare earth in the tunnel. Initially irrigation was set for 30 minutes for the 3l pots and 20 minutes

for the 2l pots once a day in the morning and this was later reduced in stages and eventually manually applied according to the needs of the plants. Weeds were removed by hand at regular intervals.

8.2.3. Experimental design

The species were grown separately. Each species was laid out in a fully randomised block design with six replicates per treatment. Each species block was guarded on all sides by one row of the same species to reduce edge effects.

8.2.4. Recordings

8.2.4.1. Plant growth

The student assessed the best measures for assessing plant response to treatment and the following weekly plant measurements were taken:

The lavender plants quickly started to show symptoms of disease and dying foliage and the proportion of each pot showing foliage death was recorded. No other measurements were taken of lavender.

The spread of foliage in hebe was measured as the height from the top of the pot to the highest point of foliage and width across the widest area of foliage.

The height of salvia was measured as the height from the top of the pot to the highest point of foliage. Leaf size allowed measurement of leaf chlorophyll content of the youngest fully expanded leaf (Minolta SPAD 502 chlorophyll meter)

A destructive harvest was carried out at the end of the experiment to determine above ground biomass. All the above ground parts of the plant were cut off and placed in a pre-labelled bread bag and weighed. They were then placed in an oven at 80° for 48 hours and re-weighed. A visual assessment of root development was also recorded.

8.2.4.2. Substrate

The field capacity of each mix was measured at the start of the experiment by saturating pots of the mixes then regularly weighing each pot as the water drained until a stable value was attained. During the experiment a soil moisture meter Theta probe (Delta T Devices Cambridge) was used to measure substrate moisture on all pots and the pH and EC of the run off from a sub-sample of pots was monitored using a Jenway 4510 Conductivity meter and a Jenway 3505 pH meter.

8.2.5. Statistics

Measurements were analysed by 1 way ANOVA using Genstat 15th Edition.

8.3. Results

8.3.1. Substrate

There was no marked difference observed in estimated field capacity between the mixes (data not presented) with an average field capacity of 42%. The pH of the run-off increased with the proportion of substrate amendment for both biochar and supplemented biochar (Figure 8.1) but the increase was greater with supplemented biochar. There was a small increase in pH over the course of the experiment.

In contrast to pH, the EC of the run-off decreased with amendment of substrate at the start of the experiment and this reduction was greater with supplemented biochar (Figure 8.2). By the end of the experiment the runoff had very low levels of EC for all treatments.

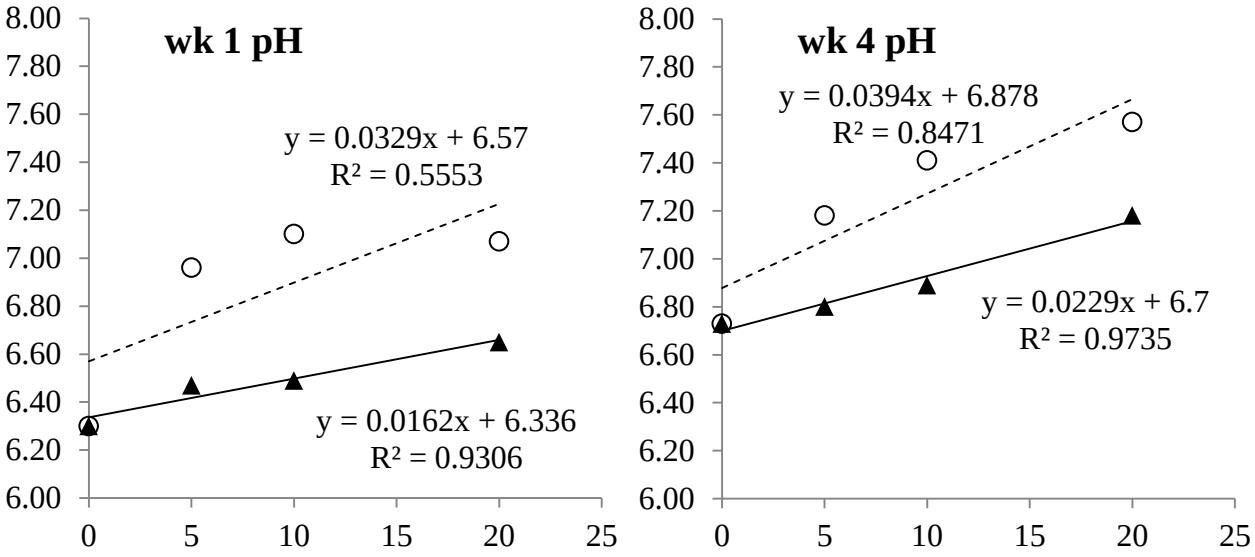

***Fig 8.1**. pH of run-off water (circles = supplemented bichar; triangles = biochar)*

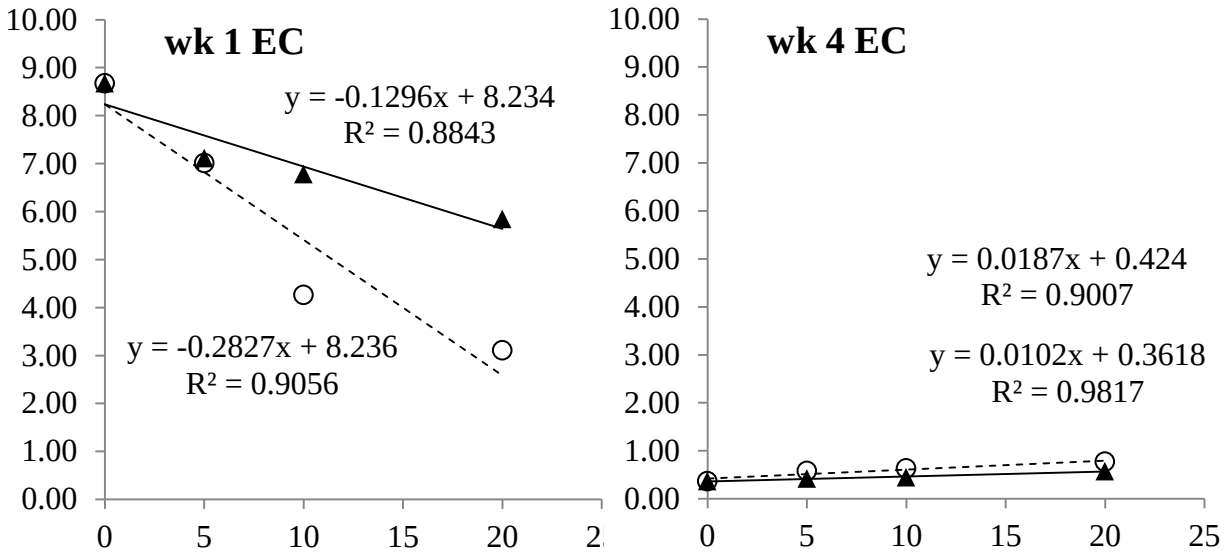

Fig 8.2. *EC of run-off water (circles = supplemented bichar; triangles = biochar)*

8.3.2. Plant growth

8.3.2.1. Lavender

Shortly after potting up, the lavender started to show signs of senescence on the foliage of some plants. The symptoms got worse as the experiment went on and the extent of damaged plants meant that no additional plant growth measures were taken and by the end of the experiment the lavender plants were unmarketable.

Significantly less dead tissue was observed on plants grown in the control mix and 20% biochar mix at both the start and end of the experiment (Table 8.1). The least dead tissue was observed on the control treatment with 6.7% and 25.2% dead tissue at the start and end of the experiment, respectively and the greatest proportion of dead tissue was found on the 20% supplemented biochar treatment with 64.2% and 90.0% dead tissue at the start and end of the experiment, respectively.

When compared to the control treatment only the 20% supplemented biochar treatment was significantly different, having a significantly greater proportion of dead tissue per plant. Overall, there was no clear response in the proportion of dead tissue per plant to addition of biochar or supplemented biochar when compared to the control treatment.

No visual difference in rooting between treatments was observed at the end of the experiment.

8.3.2.2. Hebe

The hebe grew relatively consistently across all mixes. When compared to the control treatment only the 10% biochar treatment had significantly more growth, being higher at 21.1 cm compared to 18.5 cm (Table 8.1). Overall there was no clear response in plant growth to addition of biochar or supplemented biochar when compared to the control treatment.

No visual difference in rooting between treatments was observed at the end of the experiment.

8.3.2.3. Salvia

Similarly to the Hebe, the Salvia grew relatively consistently across all mixes. When compared to the control treatment only the 5% biochar treatment had significantly more growth, at 81.8 cm compared to 63.9 cm by the end of the experiment (Table 8.1). Overall there was no clear response in plant growth to addition of biochar or supplemented biochar when compared to the control treatment.

No visual difference in rooting between treatments was observed at the end of the experiment.

Table 8.1. *Proportion of dead tissue in Lavender; mean height and width of Hebe and mean height and SPAD value of Salvia.*

	Lavender		Hebe		Salvia	
	% dead tissue 12 July	% dead tissue 12 Aug	Height (cm)	Width (cm)	Height (cm)	Leaf greenness (SPAD)
Co	6.7	25.2	18.5	63.9	29.4	40.33
5% BC	26.7	75.0	19.3	81.8	29.5	41.67
10% BC	30.0	65.0	21.1	75.4	27.8	43.33
20% BC	5.0	35.0	20.9	71.5	27.3	42.33
5% Supp BC	17.5	60.2	19.4	73.5	28.9	41.42
10% Supp BC	37.5	56.0	19.8	72.7	28.8	40.58
20% Supp BC	64.2	90.0	20.3	67.9	28.2	41.42
Mean	26.8	58.0	19.89	72.4	28.6	41.58
SE	14.1	23.1	0.88	5.3	0.7	1.43
$LSD_{(5\%)}$	40.41	46.86	2.53	15.37	3.01	4.091

8.4. Discussion

The growth of all three species was variable. The initial liners and plugs were visually uniform in size but initial manual watering may have contributed to some variation in growth early on. In addition although efforts were made to ensure the homogeneity of the mixing it is possible that rates of substrate amendment varied between pots of the same treatment. It is recommended that a larger number of reps is used to study the effects of biochar in containerised HONS.

The cause of die-back in the lavender plants is not known. No fungicides were used in the trial as symptoms were visible across the trial from early on and the decision was made to see if the biochar had an effect on plant survival. The fewest dead plants were observed with the untreated control suggesting that the addition of biochar may have contributed to plant die-back. However, this conclusion needs to be treated with caution and the growth of healthy plants may have responded differently.

In Hebe, the control plants were consistently shorter with less foliage spread than the pots containing biochar amendments. This effect was not statistically significant. There was a trend within the biochar amendments that increased proportion of biochar was associated with taller but narrower plants. Salvia plants with no amendment (control) had the palest leaves and some of the tallest plants. This effect was not statistically significant but suggests that there may have been a shortage of N in the control substrate compared to biochar amended substrates. The cause of these responses is not clear and foliage nutrient analysis would be needed to see if there was a nutritional aspect to the response of Salvia and Hebe, particularly N availability as biochar incorporation can retain N before releasing it later in plant growth (Prendergast-Miller *et al*., 2011).

There was no marked difference between the biochar and the supplemented biochar treatments in Hebe or Salvia. It may be that any benefits of the additional material in the supplemented mix are observed later in growth or when plants are planted in challenging garden environments

8.5. Conclusions

- Addition of biochar or biochar supplemented with additional components showed no consistent statistically significant benefits for the species studied
- There were some non-significant trends that suggest further work is needed to understand the potential role of biochar based substrate amendment.

8.6. References

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Experiment 9 - Does radish hypocotyl water content affect susceptibility to post-harvest splitting?

9.1. Background

Radish (*Raphanus sativus*) is a member of the mustard family, Brassicaceae. Hypocotyl splitting in radish is typically characterized by a radial longitudinal fracture which usually occurs pre-harvest or shortly (1-2 days) post-harvest during storage. Splitting in radish is an important problem for growers as levels of splits can be as high as 30% on arrival at the pack house thus exceeding supermarket tolerances of 10%. This leads to batches having to be sorted by hand which is costly. Despite these problems, little is known about the environmental and physiological causes of splitting particularly in European radishes. Identification of the factors governing splitting or splitting susceptibility may allow the development of field production, harvesting and handling practices which minimise hypocotyl damage.

Post-harvest processes include washing and storage at ambient temperature and relative humidity in open containers prior to packing. These practices may result in variable hypocotyl water contents. Hypocotyl water content may increase during washing as preliminary experiments have shown radishes are able to take up water through the periderm. Alternatively water content may decrease during storage as preliminary experiments have also shown radishes are able to loose water through the periderm of the hypocotyl due to evaporation.

Increased hypocotyl water content could enhance the susceptibility of the radish hypocotyl to splitting post-harvest by increasing turgor pressure within the tissue of the hypocotyl. There have been no reported investigations into the effects of hypocotyl water content on splitting susceptibility in European radishes but (Anon n.d.) found failure force in carrot parenchyma tissue was negatively correlated with tissue turgor and water potential suggesting there may be a relationship between turgor and susceptibility to splitting in other vegetables.

These experiments were completed to address the research question:

- *Does radish hypocotyl water content increase susceptibility to post-harvest splitting?*

9.2. Materials and Methods

The experiment was carried out at Harper Adams University during the summer of 2013. The experiment was managed by Iain Place who was a Summer Research Placement student from University of Manchester.

The project was linked to G's Growers.

9.2.1. Experiment set up

Radishes from G's farms, Cambridgeshire were couriered on the day of harvest to arrive at Harper Adams University the following morning. Upon arrival radishes were briefly washed in de-ionised water (dH_2O) to remove soil residue and trimmed to remove any remaining leaf stalks and roots. To remove some of the variability due to the heterogeneous nature of radishes they were then placed into plastic pots in groups of three, the experimental unit was one pot of three radishes. The pots of radishes were placed into a MLR-351H Versatile Environmental Test Chamber (SANYO Electric Co. Ltd., Japan) where they were either allowed to air dry or the pots were filled with approximately 100 ml of dH_2O to saturate the hypocotyls. Radishes were removed from the chamber every 2 to 3 days over the following week, weighed and subjected to texture analysis. After texture analysis the radishes were dried to a constant weight at 105 ºC to calculate the water content at the point of analysis. The chamber was set to 90% relative humidity and achieved an average of 83.5 % ranging from 62.0 % to 100.0 %, the temperature was set to 4 ºC and achieved an average of 4.5 °C ranging from 2.5 ºC to 7.4 °C. The variations in temperature and relative humidity are thought to have been due to the regular opening and closing of the chamber to remove samples.

9.2.2. Texture analyses

9.2.2.1. Puncture

Puncture tests were performed using a TA.HD.plus texture analyser (Stable Micro Systems, Surrey, England). The texture analyser was fitted with a P/2 cylindrical probe, the test speed was 1 mmS^{-1} and the test distance was 16 mm. During the experiment a curve was plotted of the force (kg) as a factor of distance. The point at which the periderm of the radish was punctured could be observed on the plotted curve as abrupt decrease in force.

9.2.2.2. Impact

Impact tests were performed using the method described by (Hartz *et al*. 2005). Radishes were dropped down a plastic tube onto an aluminium plate. There was a slight modification to the method used by Hartz *et al* (2005), in this experiment the drop height was increased

from 1 m to 1.4 m as this height is the height from which radishes are dropped commercially when they are harvested into the trailer.

9.2.2.3. Compression

Uniaxial compression tests were performed using a P/75 probe fitted to a TA.HD.plus texture analyser (Stable Micro Systems, Surrey, England). The test speed was 0.05 mmS^{-1} and the test distance was 16 mm. During the test a curve was plotted of force (kg) as a factor of distance (mm). As the compression distance increased peaks were observed in the graph profile. Each peak indicates a compression failure in the radish. For the purposes of this experiment the force of the first peak was recorded as the force required to split the radishes.

9.2.3. Statistics

All results were analysed using Genstat 15th Edition. Results from puncture and compression were analysed using linear regression. Results from dropping were log transformed and analysed using a general linear model with Poisson error structure.

9.3. Results

By air drying and saturating in dH_2O a range in hypocotyl water contents between a minimum 93% and a maximum of 97% at saturation was achieved. All radishes were considered to be commercially viable by examiners.

Puncture. There was a linear negative correlation (*P*<0.001) between the puncture force (kg) and the hypocotyl water content (%) which can be expressed by the equation:

$y = -0.3259x + 32.268$ ($R^2 = 0.71$) (Figure 9.1).

Impact. There appeared to be a threshold at a hypocotyl water content of 96.5% above which splitting as a result of dropping occurred. The average percentage of split radish per pot below a hypocotyl water content of 96.5% was 0.8% (n=42), above 96.5% this number increased to 38.1% (n=28) (Figure 9.2).

Compression. No relationship between hypocotyl water content and the force at splitting was observed (*P*=0.4 n=68). Some radishes had not split at the maximum load of 35 kg.

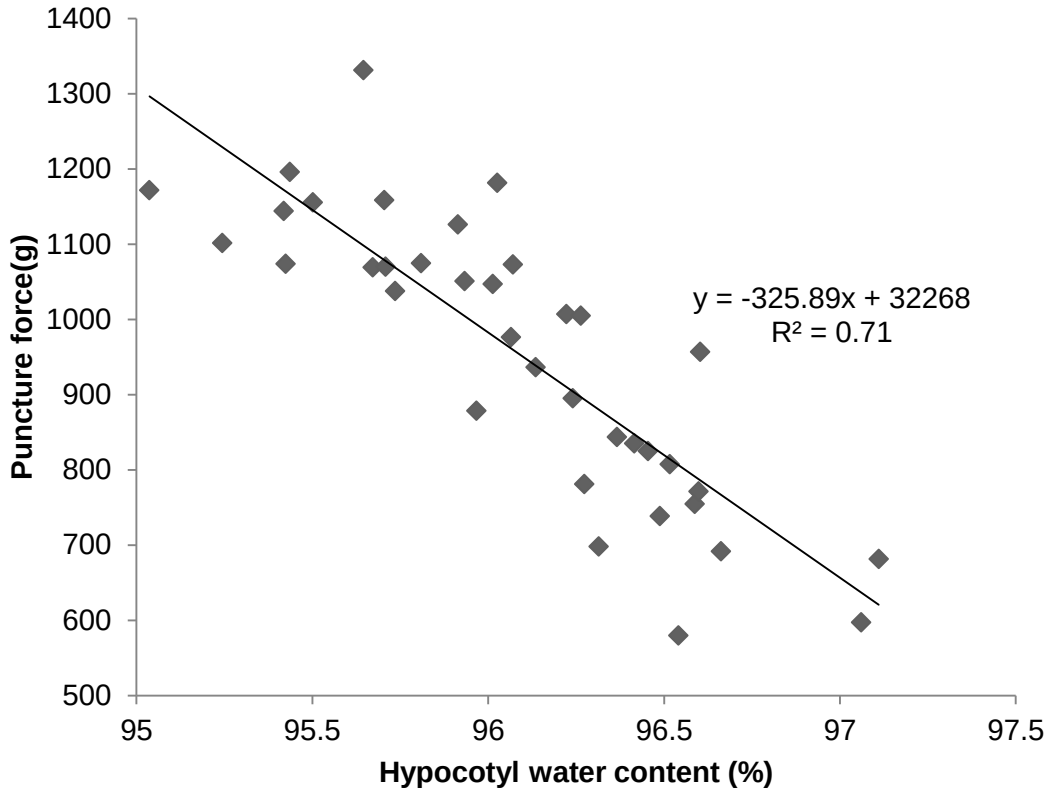

Figure 9.1 *The force required to puncture the periderm of radishes at different radish hypocotyl water contents. n=37. P<0.001.*

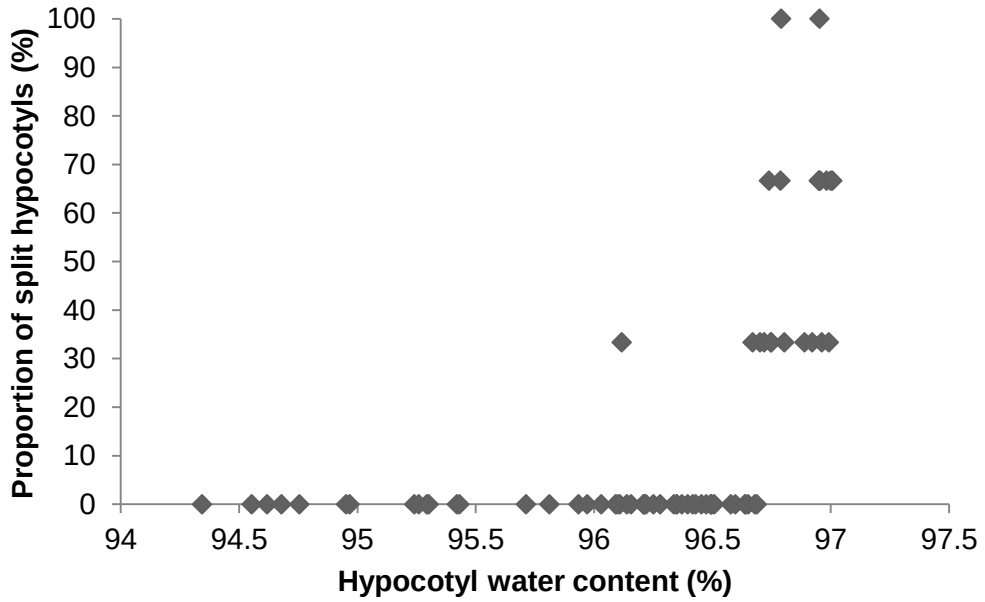

Figure 9.2 *The percentage of split radish hypocotyls in a sample of three which split as a result of dropping down a 1.4 m tube onto an aluminum plate at different hypocotyl water contents. n = 70. P<0.001.*

9.4. Discussion

Radish hypocotyls are more susceptible to damage from dropping and puncture at high hypocotyl water contents. This is in accordance with work carried out on carrots and potatoes where increased water potential and turgor have been shown to be related to increases in splitting ((Konstankiewicz & Zdunek 2001; Anon n.d.)Konstankiewicz and Zdunek, 2000; McGarry, 1993, 1995). In these experiments it was concluded that an increase in tissue turgor pressure results in an increase in the tension of the cell walls. It is thought the increase in splitting of the radish hypocotyl at high hypocotyl water contents after dropping and puncture may also be as a result of increased turgor pressure and therefore increased cell wall tension at high water contents. To make this investigation commercially relevant further work is required to determine the turgor pressure of the radish hypocotyl at different water contents and then to investigate hypocotyl water contents and turgor pressure in the commercial supply chain. In addition the puncture force radishes would be exposed to commercially should be measured.

No relationship was observed between the hypocotyl water content and the force required to crush the radish. This may have been due to the method used to crush the radishes. Radish juice was observed to be squeezed from the radishes during the crushing process. As a consequence the radishes would not have been at the same water content when they fractured as when the test commenced and the water content was measured. Further work needs to be done to refine the crushing method and ensure the hypocotyls maintain their water content throughout the process.

9.5. Conclusions

- There is a negative correlation between hypocotyl water content and the force required to puncture the hypocotyl
- Radishes are more susceptible to splitting as a result of dropping at hypocotyl water contents above 96.5%

9.6. References

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Experiment 10 – Can a Calcium foliar spray improve yield or post-harvest quality in strawberries?

10.1. Background

Strawberries are very perishable fruit having soft flesh that is prone to breakdown and fungal attack giving a shelf life of about a week (Wills, 1998). It is not unusual for a small number of fruit to have started to breakdown towards the end of life leading to customer complaints and product being wasted. Strawberry fruit are picked and cooled before entering the supply chain and refrigeration helps to maintain quality.

Crop nutrition is an important preharvest treatment affecting postharvest fruit quality. Calcium has a particular role in membrane integrity in plants (Lara *et al*., 2004). It is known that postharvest application of Ca as a fruit dip can improve strawberry fruit quality (García *et al.,* 1996) suggesting that additional Ca applied prior to harvest may improve postharvest membrane integrity and tissue firmness.

The production of a large number of strawberry fruit allowed the student to study the distribution of sugars (measured as Total Soluble Solids – TSS) within the fruit. Suppliers and retailers are frequently measuring sugar levels of fruit to ensure that specifications are complied with. Sugar levels may differ between areas of the fruit and understanding the relative distribution will allow QC protocols to be developed.

This trial was established to compare the effects of applying a foliar Ca containing spray to table-top 60 day strawberry plants and asked two research questions:

- *Does foliar application of Ca affect marketable yield or post-harvest quality of table-top strawberries?*
- *Does brix differ between the top and bottom half of a strawberry?*

10.2. Materials and methods

The experiment was carried out at Harper Adams University during the summer of 2013. The experiment was managed by Will Johnson who was a Summer Research Placement student from Bangor University.

The project was linked to Plant Impacts Ltd.

10.2.1. Treatments

Foliar applications:

1. Control - no foliar calcium
2. 5% Ca (w/w) sprayed at 1 l/ha every 1 week from first flowering
3. 5% Ca (w/w) sprayed at 1 l/ha every 2 weeks from first flowering
4. 9.5% Ca (w/w) sprayed at 1.5 l/ha every 2 weeks from first flowering

10.2.2. Experiment set up

A 27 m x 10 m x 3 m polytunnel sited at CERC, Harper Adams, supplied with mains power, potable and irrigation water was used for the 2013 HDC summer project strawberry trial. The lower edges and ends of the tunnels were fitted with black butterfly netting to allow for ventilation but prevent entry of airborne pests and the outside perimeter of the tunnel was further protected by a 50 cm mesh electric fence.

4 x 24 m lengths of ridged profile aluminium container floor board width 22 cm x 3cm deep were supported at intervals by plinths of 5 breeze blocks to a height of 53 cm arranged lengthwise down the tunnel at a spacing of 1.6m apart. 20 mm irrigation line was attached with cable ties to one edge of each aluminium strip and the far end was doubled over and secured with a cable tie. The other ends were connected to an in-line Dosatron DI-16 and feed stock tank and the irrigation and fertigation program was controlled by a Hunter ICC (Hunter Industries) irrigation controller. The controller was set to irrigate each line for 4 x 10 minute events each hour. During vegetative growth Solufeed strawberry starter feed (15:7:30) was used at a concentration of 1kg / 10 l diluted to 1:200 during an irrigation event, this was then changed for Solufeed SF-C (7:12:35) at fruit formation used at the same rate. Neither fertiliser included Ca (as this would lead to precipitation of phosphates out of the stock solution). The irrigation water was analysed before the start of the experiment and contained 51.4 mg/l Ca.

Standard growing medium bags (Bulrush Ltd) were used. Prior to laying the bags on the benching each bag was shaken to break up any compaction from storage. The bags were placed lengthwise on the bench and butted up to each other in pairs. Single-outlet drippers were attached to the main irrigation line and 2 drippers were placed in each bag with equal spacing. An extra planted irrigated bag was used to test out the spraying method. This was placed at the end of a bench on a plastic tray fitted with a spout to drain into a container to monitor water input and run off.

Each bag was planted with 10 crowns of Elsanta 18-20 mm crowns (Hargreaves Plants Ltd, Spalding) in a double row formation. After planting, the irrigation was set to constant for several days to thoroughly wet up the bags.

Once plants were established a standard spray program was applied to control Botrytis, mildew and aphids. For the first few weeks alternate sprays of Spruzit 2 l/ha and Amistar 1 l/ha were used. This was followed by a tank mix of Scala 2 l/ha and Nimrod 1.4 l/ha then the following week a tank mix of Scala 2 l/ha and Systhane 230m l/ha. In the remaining weeks of the trial the following spays were applied weekly in the order given. Nimrod 1.4 l/ha, Systhane 230 ml/ha, Fortress 250 ml/ha, Fortress 250 ml/ha. Weeds in the tunnel were controlled by regular manual hoeing and runners were regularly removed from plants by snipping them off to within 2 cm of the plant.

10.2.3. Experimental design

The tunnel contained four raised benches; each bench was treated as a block giving four blocks in total. Each block had eight experimental units consisting of two adjacent bags with 20 plants. Two experimental units of each treatment were randomly allocated in each block.

10.2.4. Calcium applications

Calcium treatments were supplied by Plant Impacts Ltd (Herts, UK). Calcium rates were calculate at an application rate of 1 l/ha which equated to applying 100 ml to each experimental unit. A spray time of 35 seconds per unit was established using water on spare plants. The calcium treatments were mixed and applied using a 1.25 l Hozelock hand pressure sprayer.

10.2.5. Recordings

The irrigation run-off from the spare bag was sampled weekly and tested for pH and EC using a Jenway 4510 Conductivity meter and a Jenway 3505 pH meter to maintain target values of EC 1.8 – 2 and pH 6.

Once plants had established soil moisture was monitored weekly in between the drippers from the side of each bag using a Delta T HH2 Theta probe (Delta T Devices Cambridge) moisture meter.

Leaf chlorophyll readings using a Konica Minolta SPAD 502 chlorophyll meter were taken each week from the youngest fully expanded leaf from 2 plants per bag (= 4 leaves per experimental unit).

10.2.6. Harvest and assessment

Harvests 1 to 4 took place bi-weekly (Monday and Thursday); harvests 5 and 6 were weekly (Monday). All fully ripened fruit were harvested into one container then graded into Class I, as defined by International Standardisation of Fruit and Vegetables marketing standards OECD (Organisation for Economic Co-operation and Development) and Class II (waste, damaged and deformed fruit). The weight of each grade was recorded. Ten Class I fruit were selected for post-harvest quality studies and stored in the 15°C cold store for 8 days after which the number of fruit displaying rots/fungi were counted. From the remaining Class I fruit, 5 randomly selected fruit were measured (calyx to base) and then were cut in half at the equator and the juice from each hemisphere was tested using a refractomer to measure total soluble solids (°Brix).

10.2.7. Statistics

All plant measurements were analysed by 1 way ANOVA using Genstat 15th Edition.

10.3. Results

There was no significant pest or disease damage to the crop.

10.3.1. Yield

The fruit were harvested over a four week period. There was no difference in yield between the treatments at any harvest date for total, Class I or Class II yield. A similar pattern was observed for all three measures with the first harvest yielding the most fruit. Class I yields ranged from an overall average of 37.0 g/plant at the first harvest to 6.2 g/plant at the final harvest (Fig 10.1). Overall treatments, Class I yield was 57.0 g/plant in the first week followed by 31.7, 11.1 and 6.2 g/plant in the subsequent weeks.

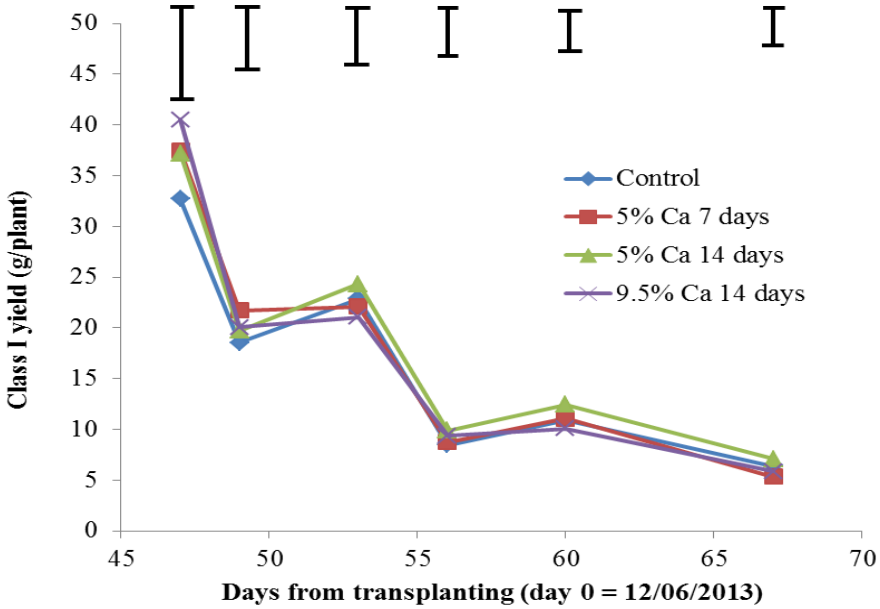

Figure 10.1. *Class I yield (g/plant). Bar =LSD$_{(5\%)}$*

10.3.2. Leaf colour

Foliar Ca treatment had no effect on leaf colour at any date. There was an average SPAD value ranging from 27.2 to 31.3 over the experiment, and an overall value of 29.6.

10.3.3. Brix

Treatment had no effect on fruit brix at any harvest (Table 10.1). Brix increased over the harvest window from 8.3 at the first harvest to 12.4 for the final harvest. This response was observed for all treatments.

Table 10.1. *Brix of entire fruit (combined top and bottom) sampled at each harvest (n=4).*

	47	**50**	**54**	**57**	**68**
Control	8.5	7.9	10.5	11.3	12.3
5% Ca 7 d	8.5	8.3	10.0	11.1	12.7
5% Ca 14 d	8.4	7.3	10.1	10.8	12.1
9.5% Ca 14 d	7.8	7.5	10.2	12.0	12.5
Mean	8.3	7.7	10.2	11.3	12.4
SE	0.71	0.44	0.39	0.56	0.85
p	0.66	0.14	0.52	0.26	0.90

7.1.5. Breakdown

There was no consistent effect of treatment on the breakdown of fruit after 8 days storage at 15°C (Table 10.2). Breakdown significantly increased with 5% Ca applied every 14 days, when compared to control at the third harvest (d 54).

Table 10.2. *Number of fruit showing breakdown (max = 10) after 8 days storage at 15°C.*

	47	**50**	**54**	**57**	**68**
Control	8.1	8.0	4.3	5.1	9.3
5% Ca 7 d	8.6	8.3	4.8	7.1	8.9
5% Ca 14 d	6.9	8.0	7.3	8.4	8.4
9.5% Ca 14 d	8.8	7.1	5.3	6.8	8.1
Mean	8.1	7.8	5.4	6.8	8.7
SE	0.93	0.97	1.47	0.87	0.94
p	0.20	0.67	0.21	0.01	0.62

7.1.6. Top v bottom hemisphere

When the brix data from all the harvests were combined a relationship was observed between the value derived from the top and bottom hemispheres of individual fruit (Fig 10.2). The relationship was described by the equation:

Top °Brix = (0.82 x bottom °Brix) + 1.16

When the brix of the top hemisphere was less than 7.5 the bottom hemisphere had a relatively lower brix value. This relationship was reversed when the top hemisphere had a brix greater than 7.5. However, the data was variable and this variance increased as brix increased.

7.1.7. Length x brix

All but one fruit were between 2.0 and 4.0 cm long with an average length of 2.9 cm. The length of fruit was not correlated with brix of the top hemisphere (Fig 4.3).

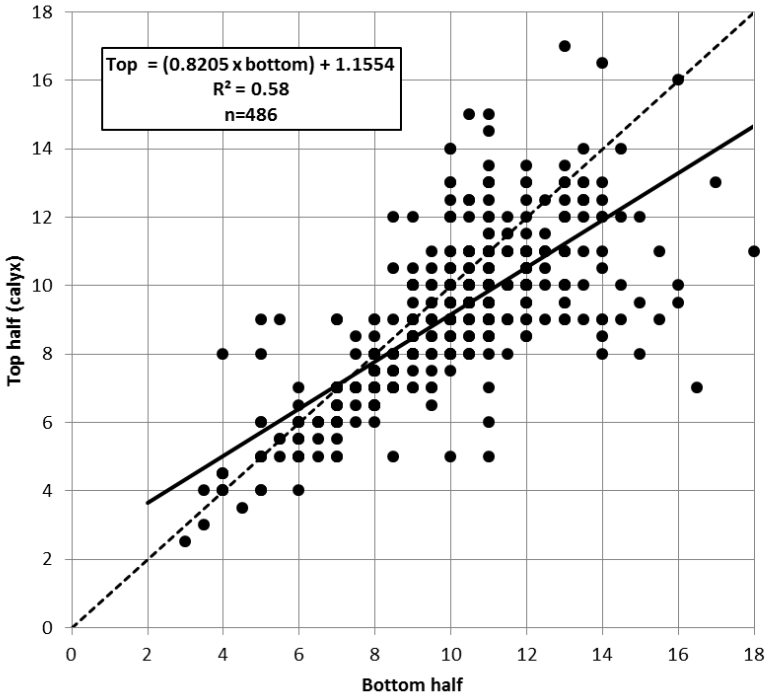

Figure 10.2. *Relationship between Brix in the top and bottom hemisphere of ripe class I fruit.*

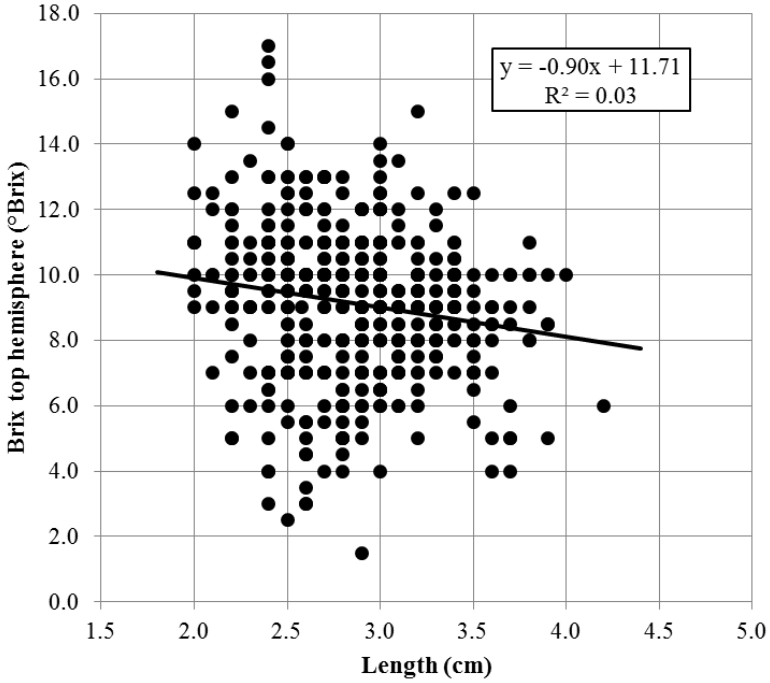

Figure 10.3. *Relationship between length and Brix of the top hemisphere of ripe class I fruit.*

10.4. Discussion

Does foliar application of Ca affect marketable yield or post-harvest quality of table-top strawberries?

In general, Class I yields declined and brix levels increased over the experiment but under the conditions of this study, additional foliar applied Ca conferred no significant difference in yield or brix of table-top strawberries. Fruit breakdown varied over the experiment but no consistent response to Ca was observed. This lack of response may be due to inadequate supply of Ca from the treatment. It is not known how much was acquired by the leaves or the fruit. The treatments were applied as a water-based spray applied to both leaves and fruit within the crop canopy. Neither the proportion of Ca directly applied to the surface of developing fruit nor the extent of foliar uptake and subsequent translocation to the fruit was measured. The fertiliser used in the study (Solufeed SF-C) contains no Ca but the irrigation water contained 51.4 mg/l and it may be that adequate Ca was supplied in the irrigation water. Further work analysing Ca levels in the plant and fruit would be needed to identify the underlying cause of the observed lack of response in this study.

Does brix differ between the top and bottom half of a strawberry?

A relationship was observed between the TSS measured as °Brix in the top and bottom hemispheres of ripe fruit. When overall brix was approximately 7.5 the top and bottom of the fruit had similar levels of sugars. When the sugar level in the top hemisphere decreased below 7.5 there was a more marked reduction in sugars accumulating in the bottom of the fruit. The opposite was observed when the level of sugar increased above 7.5 in the top of the fruit, with a greater accumulation of sugar in the bottom of the fruit. The physiological basis for this response is not clear. It may be that sugar accumulates in the fruit close to the calyx and as sugar levels increase these are preferentially allocated to the distal region of the fruit.

This response was not explained by sugar allocation as fruit expanded as there was no relationship between fruit size, measured as length, and sugar content in the top of the fruit.

10.5. Conclusions

- Under the conditions studied there was no benefit of additional foliar Ca to fruit yield, sweetness or post-harvest quality.
- Sugar accumulation was not uniform between the top and bottom of the fruit with differences as great as 2 °Brix between the top and bottom of fruit.

- This response depends on the average °Brix of the fruit and becomes more variable as the average °Brix of the fruit increases.
- Growers should ensure that samples used for QC are taken from the length of the fruit and averaged.

10.6. References

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