Project title:	The impact of pre-harvest treatments on shelf-life and quality in baby leaf spinach
Project number:	FV 438
Project leader:	Angela Huckle, ADAS UK Ltd
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Location of project:	Growers' holdings in Cheshire, Dorset, Kent, Norfolk, Shropshire and Wiltshire
Industry Representative:	Dr Graham Clarkson, Vitacress Salads UK
Date project commenced:	2 April 2014
Date project completed **(or expected completion date):**	6 February 2015

DISCLAIMER

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the studies were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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.

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CONTENTS

GROWER SUMMARY

Headline

There is no evidence to suggest that the application of pre-harvest foliar sprays extends shelf-life in baby leaf spinach. Of the nine products evaluated in this study none performed consistently better than any of the others across all sites.

Background

Baby leaf salads are a rapidly growing sector within fresh produce, with a range of species being valued for their visual appearance and flavour. As a result, the industry has seen an increase in sales in recent years. Shelf life is a critical factor for all growers, more so for bagged salad products whose quality specifications are tightly defined by the retailers. These include the ability of leaves to maintain leaf integrity to avoid breakdown whilst still on retail shelves and later in consumers' homes. Growers employ practices such as optimizing nitrogen (N) fertiliser applications, to ensure that quality remains at the specified standard for a given length of time (i.e. the produce shelf-life).

New products with claims or reports to improve shelf-life or appearance continue to make their way to the market. The UK growing industry is regularly presented with a number of pre-harvest foliar-spray chemical or biological products and it is known that some growers are using them. Some of these products are not cheap. Prior to this project, no work had been done to demonstrate the benefits of applying the individual products to a crop in comparison to a no-application control and the products had not been compared objectively within a commercial production environment.

Summary

This aim of this work was to investigate the effects of spraying different chemical and biological products on leaf quality and the extension of shelf life in baby leaf spinach in comparison to a 'no-foliar-spray' control. Six of the products that were evaluated contain a form of calcium (Stopit, InCa, Calsym, Calmax Ultra, CapiTal and Advocate), four contain other trace elements (Calmax Ultra, CapiTal, Advocate and Maxicrop) and three are biological based treatments or they are reported to contain 'bioactive agents' (Maxicrop, Tensile and ProAct, the latter based on Harpin protein). The treatments and contents of the tested products are given in the table below:

Treatment & Composition of products used in the trial:

Treatment no.	**Product**	**Composition, claims and reported nutrient analysis**
2	Stopit Yara)	Calcium chloride based (food grade). Analysis; Ca 16
3	InCa (Plant Impact)	Calcium and nitrogen based product (inorganic salts). Analysis; NPK 4.5:0:0 +Ca 7
4	Calsym (Verdesian)	Calcium and phosphorous based (no information available on analysis)
5	Calmax Ultra (Omex)	Inorganic emulsion containing calcium nitrite tetrahydrate plus trace elements. Also contains technology called 'AXM' designed to aid transport of Ca into cells. Analysis; NPK 9:0:0 +Ca 21.8
6	TenSile (Ilex)	Phosphite, potassium, and silicon plus polysaccharides derived from seaweed (2% 'bio-active agents'). Strengthens plant cells and improves shelf life by reducing transpiration and water loss. Analysis; NPK 0:2:8 +Si 8
7	CapiTal (Ilex)	Calcium phosphite based product, including zinc and boron. Analysis; NPK 4:30:8 +Ca 6.6, B 0.8, Zn 2.4
8	AdvoCate (Ilex)	Calcium based product (Calcium chloride 10%) complexed with natural sugars and amino acids (7.5% w/v 'bio-active agents'). Analysis; NPK 3.6:0:0 +Ca 9.0, B 0.02, Zn 1.5, Fe 0.18, Mo 0.1
9	ProAct (PHC)	Harpin protein based product; elicitor-reduces plant stress through Systemic Acquired Resistance (SAR)
10	Maxicrop (Maxicrop)	Seaweed extract; Benefits include stimulation of plant growth, improved biological activity around root zone. Analysis; NPK 3.1:1.4:2.9

**Treatment 1 was the no spray control*

The products were applied at the following rates:

Treatment No	**Product (manufacturer)**	**Rate of application of product (L/ha unless otherwise stated)**	**Water volume (L/ha)**
1.	Untreated control	-	-
2.	Stopit	5.0	200
3.	InCa	1.5	200
4.	Calsym	2.0	200
5.	Calmax Ultra	2.0	300
6.	TenSile	3.0	300
7.	CapiTal	3.0	300
8.	AdvoCate	3.0	300
9.	ProAct	0.2 kg/ha	300
10.	Maxicrop Triple	1.5	300

The study was carried out over six sites across the UK in a single season, these sites were chosen in geographically separate areas to represent the different climatic and soil conditions where baby-leaf is grown. As there were different sowing dates and growing conditions for each site, different spinach cultivars were used at each site.

Prior to drilling, topsoil (for pH, P, K and Mg) at 0-15 cm and Soil Mineral Nitrogen (SMN) samples at 0-30 cm depth were obtained. Treatments were applied twice over the growing period, the first at two true leaf stage and the other approximately 4-7 days prior to harvest. Each treatment was applied with an OPS sprayer with a 1.5 m spray width.

Harvest occurred in the early summer and samples were transported to ADAS Boxworth where they were weighed and then separated into 7 x 100 g samples for each treatment. The full duration of chilled storage at ADAS Boxworth was 7 days, with one sample of each treatment and each site assessed pre- and post-washing for leaf damage, dehydration and bruising. Leaves were washed in line with standard industry practice at Boxworth. For Site 14/1, on the 7th day of storage, leaf dimensions (length, width and stem length) were also measured.

Shelf life measurements that were statistically analysed were the reduction in leaf damage (holes, tears etc); leaf bruising (i.e. based on the industry protocol) and dehydration levels. Yield measurements were also made.

Shelf-life responses

The relative values of the different products varied across all treatments and sites, with no one treatment having an outstanding effect on shelf life extension overall. There were no significant differences in terms of the reduction in leaf damage, dehydration or bruising between treatments at any of the sites, compared with the control. If each assessment parameter was observed individually, treatments that extended shelf life with respect to leaf damage were Inca, Maxicrop and TenSile, which gained one extra day at 2 of the 6 sites. For dehydration, an extra day was gained at two of the six sites for Inca, CapiTal, Stopit and Calmax. There was no extra gain in shelf life length from the treatments for the bruising assessments, although at two of the sites, TenSile, ProAct and Calmax all had reduced levels of bruising compared to other treatments.

Yield responses

Averaged over all sites, eight of the nine treatments yielded more than the control. However, the results varied again between sites, and there were no significant differences between treatments at individual sites. The only sites where all treatments yielded greater than the control were Sites 14/2, 14/4 and 14/5. InCa had the greatest yield responses at Site 14/5 with a 15.3% increase in yield. Site 14/5 had the lowest P index prior to drilling, and therefore the higher yield response at this site may indicate a simple nutrient response, which could have been achieved with other fertiliser products. It was also noted that averaged over sites, the treatments which demonstrated the greatest increases in yield in comparison to the control were Stopit and ProAct, each very different in their chemical composition. Stopit is a nutrient based formulation of calcium chloride, whereas ProAct is a protein based product. Each had an average increase of 5% in yield over the control.

Financial Benefits

The statistical analyses suggest that there are no benefits in using any of these products for shelf life extension on UK summer-grown baby leaf spinach. Growers could avoid using such products, saving them money.

Action Points

- As there was no evidence in these experiments to suggest there was a positive benefit resulting from any of the products used, growers should only consider using them where there is confidence in other reported benefits (i.e. other than shelf life extension),

- Before applying any of the products used in these experiments for improving yield, based on an expected crop response to nutrients, growers should take into account nutrients applied through other fertiliser products, and where necessary seek the advice of a FACTS qualified advisor.

SCIENCE SECTION

Introduction

Costs to the horticultural industry through waste from poor shelf life affect both the producer and consumer, where poor shelf life of a product bought from a supermarket supplier by a producer could result in costly returns and a reduced demand from the consumer. The industry required more investigation into the influence of pre-harvest management of crops to improve post-harvest crop quality that then influences shelf life.

The treatments that were investigated in these experiments are manufactured to extend shelf life in horticultural crops. Six contain a form of calcium (Stopit, InCa, Calsym, Calmax Ultra, CapiTal and Advocate), four contain trace elements (Calmax Ultra, CapiTal, Advocate and Maxicrop) and three are biological based treatments or reported to contain 'bioactive agents' (Maxicrop, Tensile and ProAct, the latter based on Harpin protein). The principle for the calcium based treatments is that calcium is known for improving the integrity of plant cell walls and membranes, pH control within soil and plant cells, reduction in transpiration and ethylene control (Poovaiah, 1986). However, calcium is relatively immobile in the soil and plant, making effective uptake and transport key factors for assimilation into plant tissue cell walls. A review by Iqbal *et al.* (2013) states that calcium has been shown to be a key player in extending the shelf life of tomatoes when the level of Ca nutrition throughout the growing season has been increased, resulting in a lower level of ethylene production. This was correlated to the increase of Ca concentration in the cell wall, improving its integrity, and within the cell itself.

Information regarding the specific roles of mineral nutrition in the extension of shelf life is scarce, but the importance of key nutrients required for crop yield forming processes may also be important for shelf life improvement or extension. The majority of the information available in terms of extending shelf life relates to post harvest treatments such as chitosan and calcium chloride dips, as well as the use of an organic form of calcium, calcium lactate, which has been shown to have had some success on lettuce (Martin-Diana *et al.,* 2007).

Non-calcium based treatments have also been claimed to extend shelf life in vegetables and were studied in the present project. One of the products is protein based and two are based on seaweed extracts. One of the seaweed treatments, Maxicrop, claims to be an 'all-rounder', where it provide secondary metabolites and growth hormones to the plant to aid growth, but its concept is not wholly understood (Zamani *et al.,* 2013; Khan *et al.,* 2009). It is then suggested that it would be considered as a plant growth promoter (PGP) that improves a plants physiological system through hormonal activity. Growers in the horticultural industry are known to use seaweed extracts in propagation and establishment, as there is evidence of them having positive effects on soil health (enhancing soil biota, improving moisture retention and improving root health). Silicon is an element widely distributed and abundant in UK soils. It has a role in protecting and toughening plants, particularly the cell walls of grasses. However there is no published information on its use in baby leaf salad species. Soluble silicon compounds have found some use in soilless (hydroponic) systems, for example to increase shelf life in species like corn salad (Gottardi et al., 2012), and to improve resistance to *Pythium aphanidermatum* in cucumber (Chèrif et al., 1994).

The aim of this experimental series was to investigate the effect of nine chemical and biological treatments on leaf quality and the extension of shelf life in baby leaf spinach, compared against a control. Experiments were carried out at each of six sites across the UK for both washed and unwashed samples. The objectives were to:

- Evaluate the ability of a range of commercial plant health and fertiliser products applied during in-field production to boost yield and extend post-harvest shelf-life,
- Test whether a range of products improve robustness and shelf-life,
- Measure yield and monitor shelf-life post-harvest of the fresh produce,
- Quantify the potential commercial benefits of such products in terms of yield, quality and shelf-life extension.

Materials and methods

The study was carried out over six sites across the UK in a single season. As there were different sowing dates and growing conditions for each site, different spinach cultivars were used at each. Additionally, an experiment was undertaken to compare the effect of unwashed and washed baby leaves from site 1 only in terms of shelf life.

Site selection, treatments, harvest and assessments

Field experiments were established on grower holdings. Experimentation was carried out through the summer into early autumn of 2014, representing the full duration of the UK growing season and covering both first and second crops. Table 1 shows variety, sowing and harvest dates, SMN, pH and P, K and Mg levels. Representative topsoil (for pH, P, K and Mg) and SMN samples at a 0-15 cm depth were taken prior to drilling using a standard 12 point W-shaped sampling system pattern. Soil samples were bulked to provide a single analysis for the whole trial for background SMN for each site separately.

Table 1. Site details including crop variety, sowing and harvest dates, pH, SMN and P, K and Mg indexes on commercial growers' premises in 2014.

Site	Harvest Dates	pH	SMN	P index	K index	Mg index
14/1 Wilts	12/06/2014	7.2	81	5	3	2
14/2 Shrops	10/07/2014	6.3	219	5	3	2
14/3 Kent	04/08/2014	7.4	144	4	2+	3
14/4 Chesh	27/08/2014	7.9	237	2	2-	1
14/5 Nflk	04/09/2014	8.1	93	2	1	3
14/6 Dorset	16/09/2014	7.0	115	4	2+	3

Table 2. Table of products selected for trial by the industry, with application rates and water volumes according to the product label.

Treatment No	Product (manufacturer)	Rate of application of product (L/ha unless otherwise stated)	Water volume (L/ha)
1.	Untreated control	-	-
2.	Stopit (Yara)	5.0	200
3.	InCa (Plant Impact)	1.5	200
4.	Calsym (Verdesian)	2.0	200
5.	Calmax Ultra (Omex)	2.0	300
6.	TenSile (Ilex)	3.0	300
7.	CapiTal (Ilex)	3.0	300
8.	AdvoCate (Ilex)	3.0	300
9.	ProAct (PHC)	0.2 kg/ha	300
10.	Maxicrop Triple (Maxicrop)	1.5	300

The product compositions, and the claims made for them are detailed in Table 3.

Table 3. Table of products selected for testing, with properties, typical claims made for their benefits and published nutrient values (% nutrient content where P, K, Ca and Si are stated as their oxides P_2O_5, K_2O, CaO and SiO_2).

Treatment no.	Product	Composition, claims and reported nutrient analysis
2	Stopit	Calcium chloride based (food grade). Analysis; Ca 16
3	InCa	Calcium and nitrogen based product (inorganic salts). Analysis; NPK 4.5:0:0 +Ca 7
4	Calsym	Calcium and phosphorous based (no information available on analysis)
5	Calmax Ultra	Inorganic emulsion containing calcium nitrite tetrahydrate plus trace elements. Also contains technology called 'AXM' designed to aid transport of Ca into cells. Analysis; NPK 9:0:0 +Ca 21.8
6	TenSile	Phosphite, potassium, and silicon plus polysaccharides derived from seaweed (2% 'bio-active agents'). Strengthens plant cells and improves shelf life by reducing transpiration and water loss. Analysis; NPK 0:2:8 +Si 8
7	CapiTal	Calcium phosphite based product, including zinc and boron. Analysis; NPK 4:30:8 +Ca 6.6, B 0.8, Zn 2.4
8	AdvoCate	Calcium based product (Calcium chloride 10%) complexed with natural sugars and amino acids (7.5% w/v 'bio-active agents'). Analysis; NPK 3.6:0:0 +Ca 9.0, B 0.02, Zn 1.5, Fe 0.18, Mo 0.1
9	ProAct	Harpin protein based product; elicitor-reduces plant stress through Systemic Acquired Resistance (SAR)
10	Maxicrop	Seaweed extract; Benefits include stimulation of plant growth, improved biological activity around root zone. Analysis; NPK 3.1:1.4:2.9

Experimental design

Treatments were laid out in four replicate blocks of 10 treatments (including control), arranged in a fully randomised block design. Plots for each trial were located within a farm drilled crop and in an area of 60 m x 6 beds of 1.8 m = 650 m^2. Plot size was 5 m x bed width (1.8 m). Treatments were applied twice over the growing period, the first at two true leaf stage and the other approximately 4-7 days prior to harvest. Each treatment was applied with an OPS sprayer with a 1.5 m spray width. Crop growth stage and weather conditions were recorded at each application time. SMN and Topsoil sampling took place across each block prior to foliar fertiliser application. For SMN samples, DM%, NO_3-N (mg/kg), NH_4-N (mg/kg) were measured. Topsoil samples were taken to 15 cm depth for a standard agricultural analysis.

Figure 1. Typical baby leaf spinach experimental site, shown at the time of the first treatment spray.

Harvest

Harvest consisted of sampling from the central rows and within the central 3 m plot length to avoid any edge effects from plot ends. Leaf greenness was measured pre-harvest using a SPAD meter (5 readings per plot), as well as fresh weight, quality and shelf life. Plot samples taken using two 0.5 x 0.5 m quadrats, placed within the centre 3 m and central rows of the plot, with rows aligned across the diagonal. Once each quadrat sample was placed in a crate with plot number and treatment, sample temperature was reduced and maintained to 6 °C, transported back to ADAS Boxworth in a refrigerated van to be photographed and placed in a cold store at 6 °C. Assessments began the next day, denoted as Day 1.

Figure 2. This photo shows the crates laid out for each separate treatment at harvest.

Assessments

Shelf life assessments

From the harvested quadrat samples, 1 kg of sample was placed in a 20 L wide mouth container with 15 L of water and rolled over a distance of 2 m back and forth 16 times for approximately 1 minute. The sample was then spun using a salad spinner and set aside until touch dry. The whole sample was split into 7 x 100 g portions, taking care to gently mix the sample to achieve an even distribution of material between samples.

From Day 1, each sample was assessed daily for leaf colour using a SPAD meter, and scored for leaf damage (holes, tears, etc), bruised leaves (according to industry protocol), discolouration, and dehydration using a scale of 1 (good quality) to 4 (poor quality). At the final assessment in addition to the other measurements, leaf length, width and stem length (mm) were assessed. Sample bags were only opened on the day of sampling and sealed until the day of assessment. Material was discarded once assessed.

A separate observation was carried out for samples from Site 14/1, which compared the shelf life of unwashed and washed baby leaves. Of the sample that was taken from each treatment at this site, a separate 100 g was kept aside, bagged and labelled, as per the washed samples. This unwashed sample was opened only on Day 7 and was assessed for the same parameters as the washed samples.

Statistical Analysis

Leaf dimensions, leaf damage, dehydration, bruising and yield were analysed by analysis of variance (ANOVA) using Genstat (13^{th} ed.).

Results

This section describes the results from each site in turn. The data that are presented for each site describe the parameters that were assessed for each experiment. These include leaf damage, dehydration, bruising and sample yield, which are presented graphically. ProAct is presented as Harpin in the graphs for these parameters. An experiment that compared the difference between washed and unwashed baby leaves was only undertaken at site 14/1. The remaining data is presented in tables in the appendixes.

Site 14/1 Wiltshire

- There were no significant differences between treatments for leaf damage, dehydration or yield for Site 14/1,

- The product that reduced leaf damage the most effectively over the 7 day shelf life period was CapiTal (Ilex). The second most effective was Maxicrop (Figure 3),

- Samples for all treatments were still of marketable quality by the final day of the shelf life period,

- SPAD readings at the time of harvest showed no significant difference between treatments and leaves were scored as 1 for each treatment, depicting highest quality (data not shown),

- Unwashed samples were only assessed at this site and were assessed at day seven. There was no significant difference for dehydration (data not shown). Leaf damage showed a score of 1 for each of the treatments and therefore results were not subjected to ANOVA,

- Leaf dimensions (leaf length, width and stem length) for washed and unwashed samples on day 7 were only measured at Site 14/1 and showed no significant differences between treatments. The previous interim report mentioned that there was no significant difference between chemical treatments and washing treatment, though there was a slight significant effect of the washing treatment on leaf width, where the washed leaves were on average 1.2 mm smaller than the unwashed (LSD 95% = 0.88) (Table 4),

- In comparison to the Control and other treatments, CapiTal was the most effective treatment at reducing leaf dehydration, having a moderate rate of moisture loss over the 7 days,

- Maxicrop treatment gave the highest rate of moisture loss over the 7 day period. The leaves in the Control treatment showed a lower dehydration score over the 7 days, compared to some of the nutritional treatments in the trial (Figure 3),

- Bruising data are not presented as there was a consistent score of 1 (high quality) for each treatment sample,

- The ProAct treatment had the highest sample yield compared to the Control and the other treatments.

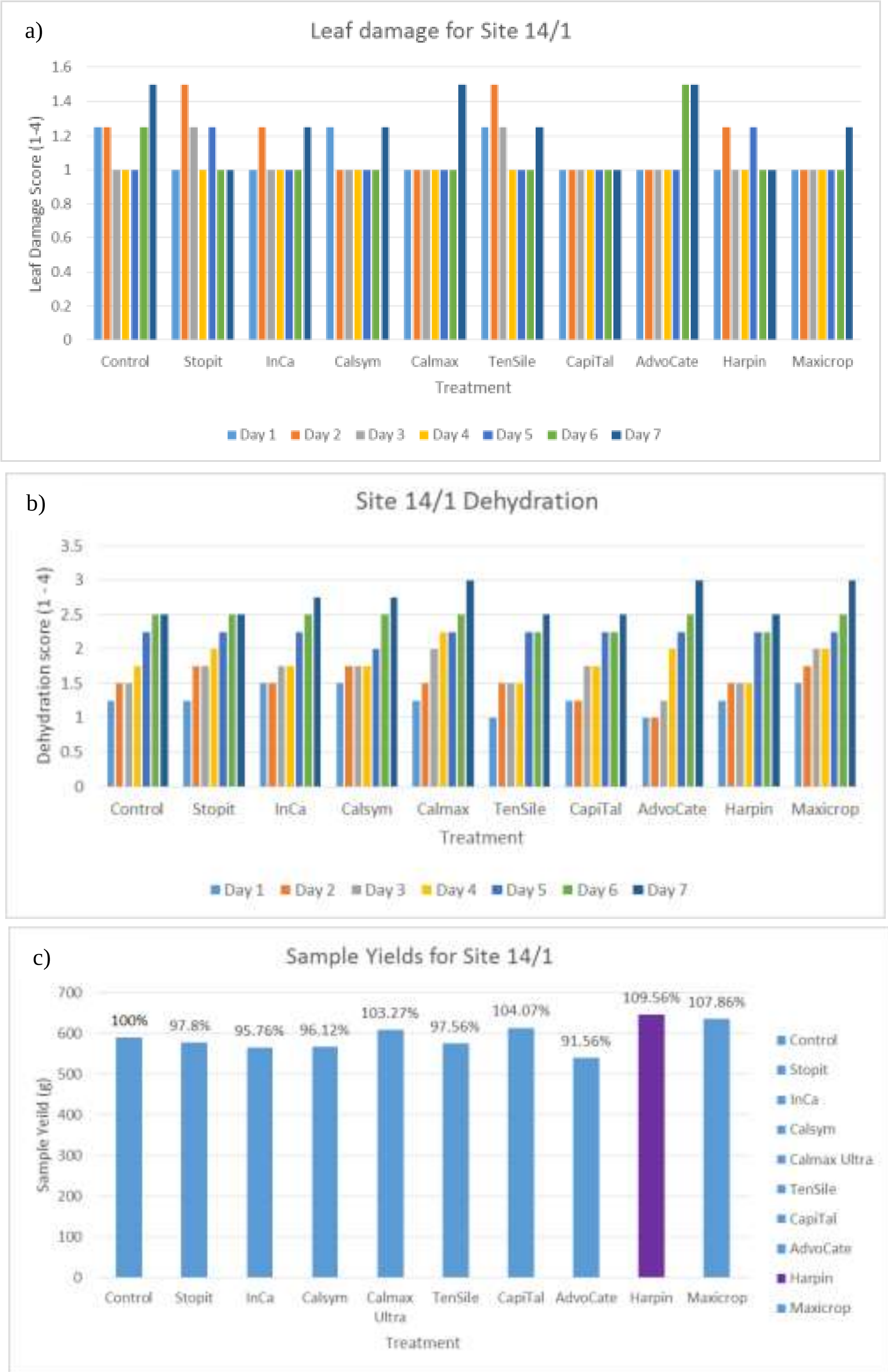

Figure 3. Graphic description of a) leaf damage, b) dehydration and c) sample yields for Site 14/1.

Table 4. Site 14/1 leaf dimensions of baby leaf spinach as per treatment as measured on Day 7. Includes LSD (95%) for washed and unwashed leaves in terms of differences between treatments.

Chemical treatment	***Product (manufacturer)***	***Leaf length (mm)***	***Leaf width (mm)***	***Stem length (mm)***
1.	Untreated control	50.7	39.5	31.0
2.	Stopit (Yara)	52.6	41.5	33.5
3.	InCa (Plant Impact)	51.0	39.3	32.6
4.	Calsym (Verdesian)	50.6	39.2	31.6
5.	Calmax Ultra (Omex)	50.8	39.8	33.0
6.	TenSile (Ilex)	51.6	39.8	33.6
7.	CapiTal (Ilex)	52.5	39.9	33.9
8.	AdvoCate (Ilex)	52.1	40.4	32.5
9.	ProAct (PHC)	52.4	41.2	32.4
10.	Maxicrop Triple (Maxicrop)	52.7	41.0	32.9
Least Significant Difference (95%)		1.23	1.97	2.95
Washed Baby Leaves		51.2	39.4	32.9
Un-Washed Baby Leaves		52.2	40.9	32.5
Least Significant Difference (95%)		1.15	0.88	1.32

Site 14/2 Shropshire

- There were no significant differences between treatments for reduction of leaf damage, dehydration, bruising or increase in sample yield for Site 14/2,
- Stopit and InCa had the lowest maintained scores for dehydration at 2, compared to the other treatments, Stopit had a lower score for bruised leaves than the other treatments and the control,
- For the bruising measurements, Stopit had a lower score for bruised leaves than the other treatments and the control. The Maxicrop treated samples stayed below the score of 2 up until day six and are close in result to the Stopit samples. However, there was no significant difference between the treatments,

- There was no significant difference in sample yield for any of the treatments for site 14/2. The sample yield results showed that Stopit out-performed the other treatments, showing a yield increase of 12.4% in relation to the Control but this was non-significant. The next highest yields were from ProAct and AdvoCate treatments,

- There was no significant difference between treatments for the SPAD readings from harvest or throughout the 7 day shelf life assessment period.

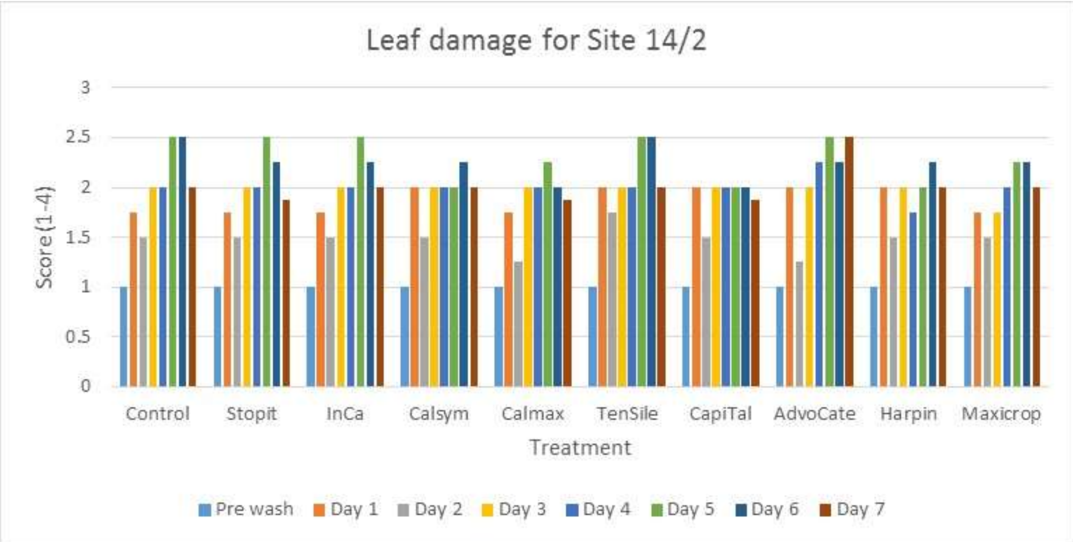

Figure 4. Leaf damage assessments for each treatment and day of the shelf life period. Parameter was measured on a score from 1 to 4.

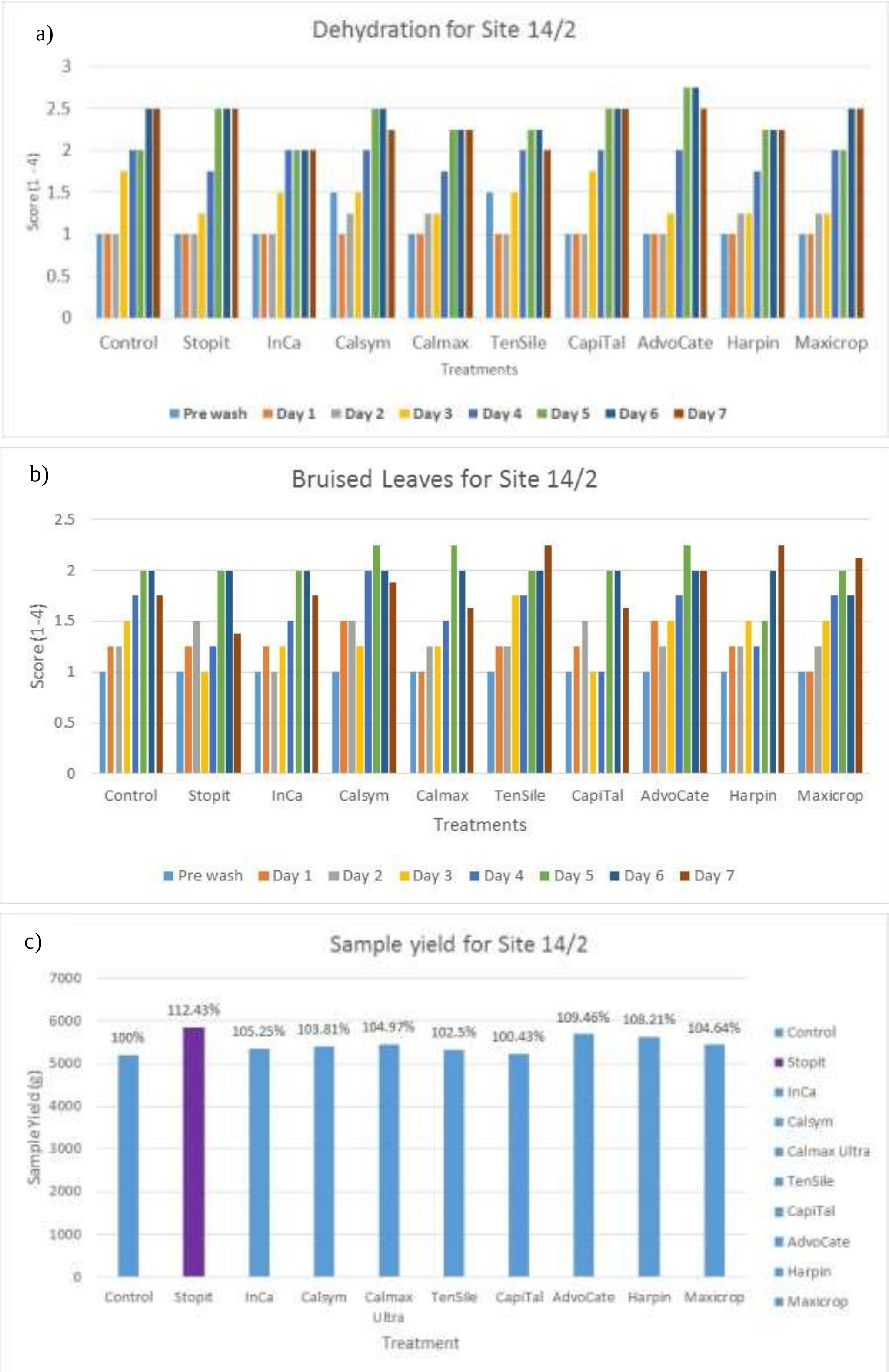

Figure 5. Graphic description of shelf life parameters assessed at Site 14/2; a) dehydration, b) leaf bruising and c) Sample yield.

Site 14/3 Kent

- For the leaf damage assessment, there were no significance differences between treatments,

- None of the treatment samples were of marketable quality for more than 2 days from the beginning of the 7 day shelf life period,

- The results for dehydration measurements were non-significant. CapiTal treated leaves had the lowest rate of moisture loss as well has having the lowest score for dehydration by day seven and therefore this was the most effective treatment at reducing dehydration. The least effective treatment was ProAct,

- Over all, for most of the treatments, the leaves scored greater than 2 for bruising by harvest. Therefore it would suggest that the growing season was not ideal for this crop at this site, as described in the Discussion section,

- The Control treatment had the largest fresh weight yield, being only slightly greater than that of CapiTal treated crops but there was no statistical significance in the effect of treatment on the sample yield,

- There was no significant difference between treatments for the SPAD readings from harvest and throughout the 7 day storage period.

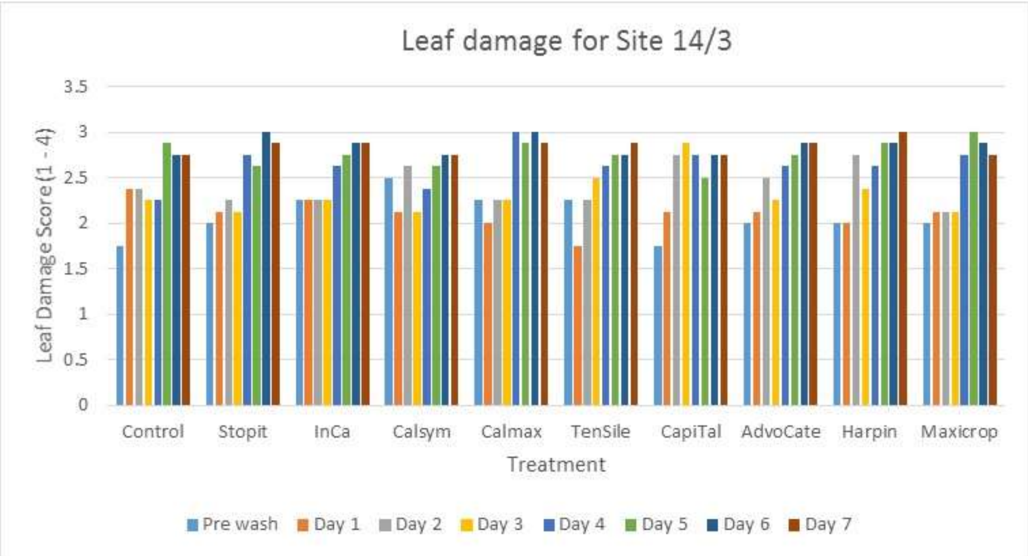

Figure 6. Leaf damage for Site 14/3. Most treatments for this site greater than the cut off score of 2 from Pre Wash.

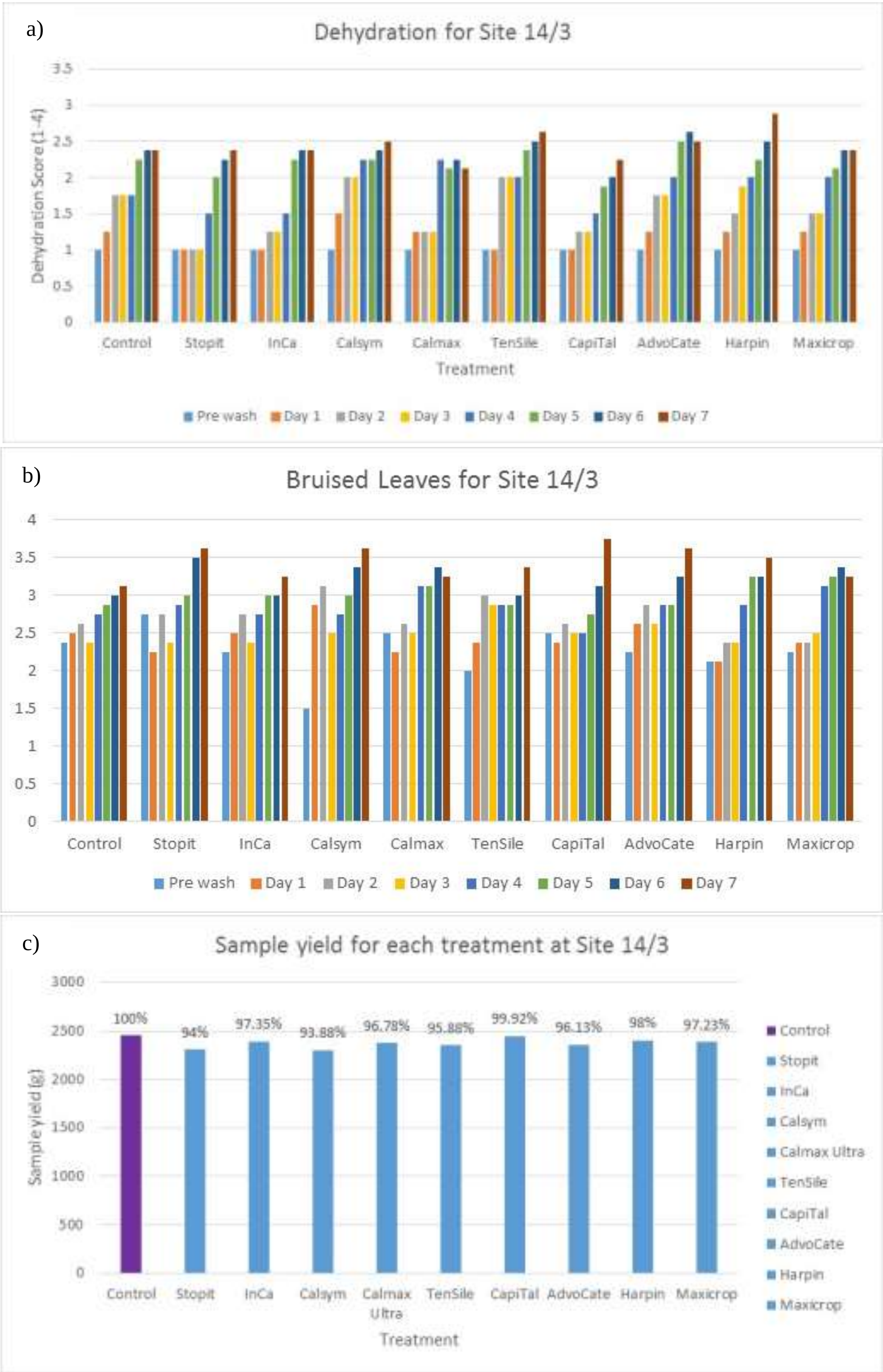

Figure 7. Parameters assessed from Site 14/3; a) dehydration, b) bruised leaves and c) sample yield.

Site 14/4 Cheshire

- There were no significant differences between treatments for the reduction of leaf damage during shelf life,

- The majority of scores from day two onwards, resulted in leaves being above the cut off level for marketable quality, apart from TenSile, Calsym and AdvoCate treated leaves, which were below or just on the max leaf damage score,

- Though there was no significant difference between treatments for Site 14/4 in dehydration assessments, the treatment that maintained the score below 2 throughout the assessment period the longest was TenSile and the least effective InCa,

- The treatment that resulted in the least overall level of bruising for the assessment period was TenSile, and the least effective, AdvoCate. There was a significant difference between treatments at pre washing ($P<0.05$) in comparison to the other assessment days. This may relate to the poor performance of AdvoCate where the majority of the scores for each day remains at or under 2 for at least 5 of the assessment days. There was no significant difference for the other days of the assessment period,

- There was no significant difference between treatments for the SPAD readings from harvest and throughout the shelf life assessment period (data not shown),

- There was no significant difference between treatments for sample fresh weights from site 14/4. ProAct had the best result, with an 8.87% increase in yield in comparison to the control. All treatments resulted in a slightly greater sample yield than the control.

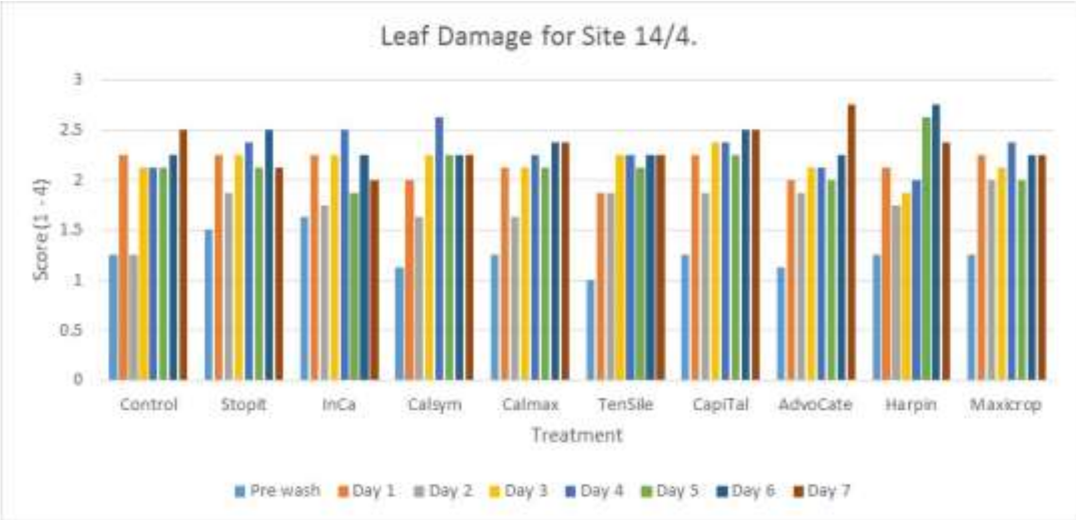

Figure 8. Leaf damage for Site 14/4. Variable across the treatments, yet there was no significant difference. Most treatments above cut off score of 2 by Day 2.

Figure 9. Graphic description of parameters assessed at Site 14/4; a) dehydration, b) leaf bruising and c) sample yield.

Site 14/5 Norfolk

- There was no significant difference between treatments for leaf damage at Site 14/5. The overall trend was variable, with most of the products above score 2 at days two and five. Leaves treated with InCa and Maxicrop had the longest period below the score of 2, until day six, compared to the other treatments,

- Calmax was the most effective treatment at reducing dehydration, with the score remaining below 2 throughout the shelf life assessment, though there was no significant difference in the reduction of dehydration between treatments overall,

- For the bruising assessment, there were no significant differences. The Control had a score below 2 for the duration of the 7 day period, though ProAct and Calmax had lower scores than Control through the assessment,

- InCa treated samples had a 15.3% increase in yield in comparison to the Control and other treatments,

- The SPAD readings showed no significant difference between treatments from point of harvest through the 7 day assessment period.

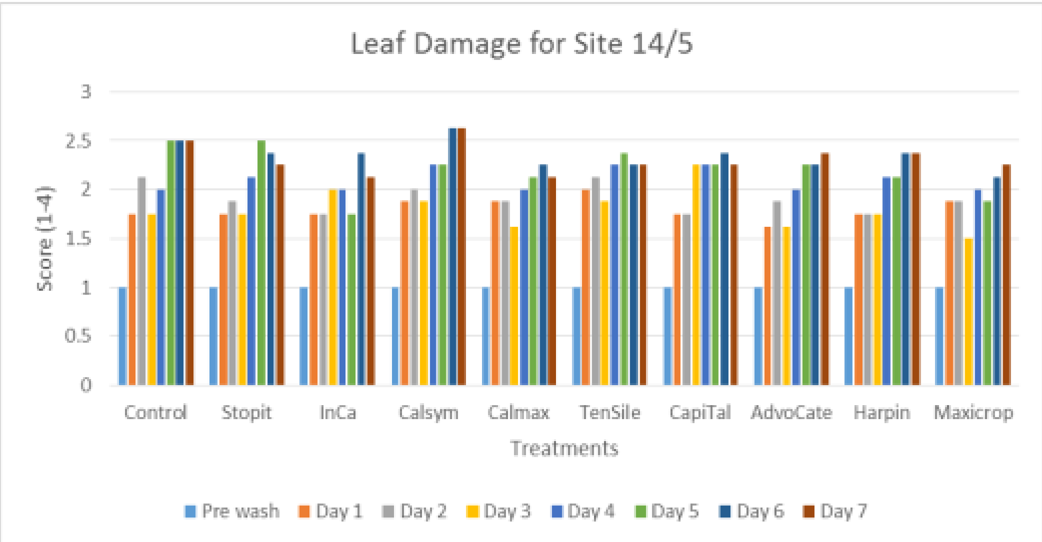

Figure 10. Leaf damage for Site 14/5. Results show no significant difference between treatments at this site.

Figure 11. Graphic description of each parameter assessed at Site 14/5; a) dehydration, b) leaf bruising and c) sample yield.

Site 14/6 Dorset

- There was no significant difference in any of the treatments for any of the assessment days for leaf damage. TenSile was the most effective treatment for the reduction of leaf damage, where the score increased above 2 by day three. In comparison to the control, where the score was above 2 by day two,

- None of the treatments had a score lower than 2 from day one for dehydration. There was only a significant difference in treatments for day six. However, the scores were too far above the limit for poor marketable quality so this is not relevant,

- There was no significant difference between treatments for bruising in Site 14/6 samples. Control, TenSile and Calsym had scores below 2 for the duration of the 7 day period. The most effective treatment to reduce bruising over the assessment period was TenSile, the least effective being Calmax,

- There was no significant difference for Site 14/6 sample yield results. However, Stopit had the greatest sample yield out of the treatments, with a yield increase of 10.6% against the control,

- For the SPAD readings, there was some significance between treatments at harvest. However, for every day of the shelf life assessment period, there was no significant difference between treatments.

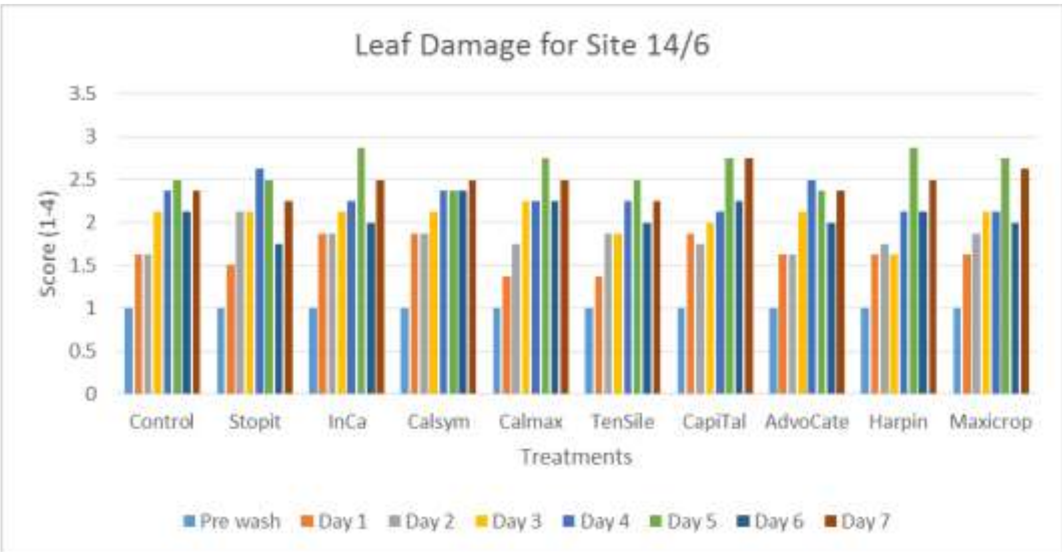

Figure 12. Results from leaf damage assessments at Site 14/6.

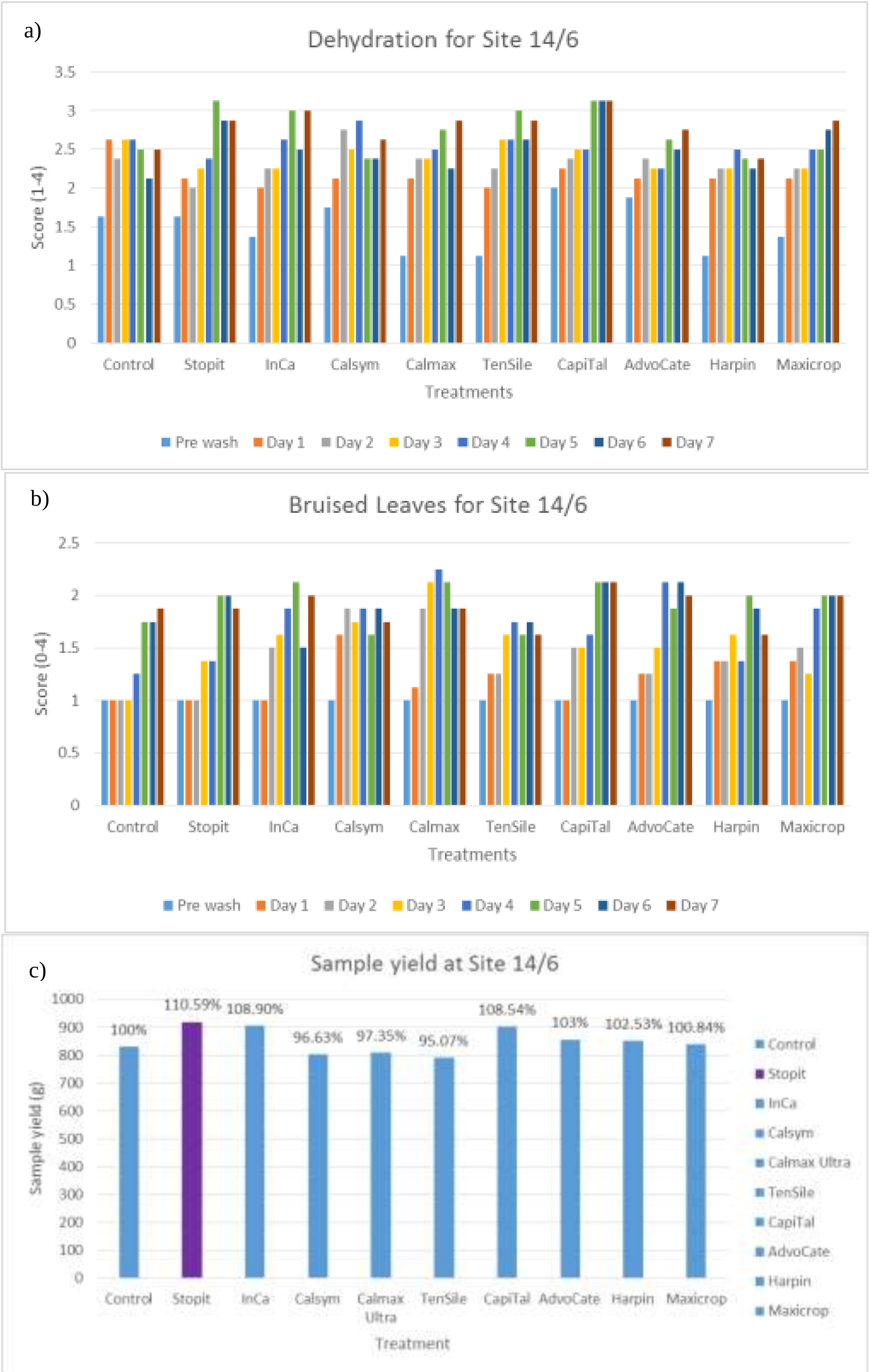

Figure 13. Graphic description of parameters assessed at Site 14/6; a) dehydration, b) leaf bruising and c) sample yield.

Discussion

The individual site data presented above showed no significant effects on yield or shelf life quality arising from application of the commercial products tested, at any of the sites. However growers may still feel that if the cost of a particular product is low enough, and potential benefit averaged across different sites positive, that the products may still have some commercial application (coupled with their other reported benefits e.g. on plant health, not tested here). The following discussion section summarises the potential benefits in terms of shelf life and yield, from these six field experiments for each variable measured.

Shelf Life Summary

There were no significant differences between shelf life scores for any of the treatments on individual days. No one product performed consistently better across all sites. The products used in this trial that are nutrient-based, are marketed based on the fact that the calcium present is a vital nutrient with a positive effect on shelf-life in crops. There were biological and non-biological products used as treatments in this trial, each giving a different result for each assessment and site.

For leaf damage, at two out of the six sites, an extra day at or below score 2 was obtained through the application of InCa, Maxicrop and TenSile (Table 5). This was also the case for the dehydration assessments, though the products that achieved this were InCa, CapiTal, Stopit and Calmax (Table 6). For the bruising assessments, the control treatments across five of the six sites scored below 2, and therefore no extra day was obtained (Table 7). At 2 of the sites, the score reduced compared to the control.

Table 5. Leaf damage summary for each site describing the best performing treatment (day = day after harvest).

Site Number	*'Best' Product (s)*	*Comparison to control – treatment effect*
14/1	CapiTal Maxicrop	Leaf damage minimal at this site Control at day six = 1.25 score, day seven = 1.5 score CapiTal maintains score 1 throughout 7 days Maxicrop maintains score 1 till day six
14/2	None/Control	Control above score 2 at day two Treatments also all above score 2 at day two or earlier
14/3	TenSile	Control and CapiTal only ones below 2 at Prewash Control above score 2 at day one after washing TenSile only treatment below score 2 on day one after washing, then all above score 2 on day two
14/4	None/Control	N/A
14/5	Inca Maxicrop	Control trend variable, above score 2 at days two and five. Inca and Maxicrop remained at or below score 2 until day six
14/6	Tensile	Control above score 2 at day three Tensile above score 2 at day four

Table 6. Summary table for dehydration, describing the best performing treatment at each site.

Site No	*'Best' Product (s)*	*Comparison to control – treatment effect*
14/1	None/Control	Control above score 2 at day five Treatments also all above score 2 at Day 5 or earlier
14/2	InCa	Control at score 2 at day four, above score 2 at day five InCa samples remained at or below score 2 through assessments.
14/3	CapiTal Stopit	Control above score 2 at day five CapiTal and Stopit less dehydrated than control, and not above score 2 till day six
14/4	CapiTal TenSile	Control at or below score 2 throughout assessments CapiTal and TenSile have lower scores than Control through assessments
14/5	Calmax Ultra	Control just above score 2 at day four Calmax at or below score 2 throughout assessments
14/6	None	All samples were above score 2 after washing

Table 7. Summary table for bruising results, describing the best performing treatment at each site.

Site Number	*'Best' Product (s)*	*Comparison to control – treatment effect*
14/1	None	All scores 1 (consistently high) for all treatments at all assessments
14/2	None	Control at or below score 2 throughout assessments No treatments have consistently lower scores through all days of assessment
14/3	None	All scores above 2 from harvest No treatments reduced bruising to below 2
14/4	TenSile	Control at or below score 2 throughout assessments TenSile below score 2 throughout assessments
14/5	ProAct Calmax Ultra	Control below score 2 throughout all assessments ProAct and Calmax have lower scores than Control through assessments
14/6	Control *TenSile* *Calsym*	Control, TenSile and Calsym below score 2 throughout all assessments Control at lowest score until day four

It is noted that results from Site 14/3 may be the most variable as the growing season was not favourable, with higher than normal temperatures, which required multiple irrigation events at this site. The crop was fast growing and became variable within each treatment in the field in terms of size and growth stage. At harvest for Site 14/3, some of the crop had started to bolt due to the timing of harvest and prior growing conditions.

Yield Summary

As each site had very different aspects, there was no 'best' treatment that consistently outperformed the others. All treatments increased yield at sites 14/2, 14/4 and 14/5 by varying percentages, with site 5 showing the greatest increase in yield. All of the applied treatments at site 14/3 reduced yield relative to the control although this was non-significant statistically. The differences in yield response can be attributed to the varying conditions of each site, in terms of soil type, weather, the season and variety. It is suggested that the low SMN at site 14/5 may have influenced how the crop responded to products that contained nitrogen. For instance, InCa contains calcium ammonium nitrate and resulted in the greatest increase in yield for all treatments, though it had variable results across sites.

The average yield increase across sites was highest for the calcium chloride-based product Stopit, with an increase of 5.05% above the yield of the control (Table 8). The overall yield increase was similar to that seen with the protein-based product, ProAct, which averaged an increase of 5.02% across sites and performed well at site 14/1, compared to Stopit.

There was only some significant difference between treatments for the SPAD readings for Site 14/6 at harvest. With the rest of the sites showing no real statistical significance, it is suggested that a variety of factors could have contributed to this result. These include variety, growing conditions, soil type and conditions, and weather.

Table 8. Summary table of sample yield responses (percentage increases) for each treatment and site in comparison to the control.

Site	*Control*	*Stopit*	*Inca*	*Calsym*	*Calmax Ultra*	*TenSile*	*CapiTal*	*Advocate*	*ProAct*	*Maxicrop*
14/1	100	-2.2	-4.3	-3.8	+3.3	-2.4	+4.3	-8.4	**+9.6**	+7.8
14/2	100	**+12.4**	+5.3	+3.8	+4.9	+2.5	+0.4	+9.5	+8.2	+4.6
14/3	100	-6.0	-2.6	-6.2	-3.2	-4.2	-0.1	-3.8	-2.0	-2.7
14/4	100	+8.2	+3.6	+0.3	+7.2	+4.5	+1.9	+0.5	**+8.9**	+4.8
14/5	100	+7.3	**+15.3**	+0.4	+6.9	+7.1	+1.0	+5.3	+2.9	+2.9
14/6	100	**+10.6**	+8.9	-3.4	-2.6	-4.9	+8.5	+3.0	+2.5	+0.8
Average	100	**+5.05**	+4.37	-1.48	+2.75	+0.43	+2.67	+1.02	**+5.02**	+3.48

Overall Summary

The comparison of the effectiveness between biological products and nutrient based products in terms of shelf life longevity has not been widely investigated. In the literature, most of the experiments are between different concentrations of a particular product and a control where only water is used. Therefore, the aspects of biological and non-biological (or chemical vs physiological) treatments will be discussed separately.

An experiment by Fan *et al.* (2014) observed the effect of the pre-harvest application of the extract of the brown algae *Ascophyllum nodosum,* at various concentrations, on the post-harvest and quality of spinach. Results showed that due to the root application of *A. nodosum* via fertigation at 1.0 g/L, loss in fresh weight and visual quality (colour and turgor) of the leaves were reduced during 35 days storage compared to the control. Seaweed extracts are commonly used as soil conditioners to increase activity and biomass of beneficial soil flora and fauna, as well as the implication that it provides the crop with nutrients (macro and micro) and plant growth hormones such as cytokinins to aid the increase in yield, shelf life and quality (Crouch and van Staden, 1993; Zodape, 2001; Rathore *et al.* 2008). However in the present study, Maxicrop, the seaweed extract, only showed an apparent benefit in terms of reducing leaf damage (albeit non-significant effects statistically) at two out of the six sites, and had no effects on leaf damage or bruising. Application recommendations of Maxicrop include use as seed treatment, a drench for transplants as well as a foliar spray for field and glasshouse grown crops. For drilled salad crops, Maxicrop is recommended as a seed treatment that would ensure better rooting and improved microbial activity around the germinating seed and root zone. In the case of the present experiment, it would be suggested that further investigation into this effect is beneficial.

In terms of the application of the ProAct harpin protein treatment in this experiment, the principle behind the technology relates to its effect as an elicitor of the plant stress response. According to the product factsheet (Plant Health Care, 2015), it is stated that as well as increasing the defensive state of the plant, the structural integrity and overall vigour is also enhanced, leading to increased yield and quality of the produce. The DNA sequence coding for the harpin protein is inserted into a bacterial culture and allowed to accumulate, before being isolated from the bacteria and purified. Another producer of the harpin technology states that its application results in an extension of storability by 3 to 7 days in vegetables. In terms of shelf life measurements, the harpin treatment (ProAct) used in this experiment only showed an effect in the reduction of bruising for one site, though there was a positive effect on yield where its average across sites almost matched that of Stopit, as noted earlier.

The use of complex chemical treatments with various ‘bio-active agents’ studied in this project provide the grower with a potential alternative to the use of straight, nutrient-based products, such as calcium nitrate or calcium chloride formulations manufactured by fertiliser companies. The aim in the present study was to target improvement in quality, both pre- and post-harvest.

Recent research has shown that pre-harvest applications of calcium to crops has resulted in an extended shelf life by reducing the rate of decay in storage. Kou *et al.* (2014) observed the effect of an application of calcium chloride to broccoli microgreens at various concentrations in terms of harvest quality and shelf life duration. Results showed that overall quality was greater at 10 mM of calcium chloride than the other treatments and the control for the duration of 21 days of storage at 5°C. Results from a study on peaches by Taylor and Brannen (2008) showed that calcium chloride reduced the incidence of disease during storage compared to the control, hence extending the shelf life by maintaining good quality produce. However, most of the literature relating to these particular nutrients are focused on post-harvest applications. Calcium is the main nutrient used, because it has an important role in maintaining cell wall integrity, its deficiency being related to disorders such as tip burn in lettuce, and bitter pit in apples. It is also stated to be effective in reducing turgor loss and respiration during storage (Rico *et al*., 2007). There are various forms of calcium that are used as post-harvest treatments, such as calcium chloride and calcium lactate. Research has shown that, due to the bitterness that is left after the post-harvest application of calcium chloride, calcium lactate is commonly used (Martin-Diana *et al*., 2007). In this project, calcium nitrate (e.g. Inca, CalMax Ultra, AdvoCate), as well as calcium phosphite (CaPital) was used as a pre-harvest treatment. However no single calcium treatment performed better than the others in terms of improving shelf life.

In terms of the non-calcium based treatments that were used in this experiment, relatively little literature has been found relating to its use for shelf life improvement, rather overall plant growth and health. TenSile is a product by Ilex that is based on potassium silicate, phosphite and polysaccharides derived from seaweed (Ilex Envriosciences, 2015). It is described as being formulated to improve cell structure and shelf life, as well as reducing transpiration and water loss during storage. Silicon is one of the more abundant elements found in soil, varying dramatically between geographic locations and soil types (Epstein, 1994). The form that plants take up silicon is silicic acid; SiO_4H_4. Plants deprived of Si are usually structurally weaker and prone to abnormalities in growth, development and reproduction (Currie and Perry, 2007). It has been described as an alleviator of biotic and abiotic stress. Its definitive role in this phenomenon is relatively unknown at this point, though it is suggested that its accumulation in the leaves provides a physical barrier against fungal pathogen attack (Epstein, 1994; Currie and Perry, 2007; Epstein, 2009). However it could be argued that silicates in plants tend to be deposited in mature tissues like the lignified stems and leaves of cereals where they may serve to improve rigidity, and also prevent herbivory, but are likely to be less abundant in young, tender leaves as found in baby leaf salads, even if plant uptake of silicic acid can be enhanced.

In terms of the overall experiment, the products that were investigated were applied without using a wetting agent or sticker. It is also suggested that some of the products may have been added with another agricultural chemical, which may have given different results but this would require further testing.

Conclusions

Growers are often presented with commercial chemical and biological products promising to deliver solutions in terms of plant health and/or nutrient management. The promised benefits can relate to disease resistance, shelf life extension, tolerance to damage, improved yield or a combination of all four. However it is generally difficult for the individual grower to test such products themselves, both because of the costs and difficulties of carrying out experiments within commercial crop scheduling. Moreover it is potentially expensive particularly in cases where the treatments effects may be small, and experiments generally need replicating a number of times in order to gain confidence. Work such as that reported here, whereby products were tested over 6 sites, allows growers to pool the risks of exploring such treatments and gain more confidence through access to date gained across a range of typical commercial sites.

Overall there were no significant effects on shelf life, of any of the chemical or physiological treatments studied. Therefore they cannot be recommended for this purpose in baby leaf spinach. Some apparent yield advantages were seen when averaged across the six sites. These too were individually non-significant, but are presented because growers may still feel that if a particular product was cheap enough, and the potential benefits great enough, then averaged over sites and seasons there may still be an economic advantage. Moreover there could be benefits from using these products, arising from other effects not studied in the present project. If growers use such products for their nutrient value alone, and/or simply to optimise yield, then the normal principles of nutrient management should be followed. It is therefore concluded that:

- Shelf life is an integral aspect of the baby leaf salad industry, the extension of which can provide a substantial financial benefit to growers,

- The treatments that were put forward for investigation in the effectiveness of extending shelf life were varied and results showed that no one treatment provided a consistent positive result overall,

- The variation in results could be explained by the influences that site, climate and growing conditions had on the effectiveness of the individual treatments,

- In terms of the average increase in yield, Stopit and ProAct showed an average increase of 5% over the other treatments and the control. Stopit is a soluble calcium based product, and ProAct is based on proteins giving elicitor effects,

- These results can provide no recommendation on an individual product based on the treatments applied in these experiments, therefore it is at the growers' discretion to use any of the products investigated to enhance shelf life and overall crop health and development.

Knowledge and Technology Transfer

- Two presentations to the HDC Leafy Salads Roadshow on the 12th and 26th of November 2014.

Opportunity for further work

- Investigate the effectiveness of the products with the addition of a wetting agent or sticker.
- Investigate the effectiveness of the seed application of seaweed or biological based products on the shelf life of a salad crop in comparison to conventional seed dressings. It may be beneficial to examine other properties of the treatment in terms of germination, establishment and subsequent growth rate.

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Appendices

Site 14/1 Summary ANOVA Tables

Leaf Damage – Score for unwashed was 1 for each treatment

Treat	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Unwashed
Control	1.25	1.25	1.00	1.00	1.00	1.25	1.50	1.00
Maxicrop	1.00	1.50	1.25	1.00	1.25	1.00	1.00	1.00
Calmax	1.00	1.25	1.00	1.00	1.00	1.00	1.25	1.00
ProAct	1.25	1.00	1.00	1.00	1.00	1.00	1.25	1.00
InCa	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.00
TenSile	1.25	1.50	1.25	1.00	1.00	1.00	1.25	1.00
CapiTal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
AdvoCate	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.00
Calsym	1.00	1.25	1.00	1.00	1.25	1.00	1.00	1.00
Stopit	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.00
P Value	0.622	0.364	0.573	NA	0.464	0.107	0.524	NA
LSD (5%)	0.392	0.557	0.330	NA	0.306	0.361	0.618	NA
SED	0.191	0.271	0.161	NA	0.149	0.176	0.301	NA

Dehydration (Washed and Unwashed) – Unwashed assessed on day 7 only.

Treat	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Unwashed
Control	1.25	1.50	1.50	1.75	2.25	2.50	2.50	2.50
Stopit	1.25	1.75	1.75	2.00	2.25	2.50	2.50	2.50
InCa	1.50	1.50	1.75	1.75	2.25	2.50	2.75	2.50
Calsym	1.50	1.75	1.75	1.75	2.00	2.50	2.75	2.75
Calmax	1.25	1.50	2.00	2.25	2.25	2.50	3.00	2.50
TenSile	1.00	1.50	1.50	1.50	2.25	2.25	2.50	2.25
CapiTal	1.25	1.25	1.75	1.75	2.25	2.25	2.50	2.00
AdvoCate	1.00	1.00	1.25	2.00	2.25	2.50	3.00	2.25
ProAct	1.25	1.50	1.50	1.50	2.25	2.25	2.50	2.50
Maxicrop	1.50	1.75	2.00	2.00	2.25	2.50	3.00	2.25
P Value	0.747	0.335	0.531	0.255	0.999	0.985	0.328	0.698
LSD (5%)	0.665	0.624	0.721	0.590	0.710	0.716	0.605	0.355
SED	0.324	0.304	0.352	0.288	0.346	0.349	0.295	0.728

Yield

Treatment	Yield (g/sample)
Control	590
Stopit	577
InCa	565
Calsym	567
Calmax	609
TenSile	576
CapiTal	614
AdvoCate	540
ProAct	646
Maxicrop	636
P Value	0.419
LSD (5%)	86.1
SED	42.0
CV %	10.1

SPAD

Treat	Harvest	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	37.51	35.82	37.00	36.19	37.09	37.68	35.65	34.88
Stopit	37.71	39.19	36.08	37.18	35.95	34.43	35.01	36.91
InCa	37.11	36.40	35.61	37.73	36.85	36.39	36.08	35.74
Calsym	36.90	36.44	37.16	38.28	35.95	35.54	37.41	33.86
Calmax	37.11	38.97	35.32	36.30	36.57	35.08	36.34	34.70
TenSile	37.90	37.14	34.93	36.46	36.36	36.97	35.77	36.16
CapiTal	37.67	37.70	37.27	37.38	35.96	36.28	37.87	35.32
AdvoCate	36.61	36.65	35.40	35.36	36.52	35.95	36.86	35.58
ProAct	36.76	36.37	34.52	35.92	37.38	34.43	34.04	35.53
Maxicrop	38.01	37.48	35.15	38.15	37.89	35.82	36.22	35.40
P Value	0.739	0.350	0.34	0.713	0.872	0.037	0.192	0.667
SED	0.865	1.477	1.28	1.562	1.330	0.900	1.283	1.357
LSD (5%)	1.774	3.031	2.63	3.204	2.740	1.950	2.632	2.784

Site 14/2 Summary ANOVA Tables

Leaf Damage

Treatment	Pre Wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.75	2.35	2.38	2.25	2.25	2.88	2.75
Stopit	1.00	2.00	2.125	2.25	2.13	2.75	2.63	3.00
InCa	1.00	2.25	2.25	2.25	2.25	2.63	2.75	2.88
Calsym	1.00	2.50	2.125	2.63	2.13	2.38	2.63	2.75
Calmax	1.00	2.25	2.00	2.25	2.25	3.00	2.88	3.00
TenSile	1.00	2.25	1.75	2.25	2.50	2.63	2.75	2.75
CapiTal	1.00	1.75	2.13	2.75	2.88	2.75	2.50	2.75
AdvoCate	1.00	2.00	2.13	2.50	2.25	2.63	2.75	2.88
ProAct	1.00	2.00	2.00	2.75	2.38	2.63	2.88	2.88
Maxicrop	1.00	2.00	2.13	2.13	2.13	2.75	3.00	2.88
P Value	NA	0.778	0.977	0.464	0.362	0.488	0.861	0.356
LSD (5%)	NA	0.490	0.789	0.229	0.318	0.678	0.684	0.487
SED	NA	0.238	0.384	0.112	0.155	0.331	0.333	0.237

Dehydration

Treatment	Pre Wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.25	1.75	1.75	1.75	2.25	2.38	2.38
Stopit	1.00	1.00	1.00	1.00	1.50	2.00	2.25	2.38
InCa	1.00	1.00	1.25	1.25	1.50	2.25	2.38	2.38
Calsym	1.00	1.50	2.00	2.00	1.25	2.25	2.38	2.50
Calmax	1.00	1.25	1.25	1.25	1.25	2.13	2.25	2.13
TenSile	1.00	1.00	2.00	2.00	2.00	2.38	2.50	2.63
CapiTal	1.00	1.00	1.25	1.25	1.50	1.88	2.00	2.25
AdvoCate	1.00	1.25	1.75	1.75	2.00	2.50	2.63	2.50
ProAct	1.00	1.25	1.50	1.88	2.00	2.25	2.50	2.88
Maxicrop	1.00	1.25	1.50	1.50	2.00	2.13	2.38	2.38
P Value	NA	0.464	0.661	0.464	0.622	0.064	0.232	0.364
LSD (5%)	NA	0.612	0.433	0.597	0.392	0.515	0.515	0.557
SED	NA	0.298	0.211	0.291	0.191	0.251	0.251	0.271

Bruising

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.25	1.25	1.50	1.75	2.00	2.00	1.75
Stopit	1.00	1.25	1.50	1.00	1.25	2.00	2.00	1.38
InCa	1.00	1.25	1.00	1.25	1.50	2.00	2.00	1.75
Calsym	1.00	1.50	1.50	1.25	2.00	2.25	2.00	1.88
Calmax	1.00	1.00	1.25	1.25	1.50	2.25	2.00	1.63
TenSile	1.00	1.25	1.25	1.75	1.75	2.00	2.00	2.25
CapiTal	1.00	1.25	1.50	1.00	1.00	2.00	2.00	1.63
AdvoCate	1.00	1.50	1.25	1.50	1.75	2.25	2.00	2.00
ProAct	1.00	1.25	1.25	1.50	1.25	1.50	2.00	2.25
Maxicrop	1.00	1.00	1.25	1.50	1.75	2.00	1.75	2.13
P Value	NA	0.836	0.899	0.341	0.279	0.249	0.969	0.44
LSD (5%)	NA	0.661	0.69	0.641	0.78	0.543	0.421	0.832
SED	NA	0.322	0.336	0.313	0.38	0.264	0.205	0.405

Yield

Treatment	Yield (g/sample)
Control	5197
Stopit	5844
InCa	5358
Calsym	5395
Calmax	5456
TenSile	5327
CapiTal	5220
AdvoCate	5689
ProAct	5624
Maxicrop	5439
P Value	0.484
LSD (5%)	152.3
SED	74
CV %	7.7

SPAD

Treat	Harvest	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	38.59	36.83	35.54	35.54	34.60	35.02	35.62	35.71
Stopit	37.46	36.66	36.97	34.88	32.13	35.62	34.92	34.16
InCa	37.03	37.68	35.33	32.99	36.66	33.32	33.55	35.93
Calsym	39.43	36.14	34.94	34.46	37.37	34.86	36.19	33.27
Calmax	37.54	36.65	33.60	35.32	33.29	36.34	33.68	35.75
TenSile	38.10	36.10	35.17	37.30	35.80	35.73	36.19	36.34
CapiTal	37.06	37.43	36.30	33.74	35.58	34.58	34.22	36.32
AdvoCate	38.74	34.78	35.53	35.88	32.95	34.13	35.01	35.03
ProAct	37.23	34.86	37.16	34.55	33.61	35.28	33.07	34.49
Maxicrop	38.52	34.27	37.61	35.38	33.64	35.03	35.31	35.95
P Value	0.332	0.140	0.306	1.350	0.020	0.834	0.573	0.429
SED	1.061	1.256	1.523	1.286	1.470	1.669	1.689	1.416
LSD (5%)	2.178	2.577	3.126	2.638	3.017	3.424	3.466	2.906

<u>Site 14/3 Summary ANOVA Tables</u>

Leaf Damage

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.75	2.38	2.38	2.25	2.25	2.88	2.75	2.75
Stopit	2.00	2.13	2.25	2.13	2.75	2.63	3.00	2.88
InCa	2.25	2.25	2.25	2.25	2.63	2.75	2.88	2.88
Calsym	2.50	2.13	2.63	2.13	2.38	2.63	2.75	2.75
Calmax	2.25	2.00	2.25	2.25	3.00	2.88	3.00	2.88
TenSile	2.25	1.75	2.25	2.50	2.63	2.75	2.75	2.88
CapiTal	1.75	2.13	2.75	2.88	2.75	2.50	2.75	2.75
AdvoCate	2.00	2.13	2.50	2.25	2.63	2.75	2.88	2.88
ProAct	2.00	2.00	2.75	2.38	2.63	2.88	2.88	3.00
Maxicrop	2.00	2.13	2.13	2.13	2.75	3.00	2.88	2.75
P Value	0.464	0.939	0.541	0.451	0.331	0.285	0.354	0.904
LSD (5%)	0.688	0.784	0.701	0.662	0.549	0.382	0.265	0.371
SED	0.335	0.382	0.341	0.323	0.268	0.186	0.129	0.181

Dehydration

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.25	1.75	1.75	1.75	2.25	2.38	2.38
Stopit	1.00	1.00	1.00	1.00	1.50	2.00	2.25	2.38
InCa	1.00	1.00	1.25	1.25	1.50	2.25	2.38	2.38
Calsym	1.00	1.50	2.00	2.00	2.25	2.25	2.38	2.50
Calmax	1.00	1.25	1.25	1.25	2.25	2.13	2.25	2.13
TenSile	1.00	1.00	2.00	2.00	2.00	2.38	2.50	2.63
CapiTal	1.00	1.00	1.25	1.25	1.50	1.88	2.00	2.25
AdvoCate	1.00	1.25	1.75	1.75	2.00	2.50	2.63	2.50
ProAct	1.00	1.25	1.50	1.88	2.00	2.25	2.50	2.88
Maxicrop	1.00	1.25	1.50	1.50	2.00	2.13	2.38	2.38
P Value	NA	0.464	0.038	0.013	0.085	0.21	0.316	0.006
LSD (5%)	NA	0.489	0.641	0.603	0.61	0.428	0.448	0.324
SED	NA	0.238	0.312	0.294	0.297	0.209	0.218	0.158

Bruising

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	2.38	2.50	2.63	2.38	2.75	2.88	3.00	3.13
Stopit	2.75	2.25	2.75	2.38	2.88	3.00	3.50	3.63
InCa	2.25	2.50	2.75	2.38	2.75	3.00	3.00	3.25
Calsym	1.50	2.88	3.13	2.50	2.75	3.00	3.38	3.63
Calmax	2.50	2.25	2.63	2.50	3.13	3.13	3.38	3.25
TenSile	2.00	2.38	3.00	2.88	2.88	2.88	3.00	3.38
CapiTal	2.50	2.38	2.63	2.50	2.50	2.75	3.13	3.75
AdvoCate	2.25	2.63	2.88	2.63	2.88	2.88	3.25	3.63
ProAct	2.13	2.13	2.38	2.38	2.88	3.25	3.25	3.50
Maxicrop	2.25	2.38	2.38	2.50	3.13	3.25	3.38	3.25
P Value	0.106	0.684	0.512	0.936	0.537	0.601	0.778	0.757
LSD (5%)	0.724	0.731	0.731	0.737	0.563	0.533	0.685	0.781
SED	0.353	0.356	0.356	0.359	0.275	0.26	0.334	0.381

Yield

Treatment	Yield (g/sample)
Control	2452
Stopit	2305
InCa	2387
Calsym	2302
Calmax	2373
TenSile	2351
CapiTal	2450
AdvoCate	2357
ProAct	2403
Maxicrop	2384
P Value	0.934
LSD (5%)	243.1
SED	118
CV%	7.0

SPAD

Treat	Harvest	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	36.11	34.75	34.78	35.19	32.41	33.04	33.27	32.87
Stopit	37.28	37.54	35.38	34.48	33.35	34.59	33.84	33.08
InCa	38.19	35.96	36.17	35.18	36.38	33.84	35.71	33.90
Calsym	36.93	35.04	33.34	35.75	33.80	33.36	31.81	32.23
Calmax	36.89	35.32	35.16	33.65	34.59	35.78	33.33	32.62
TenSile	36.95	38.40	35.17	35.10	34.12	33.93	33.68	34.83
CapiTal	38.39	36.20	34.27	33.41	34.18	34.91	35.22	34.26
AdvoCate	37.55	35.45	34.22	33.83	34.82	33.63	33.92	33.26
ProAct	38.13	37.11	35.43	33.55	34.77	34.66	34.95	35.03
Maxicrop	35.89	37.52	33.64	35.01	34.73	33.25	33.53	34.22
P Value	0.702	0.195	0.810	0.849	0.239	0.546	0.096	0.618
SED	1.440	1.431	1.649	1.656	1.252	1.297	1.156	1.509
LSD (5%)	2.954	2.935	3.383	3.398	2.569	2.666	2.371	3.097

Site 14/4 Summary ANOVA Tables

Leaf Damage

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.25	2.25	1.25	2.13	2.13	2.13	2.25	2.50
Stopit	1.50	2.25	1.88	2.25	2.38	2.13	2.50	2.13
InCa	1.63	2.25	1.75	2.25	2.50	1.88	2.25	2.00
Calsym	1.13	2.00	1.63	2.25	2.63	2.25	2.25	2.25
Calmax	1.25	2.13	1.63	2.13	2.25	2.13	2.38	2.38
TenSile	1.00	1.88	1.88	2.25	2.25	2.13	2.25	2.25
CapiTal	1.25	2.25	1.88	2.38	2.38	2.25	2.50	2.50
AdvoCate	1.13	2.00	1.88	2.13	2.13	2.00	2.25	2.75
ProAct	1.25	2.13	1.75	1.88	2.00	2.63	2.75	2.38
Maxicrop	1.25	2.25	2.00	2.13	2.38	2.00	2.25	2.25
P Value	0.263	0.708	0.859	0.778	0.06	0.472	0.507	0.742
LSD (5%)	0.454	0.479	0.493	0.5	0.372	0.591	0.513	0.764
SED	0.221	0.233	0.24	0.243	0.181	0.288	0.25	0.373

Dehydration

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.25	1.63	1.88	1.88	1.75	2.00	1.75
Stopit	1.00	1.13	1.63	1.62	1.88	2.00	2.25	1.50
InCa	1.00	1.00	1.38	1.75	2.00	2.25	2.25	2.25
Calsym	1.00	1.00	1.25	1.62	2.13	2.00	2.13	1.88
Calmax	1.00	1.00	1.38	1.75	2.13	2.13	2.38	2.25
TenSile	1.00	1.00	1.38	1.38	1.63	1.50	1.88	1.88
CapiTal	1.00	1.00	1.38	1.38	1.88	1.75	1.88	1.63
AdvoCate	1.00	1.25	1.50	1.32	2.25	2.25	2.25	2.50
ProAct	1.00	1.25	1.13	1.12	1.63	1.75	1.87	2.00
Maxicrop	1.00	1.00	1.13	1.38	1.63	2.00	2.25	2.25
P Value	NA	0.363	0.855	0.845	0.586	0.65	0.395	0.399
LSD (5%)	NA	0.321	0.655	0.922	0.717	0.812	0.897	0.887
SED	NA	0.156	0.319	0.449	0.349	0.396	0.437	0.432

Bruising

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.13	1.88	1.18	1.88	2.00	1.88	1.88	1.88
Stopit	1.63	2.13	1.63	1.88	1.75	1.88	2.00	1.75
InCa	1.63	1.75	1.63	2.00	2.00	1.63	2.00	2.00
Calsym	1.25	1.63	1.50	1.50	1.88	2.00	2.00	1.88
Calmax	1.50	1.75	1.38	1.38	1.38	2.00	2.13	1.63
TenSile	1.25	1.75	1.38	1.38	1.50	1.50	1.63	1.75
CapiTal	1.38	1.75	1.63	1.63	1.88	1.75	1.88	2.00
AdvoCate	1.25	2.13	1.75	1.75	1.75	1.75	2.00	2.63
ProAct	1.25	2.13	1.50	1.63	1.63	1.75	2.00	1.75
Maxicrop	1.00	2.00	1.88	1.88	1.75	1.50	1.88	1.88
P Value	0.024	0.387	0.583	0.379	0.573	0.344	0.734	0.313
LSD (5%)	0.367	0.524	0.572	0.608	0.64	0.483	0.481	0.721
SED	0.179	0.255	0.279	0.296	0.311	0.235	0.235	0.351

Yield

Treatment	Yield (g/sample)
Control	1737
Stopit	1879
InCa	1800
Calsym	1742
Calmax	1861
TenSile	1816
CapiTal	1770
AdvoCate	1745
ProAct	1891
Maxicrop	1820
P Value	0.360
LSD (5%)	155
SED	76
CV %	5.9

SPAD

Treat	Harvest	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	35.58	35.25	34.61	34.10	31.92	31.95	32.76	34.53
Stopit	34.87	32.60	33.49	32.37	32.08	32.98	33.63	33.24
InCa	34.62	34.49	33.80	32.96	31.38	31.48	32.31	32.92
Calsym	35.07	34.94	34.04	33.70	33.02	34.45	31.83	32.80
Calmax	33.03	35.84	33.08	33.36	31.60	34.35	35.05	33.60
TenSile	33.99	35.53	33.07	32.49	33.20	32.95	33.42	34.88
CapiTal	34.35	35.16	34.29	32.68	31.69	32.25	32.58	34.00
AdvoCate	34.17	35.57	35.05	32.70	33.02	33.38	33.84	34.57
ProAct	34.01	33.64	32.80	33.15	33.69	33.60	32.55	34.76
Maxicrop	33.29	36.51	34.80	34.36	34.35	34.14	33.46	34.82
P Value	0.129	0.060	0.905	0.891	0.361	0.164	0.432	0.380
SED	0.840	1.092	1.689	1.429	1.316	1.148	1.287	1.086
LSD (5%)	1.723	2.24	3.665	2.932	2.700	2.355	2.642	2.227

Site 14/5 Summary ANOVA Tables

Leaf Damage

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.75	2.13	1.75	2.00	2.50	2.50	2.50
Stopit	1.00	1.75	1.88	1.75	2.13	2.50	2.38	2.25
InCa	1.00	1.75	1.75	2.00	2.00	1.75	2.38	2.13
Calsym	1.00	1.88	2.00	1.88	2.25	2.25	2.63	2.63
Calmax	1.00	1.88	1.88	1.63	2.00	2.13	2.25	2.13
TenSile	1.00	2.00	2.13	1.88	2.25	2.38	2.25	2.25
CapiTal	1.00	1.75	1.75	2.25	2.25	2.25	2.38	2.25
AdvoCate	1.00	1.63	1.88	1.63	2.00	2.25	2.25	2.38
ProAct	1.00	1.75	1.75	1.75	2.13	2.13	2.38	2.38
Maxicrop	1.00	1.88	1.88	1.50	2.00	1.88	2.13	2.25
P Value	NA	0.995	0.851	0.151	0.852	0.552	0.822	0.157
LSD (5%)	NA	0.739	0.574	0.484	0.465	0.754	0.553	0.361
SED	NA	0.360	0.280	0.236	0.227	0.368	0.270	0.176

Dehydration

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.75	1.88	1.75	2.13	2.13	1.88	2.13
Stopit	1.00	1.38	1.63	1.50	2.00	2.38	2.25	2.63
InCa	1.00	1.25	1.75	2.00	2.25	1.63	1.75	1.88
Calsym	1.00	1.50	2.13	2.00	2.25	2.25	2.38	2.50
Calmax	1.00	1.38	1.75	1.63	2.00	1.63	1.75	1.88
TenSile	1.00	1.63	1.88	1.88	2.25	2.13	2.13	2.38
CapiTal	1.00	1.13	1.38	1.50	2.00	1.88	1.75	2.25
AdvoCate	1.00	1.50	1.75	1.88	2.25	2.00	1.88	2.13
ProAct	1.00	1.38	1.63	1.75	2.00	2.25	2.25	2.63
Maxicrop	1.00	1.50	2.25	1.88	2.50	2.13	2.38	2.38
P Value	NA	0.494	0.261	0.271	0.676	0.253	0.286	0.122
LSD (5%)	NA	0.531	0.629	0.465	0.567	0.639	0.674	0.601
SED	NA	0.259	0.307	0.227	0.276	0.312	0.328	0.293

Bruising

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.00	1.63	1.50	1.50	1.88	1.50	1.88
Stopit	1.00	1.00	1.88	1.63	1.50	1.50	1.88	1.63
InCa	1.00	1.38	1.63	1.75	1.50	1.25	1.75	1.63
Calsym	1.00	1.00	1.63	1.38	1.50	1.38	1.88	1.88
Calmax	1.00	1.00	1.50	1.50	1.50	1.75	1.50	1.50
TenSile	1.00	1.25	1.63	1.75	2.00	2.00	1.88	1.75
CapiTal	1.00	1.50	1.50	1.50	1.75	1.63	1.88	1.75
AdvoCate	1.00	1.38	1.25	1.50	1.50	1.50	2.00	2.00
ProAct	1.00	1.00	1.38	1.25	1.38	1.50	1.50	1.50
Maxicrop	1.00	1.25	1.63	1.50	1.38	1.63	1.75	1.75
P Value	NA	0.560	0.794	0.854	0.694	0.360	0.527	0.657
LSD (5%)	NA	0.608	0.639	0.624	0.647	0.612	0.565	0.550
SED	NA	0.296	0.312	0.304	0.315	0.298	0.276	0.268

Yield

Treatment	Yield
Control	1002
Stopit	1075
InCa	1155
Calsym	1006
Calmax	1071
TenSile	1073
CapiTal	1012
AdvoCate	1055
ProAct	1031
Maxicrop	1232
P Value	0.283
LSD (5%)	60
SED	1108
CV%	8.0

SPAD

Treat	Harvest	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	35.16	37.14	35.13	36.97	33.88	33.45	34.05	33.78
Stopit	35.46	36.58	34.61	35.52	34.35	33.42	33.37	34.60
InCa	34.34	36.84	34.98	34.18	36.52	33.83	33.77	35.73
Calsym	35.75	36.58	36.13	37.78	34.56	34.55	35.07	34.94
Calmax	35.50	36.45	35.06	35.75	33.88	34.01	33.34	33.16
TenSile	34.89	35.05	35.93	37.46	33.74	34.88	34.98	35.05
CapiTal	34.69	34.46	34.97	36.71	34.07	34.47	34.30	33.15
AdvoCate	35.83	36.45	36.05	34.72	35.42	35.23	34.55	33.84
ProAct	34.09	35.78	33.34	36.05	33.37	36.12	35.66	34.70
Maxicrop	34.88	36.96	35.35	36.82	35.53	34.23	34.89	35.22
P Value	0.455	0.083	0.672	0.144	0.061	0.178	0.475	0.291
SED	0.825	0.874	1.352	1.276	0.956	0.943	1.101	1.204
LSD (5%)	1.692	1.794	2.774	2.618	1.961	1.935	2.258	2.471

Site 14/6 Summary ANOVA Tables

Leaf Damage

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.63	1.63	2.13	2.38	2.50	2.13	2.38
Stopit	1.00	1.50	2.13	2.13	2.63	2.50	1.75	2.25
InCa	1.00	1.88	1.88	2.13	2.25	2.88	2.00	2.50
Calsym	1.00	1.88	1.88	2.13	2.38	2.38	2.38	2.50
Calmax	1.00	1.38	1.75	2.25	2.25	2.75	2.25	2.50
TenSile	1.00	1.38	1.88	1.88	2.25	2.50	2.00	2.25
CapiTal	1.00	1.88	1.75	2.00	2.13	2.75	2.25	2.75
AdvoCate	1.00	1.63	1.63	2.13	2.50	2.38	2.00	2.38
ProAct	1.00	1.63	1.75	1.63	2.13	2.88	2.13	2.50
Maxicrop	1.00	1.63	1.88	2.13	2.13	2.75	2.00	2.63
P Value	NA	0.220	0.623	0.681	0.317	0.489	0.375	0.514
LSD (5%)	NA	0.460	0.479	0.609	0.467	0.577	0.483	0.414
SED	NA	0.224	0.233	0.297	0.228	0.281	0.236	0.202

Dehydration

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.63	2.63	2.38	2.63	2.63	2.50	2.13	2.50
Stopit	1.63	2.13	2.00	2.25	2.38	3.13	2.88	2.88
InCa	1.38	2.00	2.25	2.25	2.63	3.00	2.50	3.00
Calsym	1.75	2.13	2.75	2.50	2.88	2.38	2.38	2.63
Calmax	1.13	2.13	2.38	2.38	2.50	2.75	2.25	2.88
TenSile	1.13	2.00	2.25	2.63	2.63	3.00	2.63	2.88
CapiTal	2.00	2.25	2.38	2.50	2.50	3.13	3.13	3.13
AdvoCate	1.88	2.13	2.38	2.25	2.25	2.63	2.50	2.75
ProAct	1.13	2.13	2.25	2.25	2.50	2.38	2.25	2.38
Maxicrop	1.38	2.13	2.25	2.25	2.50	2.50	2.75	2.88
P Value	0.127	0.762	0.807	0.732	0.660	0.658	0.018	0.239
LSD (5%)	0.709	0.648	0.721	0.572	0.560	0.597	0.538	0.562
SED	0.346	0.316	0.352	0.279	0.273	0.291	0.262	0.274

Bruising

Treat	Pre wash	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	1.00	1.00	1.00	1.00	1.25	1.75	1.75	1.88
Stopit	1.00	1.00	1.00	1.38	1.38	2.00	2.00	1.88
InCa	1.00	1.00	1.50	1.63	1.88	2.13	1.50	2.00
Calsym	1.00	1.63	1.88	1.75	1.88	1.63	1.88	1.75
Calmax	1.00	1.13	1.88	2.13	2.25	2.13	1.88	1.88
TenSile	1.00	1.25	1.25	1.63	1.75	1.63	1.75	1.63
CapiTal	1.00	1.00	1.50	1.50	1.63	2.13	2.13	2.13
AdvoCate	1.00	1.25	1.25	1.50	2.13	1.88	2.13	2.00
ProAct	1.00	1.38	1.38	1.63	1.38	2.00	1.88	1.63
Maxicrop	1.00	1.38	1.50	1.25	1.88	2.00	2.00	2.00
P Value	NA	0.174	0.119	0.054	0.114	0.620	0.744	0.760
LSD (5%)	NA	0.496	0.666	0.587	0.714	0.640	0.685	0.609
SED	NA	0.242	0.325	0.286	0.348	0.312	0.334	0.297

Yield

Treatment	Yield
Control	831
Stopit	919
InCa	905
Calsym	803
Calmax	809
TenSile	790
CapiTal	902
AdvoCate	856
ProAct	852
Maxicrop	838
P Value	0.141
LSD (5%)	102
SED	50
CV %	8.2

SPAD

Treat	Harvest	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	36.87	37.07	36.51	37.60	35.87	36.16	35.95	35.23
Stopit	36.18	37.94	34.97	35.66	35.85	34.90	36.69	35.17
InCa	37.05	34.08	35.65	36.59	34.01	34.99	36.38	35.94
Calsym	36.09	36.69	36.41	36.52	38.08	35.83	37.05	36.84
Calmax	36.70	37.10	37.08	37.62	34.45	35.45	36.39	35.12
TenSile	38.80	37.06	38.44	36.11	36.57	34.63	36.13	35.98
CapiTal	35.56	36.82	35.52	35.62	34.98	36.70	36.08	36.35
AdvoCate	35.87	36.13	37.06	36.19	36.05	36.31	38.30	35.51
ProAct	38.36	37.33	37.81	36.17	35.94	35.77	37.48	36.98
Maxicrop	35.26	37.24	37.71	37.23	35.80	36.64	36.41	36.66
P Value	0.004	0.228	0.094	0.372	0.055	0.630	0.563	0.424
SED	0.856	1.240	1.141	0.973	1.082	1.167	1.113	0.975
LSD (5%)	1.757	2.545	2.341	1.996	2.220	2.395	2.284	2.001