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Project leader:	Dr Richard J. Colgan
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Location of project:	Jim Mount Centre for Post-harvest Research East Malling Research New Road East Malling, Kent ME19 6BJ
Project coordinator:	TBA
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DISCLAIMER:

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.

Signature ....Richard Colgan........................ Date . 21st May 2012.

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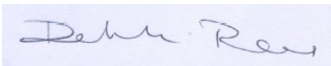
Signature .....  .... Date 21st May 2012

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Grower Summary

Headline

This project is helping to reduce waste and crop losses by developing strategies to improve quality and storage life of broccoli.

Background and expected deliverables

The aim of this project is to define strategies for pre and post-harvest management of broccoli to improve quality and extend storage life. The outputs of the project will enable the industry to reduce waste and crop losses both in the field and post-harvest. The strategies tested include technologies to reduce the concentrations of ethylene in packhouses and store rooms, the use of the ethylene antagonist SmartFresh™ (1-MCP) and the use of pre-harvest chemical treatments to manipulate ethylene production and response by broccoli heads. In addition the project is investigating the use of chlorophyll fluorescence to assess maturity and shelf-life of broccoli at harvest and thereby to improve the consistency of the harvested crop.

Summary of the project and main conclusions

Background ethylene concentrations were sampled at four broccoli handling facilities. Within store rooms the concentrations ranged from 4 to 400 ppb. Trials to determine the effect of ethylene concentration on broccoli shelf-life indicated that at the higher concentrations this is sufficient to accelerate the rate of broccoli senescence during shelf-life.

The first year of trials indicate that SmartFresh™ can ameliorate the loss of visual quality during shelf life of cv. Ironman; applied as a single dose (625 ppb) at harvest or as a split application (321 ppb) applied at harvest. After 8 days of storage at 1°C (100 % RH) SmartFresh™ reduced loss of green colour during shelf-life (18°C) and improved the visual appearance of florets. The effectiveness of SmartFresh™ in maintaining the harvest quality is dependent on the quality of fresh produce at the point of treatment.

Trials were also carried out to determine the impact of pre-harvest sprays of Permasect C and Amistar used as part of standard crop protection programmes on broccoli quality. Results from trials in year one indicates that in some cases they can have secondary beneficial effects on shelf-life quality of broccoli.

Chlorophyll fluorescence has been used as a tool to study the process of photosynthesis for many decades. Models of the functioning of the photosynthetic system have been used to relate the fluorescence characteristics to specific physiological aspects of chloroplasts. The characteristic that appeared to be most sensitive to broccoli senescence was RC/CS (reaction centres/cross-section), which relates to the concentration of functional photosynthetic reaction centres. This will be studied in more detail in the second year of the project to see if it can be used as a practical tool to predict broccoli shelf-life.

Financial benefits

No financial benefits have been determined so far

Action points for growers

- The use of electric powered fork-lifts may be preferential in confined spaces to prevent the buildup of ethylene that can impact on the shelf-life potential of broccoli

SCIENCE SECTION

Introduction

In order to meet the fluctuating demand for broccoli by the retail sector and to ensure a year round supply of broccoli for UK consumers, broccoli may need to be stored for periods of up to 2-3 weeks. Moreover, the year round demand for broccoli in the UK necessitates the import of produce overland from Spain and other Mediterranean countries between December and May. Maintaining the quality of UK stored product and that of imported broccoli requires intervention in the supply chain to ensure broccoli maintains a fresh-green appearance with minimal water loss.

Overall aim of project

To define strategies for broccoli pre- and post-harvest management to improve quality and extend storage life.

Specific Objectives

To evaluate the potential to improve quality and to extend storage/shelf-life through:

a) The management of ethylene concentrations in packhouses and store rooms.
b) The use of post-harvest treatments of broccoli heads with SmartFresh^{TM} (1-MCP).
c) The use of pre-harvest chemical treatments to manipulate ethylene production and response.
d) To define a protocol to use chlorophyll fluorescence to assess maturity and shelf-life of broccoli at harvest and thereby to improve the consistency of the harvested crop.

Materials and methods

Harvesting and initial inspection

Broccoli (*Brassica oleracea var. italica*) cv. Ironman was harvested from Lincolnshire on three separate occasions (20th June, 18th July and 4th August 2011). cv Parthenon was harvested on the 18th July and the 11th August 2011 from a farm belonging to the East of Scotland Growers. Produce was transported overnight by cool chain to the Produce Quality Centre at East Malling Research, Kent, UK.

On arrival, broccoli was placed in a 3°C jacketed air store to facilitate sorting and randomisation of samples. Thereafter broccoli was transferred to a holding temperature of 1°C. Unless otherwise stated ten heads of broccoli were placed in plastic boxes, each box represented a replicate, and three replicates per variety were used. All boxes were initially weighed using a tarred balance before loading into controlled atmosphere storage cabinets; each chamber was 360 L in volume. Data loggers (Easylog) recording humidity and temperature were placed inside each cabinet.

Quantification of ethylene

Ethylene concentrations were monitored regularly during the ethylene treatment phase of the project. Replicate 1 mL samples of the cabinet head space were analysed by a gas chromatograph (GC) with a flame ionization detector (FID). Samples were injected into an injection port heated to 130°C on a GC (ATI-Unicam 610 series) fitted with an FID set at 250°C and a 1 m long, 6 mm OD glass column packed with 100/120 mesh alumunia maintained at 130°C and flushed with nitrogen at 43 mL min^{-1} at 10 psi. Eluted peaks were integrated using a delta integrator (Delta Data Systems). A standard ethylene gas mixture (840 nL L^{-1}) supplied by BOC was used to calibrate the GC at the beginning of each run. The limit of detection was 4 nL L^{-1}.

Assessments of Quality

Assessments of product quality were made after 0, 7, 14, 21 days of storage at 1°C, 100% RH. Boxes were removed individually from cold store and a colour measurement on the greenest part of each broccoli head was made using a Minolta colour meter. Subsequently, chlorophyll fluorescence of selected heads was measured using a Handy Pea- chlorophyll fluorescence meter. Each box was weighed, photographed and heads were scored for visual appearance before samples were returned to store. After 21 days at 1°C, broccoli was transferred to a shelf-life room at 18°C where samples were reassessed after 2, 3 and 6 days.

Visual Assessment

Heads were assessed for signs of deterioration and scored on a scale A-I, where A represented: freshly harvested, green/blue, B (Dark green), C (Green, outer florets starting to loosen), D (first signs of yellowing -0-5%), E (5-10% yellowing), F (10-25% yellowing) , G (25-50% yellowing), H (50-75% yellow/brown) and I (100% yellow/brown). Heads scored between A-B were considered of sufficient quality to be sent onwards through the retail chain while heads scored as C while showing a minor decline in visual quality were considered of saleable quality. Heads scored D-I had no market value.

Colour measurements

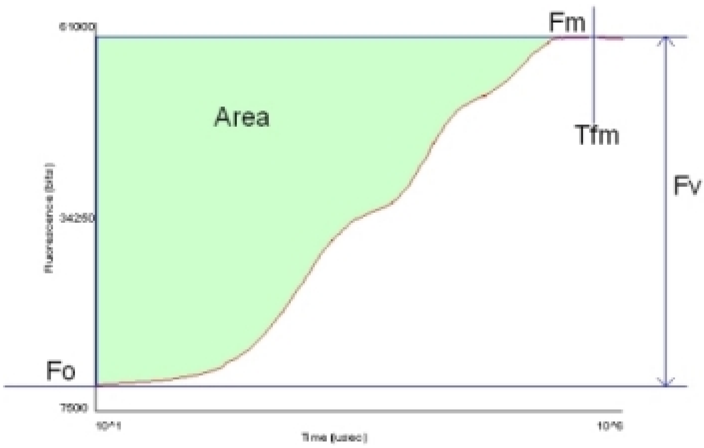
Colour measurement using a Minolta colour meter set to measure in L *a *b mode provided a measure of loss of green background (*a scale) and the increase in yellowing (*b scale).

In addition, the transformation of colour data to generate Chroma $(*a^2 + *b^2)^{0.5}$ and Hue angle: (arctangent(*b/*a)/2π)x 360° values were used to measure the overall change in visual appearance with time. Data was analysed by ANOVA using Genstat version 11.

Chlorophyll fluorescence

Deterioration/senescence of broccoli is associated with a progressive loss of chlorophyll from the heads, and a loss in the ability of buds to photosynthesise. Whereas the loss of chlorophyll can be assessed by measuring colour changes, characteristics of chlorophyll fluorescence (CF) can be used to assess not only chlorophyll concentrations, but also loss of photosynthetic function. Potentially, therefore, CF could provide a more accurate measure of senescence/deterioration than colour. Measurements of chlorophyll fluorescence were made on a four broccoli heads selected per replicate.

The figure below shows a typical fluorescence trace obtained using a fluorimeter such as the Handy PEA. Several characteristics of the trace can be measured; Fo, Fv, Fm, Tfm and Area above the curve are indicated in the figure. Models of the functioning of the photosynthetic system have been used to relate the fluorescence characteristics to specific physiological aspects of chloroplasts (www.hansatech-instruments.com).



A typical fluorescence trace obtained using a non-modulated fluorimeter such as the Handy PEA (Hansatech Instruments Ltd, UK).

The impact of ethylene on Broccoli quality

Environmental monitoring of ethylene in pack-houses store rooms and packing rigs.

On visits to Lincolnshire replicated samples of air taken using a vacuum pump to fill 1 L sample bags (Tedlar) from a series of pack houses, stores and harvesting rigs. Similar measurements were taken by East of Scotland Growers. Air samples were then analysed for the presence of ethylene by GC-FID.

Assessing the impact of background ethylene concentrations on storage quality of broccoli

Broccoli cv Iron Man was placed into storage cabinets on the 21^{St} June. Six replicates of 10 heads per replicate were used. Cabinets were attached to a flow (3 L min^{-1}) of humidified air or air amended with 100, 250 or 500 ppb ethylene (BOC). Measurement of ethylene concentrations were made bi-weekly.

Improving storage quality of broccoli with post-harvest application of SmartFresh™

After loading into chambers, SmartFresh™ powder was weighed on a calibrated Sartorius balance and transferred to a sealed 100 mL Duran bottle. Deionised water (10 ml) at room temperature (20°C) was added before sealing, after rapid mixing bottles were placed inside each cabinet and opened followed by immediate sealing of air tight cabinet lids. Each CA chamber contained a motorised fan allowing circulation of air around the boxes during the 24 hour treatment phase. All automatic ventilation/CA correction controls were inactivated and external ports sealed during SmartFresh™ -treatment. Control cabinets were treated in a similar manner. Treatments consisted of 625 ppb SmartFresh™ on day 0, a half dose of 312 ppb SmartFresh™ on Day 0 repeated on day 8, or untreated controls.

After 24 hour treatment, cabinet lids were opened and SmartFresh™ exhausted, cabinets were resealed and a flow of humidified air at 2 L per minute was passed through the chamber. In addition, the maximum tolerance for CO_2 build up for each cabinet was set at 0.2% and controlled by automatic injection of compressed air, oxygen and carbon dioxide concentrations were monitored and regulated using an ICA66 controlled atmosphere system.

Pre-harvest management factors affecting post-harvest quality of broccoli: Impact of pre-harvest sprays of Permasect C and Amistar

A trial site for Iron Man in Lincolnshire was kindly supplied by Marshalls (Produce World) and a field site for Parthenon in Fife was supplied by the East of Scotland Growers. Spray trials were designed by Allium and Brassica Agronomy ltd (Appendix 1). The trial area consisted of a 24 m x 69 m site within which 3 replicated randomised plots were assigned to each treatment. Each plot consisted of 8 rows x 23 m in length; plant spacing was 40-41 cm per row and approximately 56 plants per row with a total of 448 plants per plot.

Amistar 250 WC (azoxystrobin 22.9% [w/w]) was applied at a rate of 1L ha^{-1} in a volume of 300 L ha^{-1} and Permasect C (cypermethrin 11 % EC [w/w]) at 0.25 L ha^{-1} in a volume of 300 L ha^{-1} using a Berthoud Electric Sprayer with 02 – F110 VP nozzles spaced at 50 cm intervals. Sprays were applied 3 weeks before harvest, by AB Agronomy ltd on the Lincolnshire field site and by EoSG on the site situated in Fife

Results and Discussion

Ethylene monitoring

The background readings for ethylene sampled from various points in the broccoli supply chain were measured for four handling facilities and were variable. In general, store-rooms and chillers had higher ethylene concentrations than pack-houses. In the latter, the larger areas and greater air-flow reduced ethylene to 44 ppb or lower, with one packhouse recording ethylene below the threshold of detection (2 ppb). Ethylene concentrations in storerooms and chillers ranged from 210-386 ppb at one site, while at others background ethylene in storerooms was measured between 4-47 ppb. The range in concentrations may be a consequence of the intensity of fork-lift activity.

Table 1.1. Ethylene mapping of stores packhouses and harvesting rigs (facility 1). Air samples were collected using a Vac-U-Sampler (SKC) filling 1 Litre Teflon coated sample bags (SKC). Air samples (1 mL) were analysed using GC-FID (Agilient 6890N).

Location	**Ethylene ppb**	**SE**
Broccoli store, 6°C, misted, stocks up to 3 days from harvest	325.0	12.6
Broccoli store, not misted, stocks up to 5 days from harvest	210.4	16.3
Blast chiller	386.5	13.5
Cauliflower storeroom	294.5	83.5
Pack-house	44.0	1.0
Harvesting rig	1.0	0.0

Table 1.2 Ethylene mapping of stores packhouses and harvesting rigs at facilities 1-3.. Air samples were collected using a Vac-U-Sampler (SKC) filling 1 Litre Teflon coated sample bags (SKC). Air samples (1 mL) were analysed using GC-FID (Agilient 6890N).

Location	Ethylene ppb	SE
Site 2		
Pack-house	0.4	0.4
Chiller	10.8	1.5
Field	0.0	
Site 3		
Chiller	4.1	1.5
Site 4		
Chiller	46.8	1.3
Pack-house	43.5	1.6

Assessing the impact of background ethylene concentrations on storage quality of broccoli

A gradual colour change in broccoli from blue/green to green was observed during 21 days of storage at 1°C (Figure 1.) leading to an increase in Minolta '-a values'. During this storage phase no significant differences were observed between treatments Transfer to shelf-life conditions accelerated changes in blue-green to dark green colour with a further initial increase in Minolta '-a values'. After 3 days of shelf-life heads exposed previously to 500 ppb ethylene showed a significant ($P<0.05$) reduction in background green colour as the first signs of senescence was observed. After 6 days broccoli from all treatments had deteriorated and with heads in an advanced state of senescence. Those exposed to 250-500 ppb ethylene exhibited the greatest deterioration. An increase in background yellow colour (b-values) was observed earlier than changes in green colour during shelf-life (Figure 2). Broccoli exposed to 250 and 500 ppb ethylene during storage led to an increase in yellow colour development after 2 days and 100 ppb treatment after 3 days shelf-life.

The shape of the fluorescence rise measured using the chlorophyll fluorimeter can be used to calculate a range of chloroplast characteristics using models that have been developed of chloroplast function. Several characteristics were tested for their sensitivity to broccoli senescence. The characteristic that appeared to be most sensitive was RC/CS (reaction centres/cross-section), which relates to the concentration of functional photosynthetic reaction centres. Changes in RC/CS were in advance of those detected by the colour meter, with a decline in ethylene treated broccoli seen after 2 days of shelf-life, and a significant difference between treatments

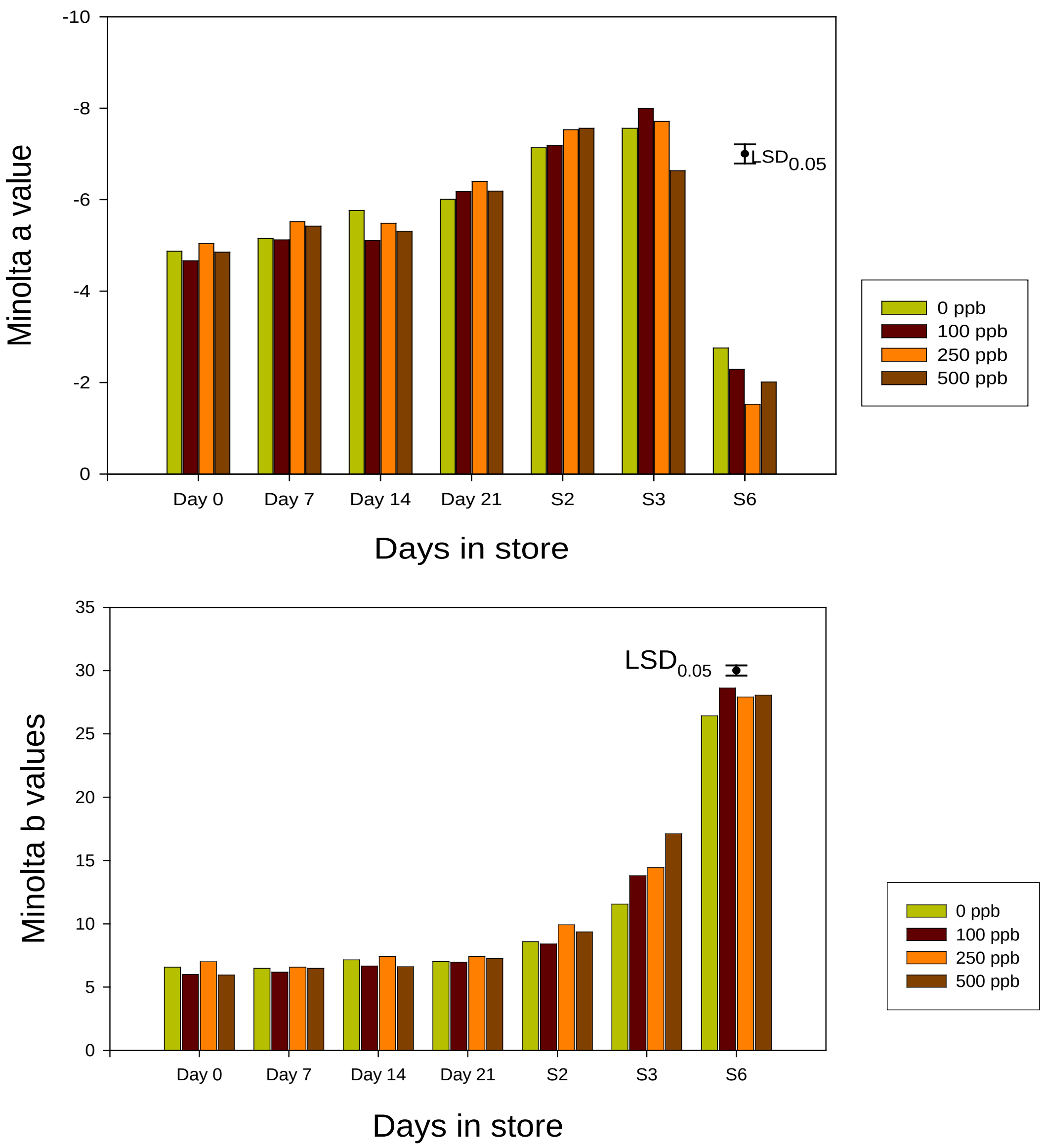


Figure 1.1 The effect of ethylene on background green (Minolta '-a value') and yellow colour (Minolta b values) of broccoli cv Ironman during storage at 1°C (100% RH) followed by 6 days shelf-life at 18°C (S2…S6)

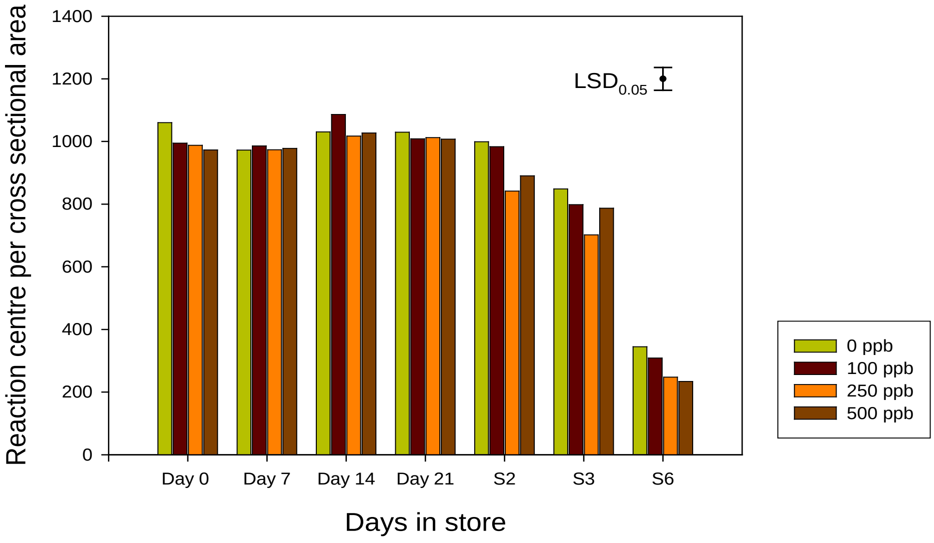


Figure 1.2 The effect of ethylene on chlorophyll fluorescence profiles of broccoli cv Ironman during storage at 1°C (100% RH) followed by 6 days shelf-life at 18°C (S2…S6)

Visual assessment

A visual assessment of broccoli during storage recorded colour changes (Table 1.3.) from blue/dark-green (score A) to dark-green (score B). Observed colour changes mirrored Minolta ‘a values’ where background green intensity (more negative a values) increased during storage. Broccoli exposed to 250-500 ppb ethylene changed from blue/green to green more rapidly. By the end of 21 days storage broccoli retained its green background colour in all treatments however, those exposed to ethylene were generally more flaccid and outer florets showing signs of drooping (score C), but was less evident where ethylene was removed from the storage environment. During shelf-life broccoli that had been exposed to 250-500 ppb ethylene during storage senesced earlier than untreated controls.

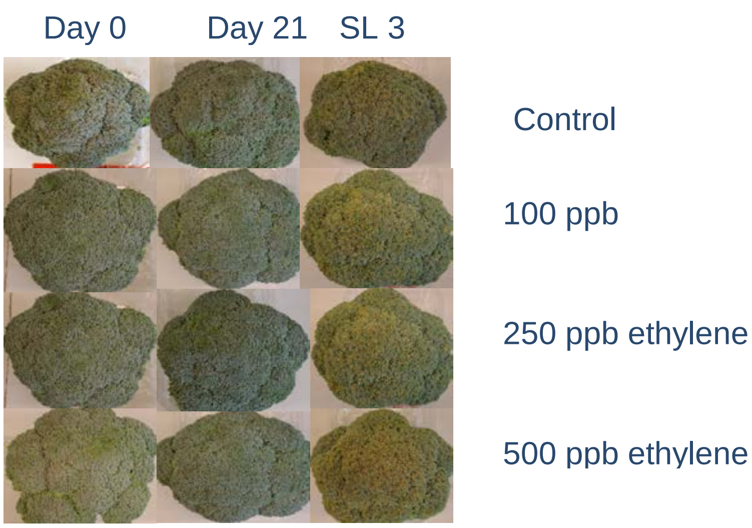


Figure 1.3 The effect of low concentrations of background ethylene on the storage quality and shelf-life (SL 3) of broccoli cv Ironman.

Table 1.3. Visual assessment scores of (*Brassica oleracea var. italica*) cv. Ironman exposed to 0,100, 250 or 500 ppb ethylene during 21 days storage at 1°C (100% RH) followed by 6 days shelf-life (SL). Heads were assessed on arrival (Day 0) and after 7, 14 and 21 days. Shelf-life assessments were carried out after 2, 3 and 6 days (SL2..SL6).

		Ironman		
Inspection	Control	100 ppb	250 ppb	500 bbp
Blue-green				
Day 0	100	100	97.5	100
Day 7	92.5	87.5	95	92.5
Day 14	82.5	80	**65**	**75**
Day 21	15	**5**	**0**	**2.5**
SL 2	0	0	0	0
SL 3	0	0	0	0
SL 6	0	0	0	0
LSD $_{0.05}$ 10.1 on 84 df				
Green				
Day 0	0	0	0	0
Day 7	7.5	12.5	2.5	7.5
Day 14	17.5	20	30	25
Day 21	72.5	65	**55**	67.5
SL 2	50	40	22.5	25
SL 3	97.5	87.5	27.5	60
SL 6	0	0	0	0
LSD $_{0.05}$ 14.4 on 84 df				
Green-florets starting to loosen				
Day 0	0	0	2.5	0
Day 7	0	0	2.5	0
Day 14	0	0	5	0
Day 21	12.5	**30**	**37.5**	**30**
SL 2	50	57.5	50	57.5
SL 3	2.5	12.5	**72.5**	40
SL 6	0	0	0	0
LSD $_{0.05}$ 11.9 0n 84 df				
Senescent				
Day 0	0	0	0	0
Day 7	0	0	0	0
Day 14	0	0	0	0
Day 21	0	0	**7.5**	0
SL 2	0	2.5	**27.5**	**17.5**
SL 3	0	0	0	0
SL 6	100	100	100	100
LSD$_{0.05}$ 6.3 on 84 df				

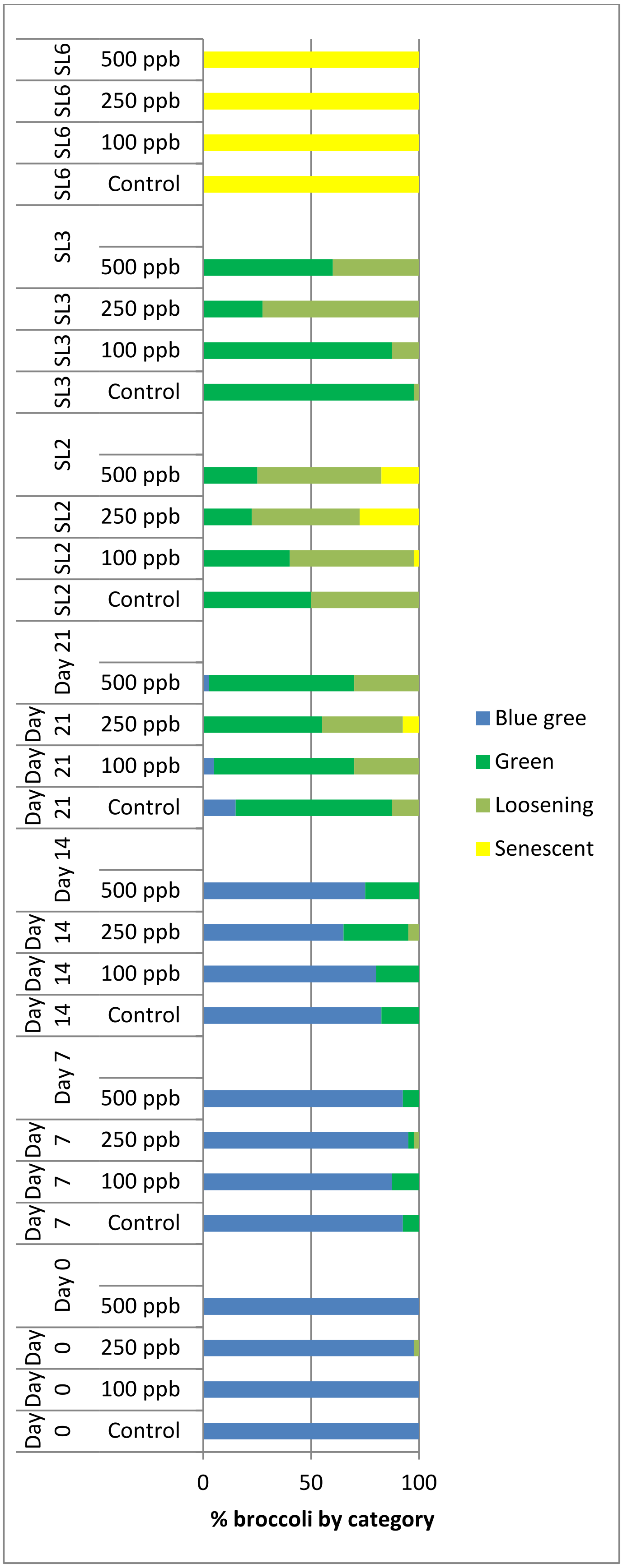


Figure 1.4 Graphical presentation of data in Table 1.3.

Improving storage quality of broccoli with post-harvest application of SmartFresh^{TM}

The effects of SmartFresh^{TM} treatment on broccoli colour measured using a Minolta colour meter are shown in figures 2.1 and 2.2. The background green colour of Parthenon harvested for trials with SmartFresh^{TM} were generally dark-green in appearance and lacked the blue/green hue observed in Ironman. Therefore the background green colour of Parthenon changed little during storage, with only a small intensification in green colour observed during the initial stages of shelf-life. However the green colour declined rapidly by day 6 of shelf-life due to chlorophyll degradation. Only a small non-significant change in 'green- background' colour was observed with SmartFresh^{TM} treatments and the lack of effects was a likely consequence of the favourable storage environment of low-temperature (1°C) and a constant movement of saturated air over the heads. Measurements of background yellow development (Minolta b values) of florets found no treatment effects during storage and a small decrease in yellowing associated with SmartFresh^{TM}-treated heads after 2 days shelf-life. However no difference between a single dose and split dose treatments on background yellow development was observed (Fig 2.1).

No increase in green background colour of Ironman occurred during 21 days of storage at 1°C (100 % RH). After transfer to shelf-life conditions a change from blue/green to green colour was observed in untreated broccoli during the first 3 days of shelf-life followed by a drop in green colour by day 6. SmartFresh^{TM} treated broccoli showed a slower rate of change in green colour and the subsequent drop in green-colour during the later stages of shelf-life was reduced. A corresponding increase in yellow background was observed during shelf-life but no treatment effects of SmartFresh^{TM} were observed (Fig 2.2).

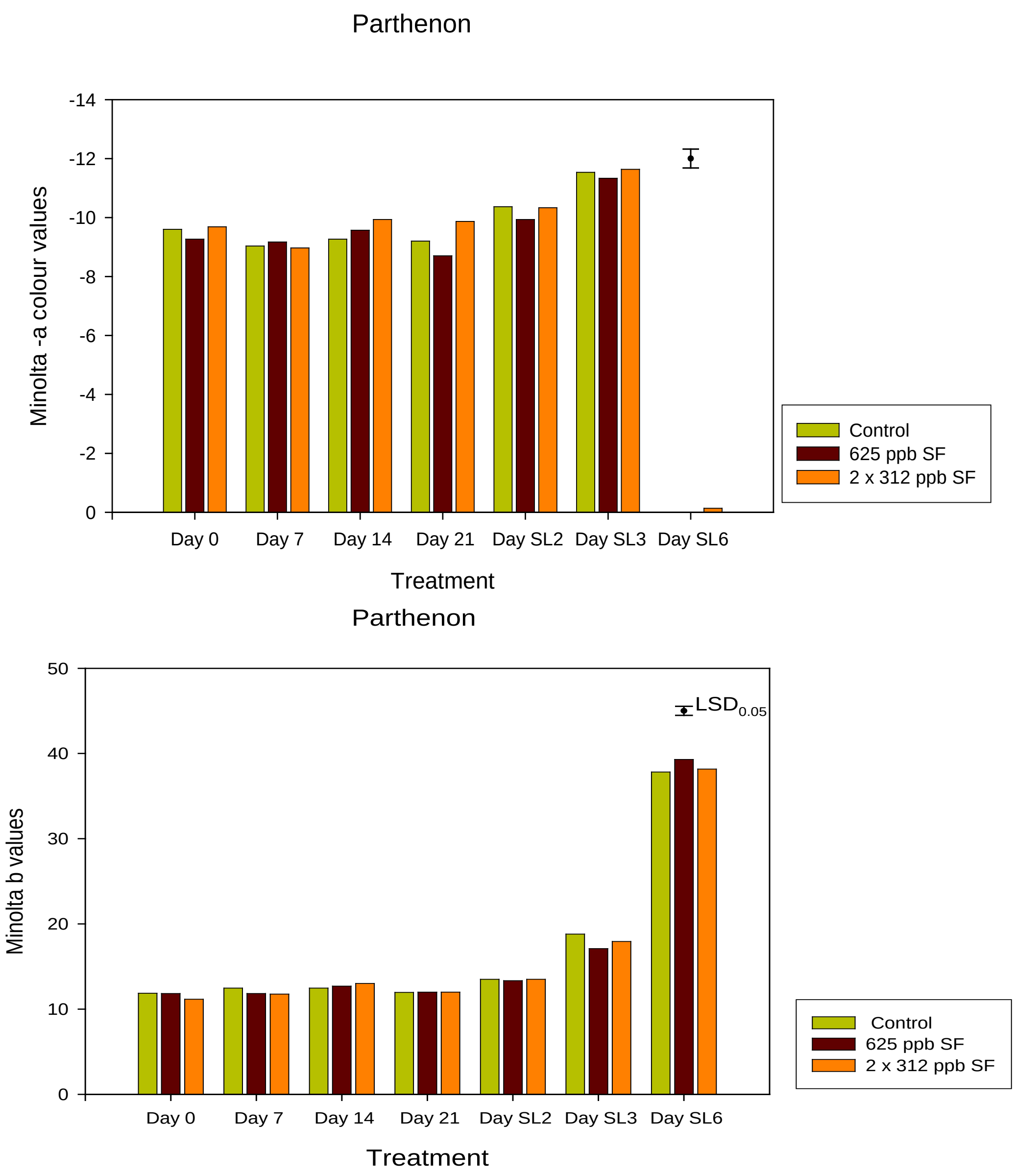
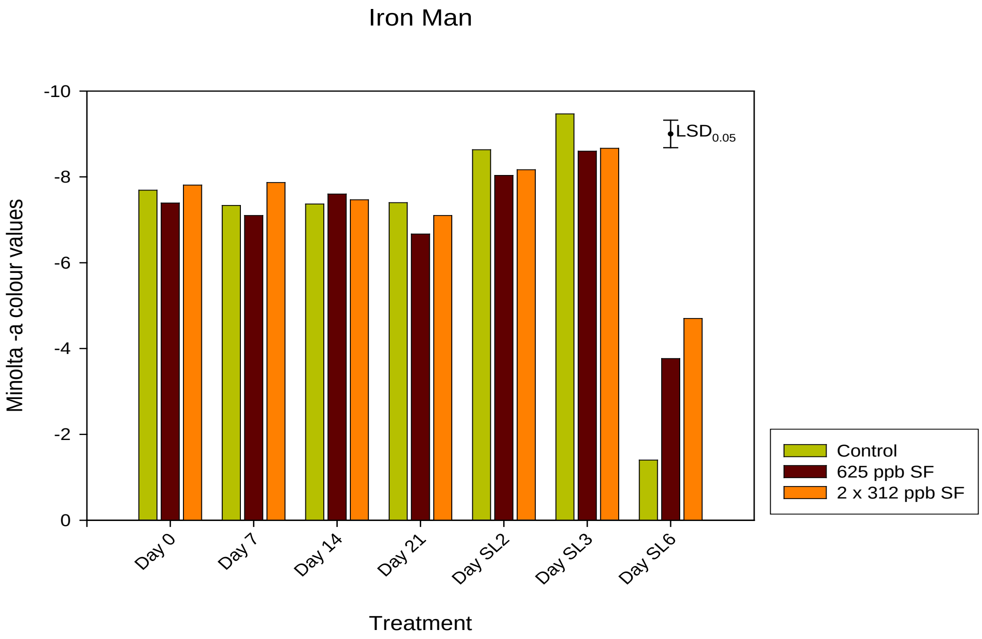


Figure 2.1. The effect of SmartFresh™ on background green (Minolta '–a values') and background yellow (Minolta 'b values') colour of broccoli cv Parthenon during storage at 1°C and shelf-life at 18°C.



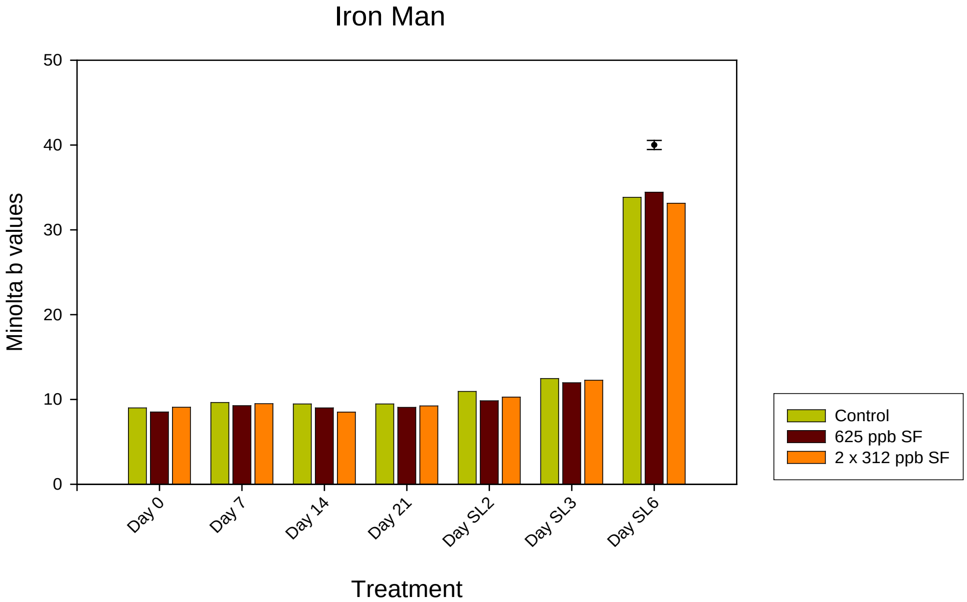


Figure 2.2: The effect of SmartFresh^{TM} on background green (Minolta '–a values') and yellow colour (Minolta 'b' values) of broccoli cv IronMan during storage and shelf-life.

Visual Assessment

Whereas treatment effects were not observed or were very small in terms of Minolta colour meter measurements, visual assessment appears to have been more sensitive in picking up differences. SmartFresh treatments generally improved the visual quality of Ironman (Table 2.1), larger numbers of broccoli heads were categorised as maintaining blue/green appearance after 14 days of storage than untreated broccoli. Maintaining the compactness of the inflorescence and reducing the amount of flaccid outer florets after 2-3 weeks storage at 1°C. While SmartFresh improved the visual quality of Parthenon compared to untreated controls on days 14 and 21.

Table 2.1 Visual assessment scores of (*Brassica oleracea var. italica*) cv. Ironman treated with 625 ppb SmartFresh^{TM} (1-methylcylopropene) on day 0 or a split application of 312 ppb SmartFresh^{TM} on day 0 repeated on day 8. Treatment lasted 24 hours at 1°C. Broccoli was stored for 21 days storage at 1°C (100% RH) followed by 6 days shelf-life (SL). Heads were assessed on arrival (Day 0) and after 7, 14 and 21 days. Shelf-life assessments were carried out after 2, 3 and 6 days (SL2..SL6).

	Ironman			Parthenon		
Inspection	SF 312ppb	SF 625ppb	Control	SF 312ppb	SF 625ppb	Control
Blue-green				**Dark-green**		
Day 0	100.0	100.0	100.0	100	100	100
Day 7	100.0	100.0	100.0	86.7	96.7	86.7
Day 14	**30.0**	**50.0**	0.0	46.7	43.3	33.3
Day 21	0.0	0.0	0.0	0.0	0.0	0.0
SL 2	0.0	0.0	0.0	0.0	0.0	0.0
SL 3	0.0	0.0	0.0	0.0	0.0	0.0
SL 6	0.0	0.0	0.0	0.0	0.0	0.0
LSD $_{0.05}$ 6.2 on 81 df						
Green						
Day 0	0.0	0.0	0.0	0.0	0.0	0.0
Day 7	0.0	0.0	0.0	3.3	3.3	10.0
Day 14	36.7	40.0	40.0	43.3	43.3	46.7
Day 21	10.0	**36.7**	10.0	**76.7**	**70.0**	46.7
SL 2	53.3	43.3	40.0	16.7	20.0	15.0
SL 3	46.7	43.3	46.7	0.0	0.0	13.3
SL 6	0.0	0.0	0.0	0.0	0.0	0.0
LSD $_{0.05}$ 14.8 on 81 df						
Green-florets starting to loosen						
Day 0	0.0	0.0	0.0	0.0	0.0	0.0
Day 7	0.0	0.0	0.0	6.7	0.0	3.3
Day 14	16.7	10	50	10.0	10.0	20.0
Day 21	66.7	53.3	63.3	**23.3**	**30.0**	53.3
SL 2	46.7	56.7	60.0	33.3	**46.7**	25.0
SL 3	53.3	56.7	53.3	23.3	33.3	26.7
SL 6	0.0	0.0	0.0	0.0	0.0	0.0
LSD $_{0.05}$ 15.4 0n 81 df						
Senescent						
Day 7	0.0	0.0	0.0	0.0	0.0	0.0
Day 14	0.0	0.0	0.0	3.3	0.0	0.0
Day 21	16.7	**0.0**	10.0	0.0	3.3	0.0
SL 2	**6.7**	**0.0**	26.7	0.0	0.0	0.0
SL 3	0.0	0.0	0.0	50.0	**16.7**	55.0
SL 6	0.0	0.0	0.0	76.7	63.3	60.0
$LSD_{0.05}$ 10.96 on 81 df	100.0	100.0	100.0	100	100.0	100.0

Weight loss of Parthenon and Iron man at 1°C was not affected by SmartFresh^{TM} treatment alone (data not shown).

Parthenon

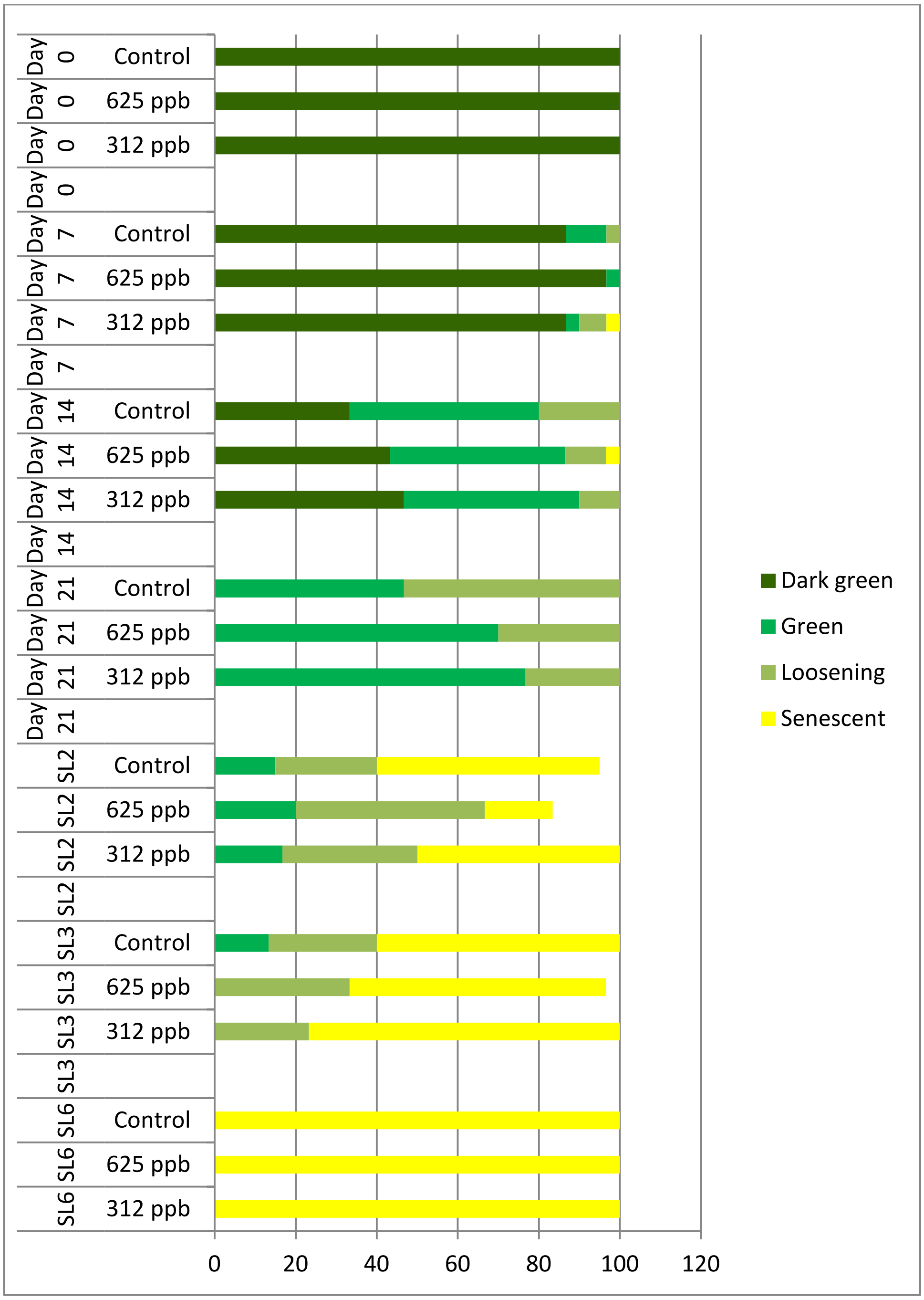


Figure 2.3 Graphical presentation of data on Parthenon from Table 2.1

Iron Man

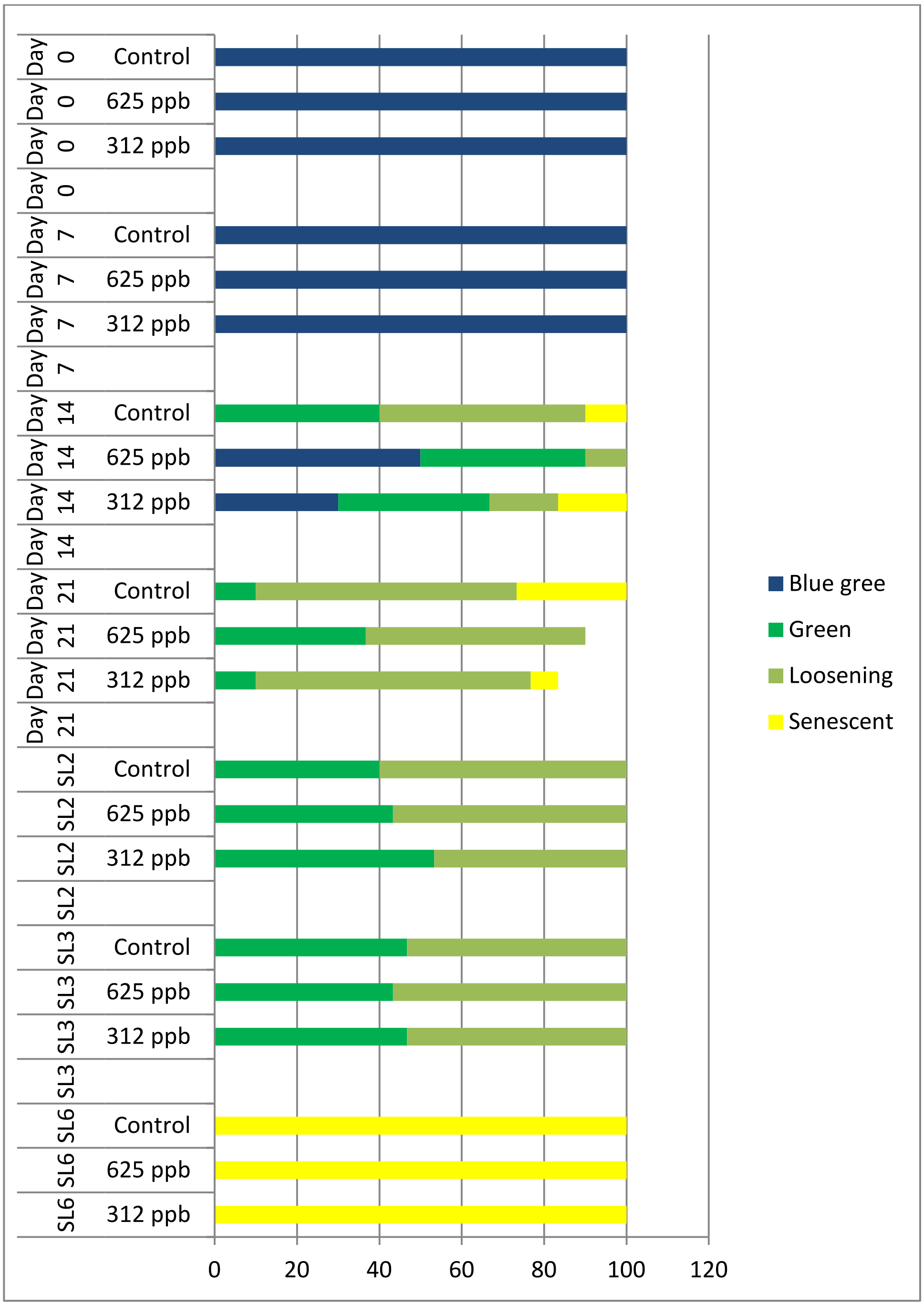


Figure 2.4 Graphical presentation of data on Iron Man from Table 2.1

Pre-harvest management factors affecting post-harvest quality of broccoli: Impact of pre-harvest sprays of Permasect C (cypermethrin) and Amistar (Azoxystobin)

The background green colour (Minolta -a values) of Ironman rose slowly during storage (Fig. 3.1), while the yellow (Minolta b values) colour remained constant. Transfer to shelf-life conditions saw broccoli change from blue/green to green leading to a small increase in back-ground green colour.

No significant trend in treatment effects was observed in background green colour assessments. However, Amistar and Permasect-C-treated Ironman were less prone to senescence (lower b values) during shelf-life than untreated controls (Figure 3.1).

The effect of Amistar and Permasect-C treatment on Parthenon was less apparent. Few changes in background green or yellow colour were observed over the 21 day storage period (Fig 3.2). Under shelf-life conditions a slight rise in the background green colour was observed during the first 3 days of shelf-life followed by a decline by day 6. Permasect-C treated Parthenon appeared to be more resilient to loss of green colour than other treatments. Changes in Minolta b values between treatments was less evident, however, in general, Permasect-C treated broccoli was less yellow during storage.

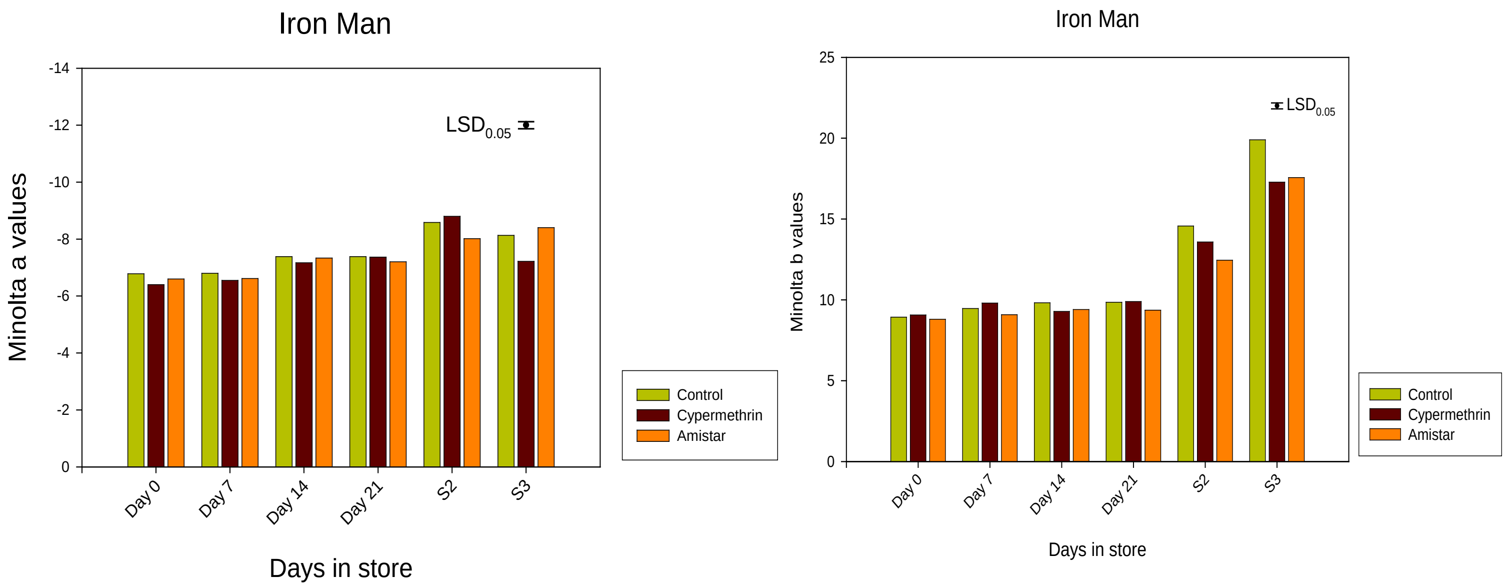


Figure 3.1 Effect of pre-harvest application of cypermethrin (Permasect C) and azoxystrobin (Amistar) on green colour retention and yellowing in Ironman, Minolta a & b values. Sprays were applied 3 weeks before harvest. Broccoli was stored at 1°C (100% RH) for 21 days followed by 6 days shelf-life at 18°C

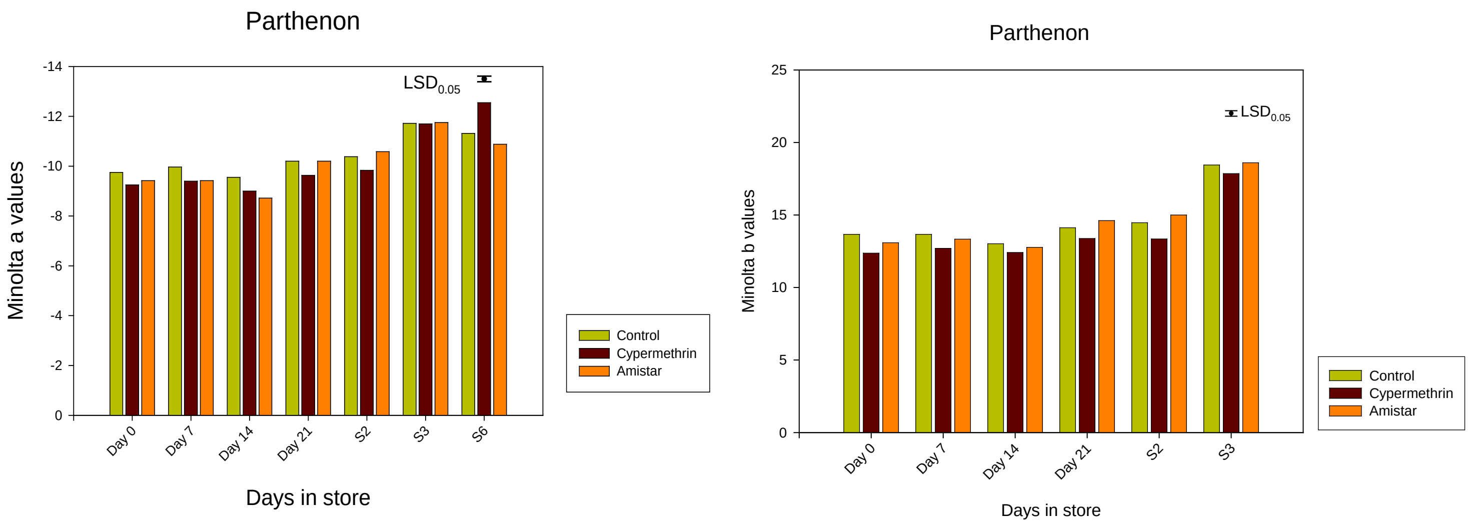
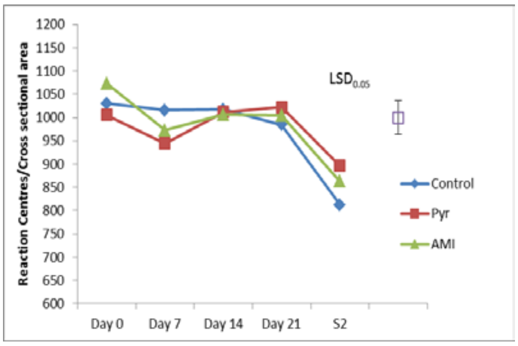


Figure 3.2 Effect of pre-harvest application of cypermethrin (Permasect C) and azoxystrobin (Amistar) on green colour retention and yellowing in Parthenon, Minolta a & b values. Sprays were applied 3 weeks before harvest. Broccoli was stored at 1°C (100% RH) for 21 days followed by 6 days shelf-life at 18°C

Amistar treated Ironman had higher fluorescence readings at harvest and after 7 days storage compared to other treatments, but thereafter a steep decline in fluorescence was recorded and no further treatment differences were observed.

The drop in chlorophyll content was not mirrored in colour-meter readings and suggests the technique may be able to discriminate biochemical changes in florets before visual signs of deterioration are observed. Chlorophyll fluorescence in Parthenon remained stable over the storage period but declined during shelf-life.

Parthenon



Iron Man

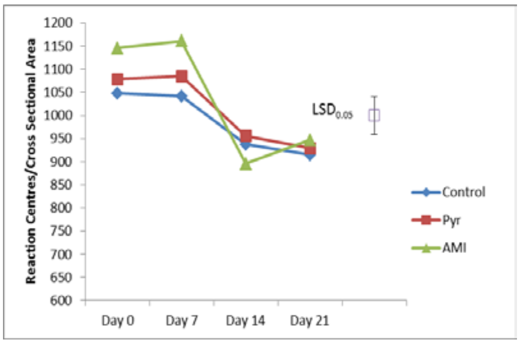


Figure 3.3. Chlorophyll fluorescence profiles for Parthenon and Ironman treated pre-harvest sprays of cypermethrin (Permasect C) and azoxystrobin (Amistar). Sprays were applied 3 weeks before harvest. Broccoli was stored at 1°C (100% RH) for 21 days followed by shelf-life at 18°C.

Variety	Ironman			Parthenon		
Inspection	Control	Cypermethrin	Azoxystrobin	Control	Cypermethrin	Azoxystrobin
Blue-green						
Day 0	41.68	**12.5**	**34.73**	100	100	**81**
Day 7	0	0	0	16.7	**0**	**0**
Day 14	0	0	0	0	0	0
Day 21	0	0	0	0	13.9	0
SL 2	0	0	0	0	0	0
SL 3	0	0	0	0	0	0
SL 6	0	0	0			
$LSD_{0.05}$ 4.2 on 105 df					$LSD_{0.05}$ 15.6 on 90 df	
Green						
Day 0	54.2	**87.5**	**65.3**	0	0	8.3
Day 7	27.8	27.8	**44.4**	38.9	**60.9**	45.9
Day 14	19.4	**26.4**	**33.3**	97.2	97.2	94.9
Day 21	30.5	**19.5**	38.9	100	**83.3**	**75.4**
SL 2	0.0	0.0	0.0	16.7	0	0
SL 3	0.0	0.0	0.0	0	0	0
SL 6	0.0	0.0	0.0			
$LSD_{0.05}$ 10.1 on 105 df					$LSD_{0.05}$ 17.5 on 90 df	
Green-florets starting to loosen						
Day 0	4.2	0.0	0.0	0.0	0.0	8.3
Day 7	68.0	70.8	**55.6**	44.4	39.1	54.2
Day 14	58.3	63.9	61.1	1.4	0.0	0.0
Day 21	40.3	**61.1**	**58.3**	0.0	0.0	3.1
SL 2	22.5	**38.9**	31.7	1.4	4.2	5.8
SL 3	1.7	6.1	11.5	0.0	0.0	0.0
SL 6	0.0	0.0	0.0			
$LSD_{0.05}$ 11.7 on 105 df					$LSD_{0.05}$ 9.4 on 90 df	
Senescent						
Day 0	0.0	0.0	0.0	0.0	0.0	0.0
Day 7	4.2	1.4	0.0	0.0	0.0	0.0
Day 14	20.9	**7.0**	**4.2**	1.4	2.8	2.8
Day 21	29.2	**19.4**	**2.8**	0.0	0.0	4.2
SL 2	77.5	**56.9**	**68.3**	94.7	90.3	91.4
SL 3	98.3	93.9	88.5	100.0	97.2	100.0
SL 6	100.0	100.0	100.0			
$LSD_{0.05}$ 8.7 on 105 df					$LSD_{0.05}$ 5.9 on 90 df	

Table 1.5. Visual assessment scores of (*Brassica oleracea var. italica*) cvs. Ironman and Parthenon treated pre-harvest with sprays of cypermethrin (Permasect C) and azoxystrobin (Amistar). Sprays were applied 3 weeks before harvest. Broccoli was stored for 21 days storage at 1°C (100% RH) followed by 6 days of shelf-life (SL). Heads were assessed on arrival (Day 0) and after 7, 14 and 21 days. Shelf-life assessments were carried out after 2, 3 and 6 days (SL2…SL6).

Visual assessment

The broccoli cv Ironman was subject to heat stress prior to harvesting and the quality of produce was inferior to earlier consignments. A greater proportion of Permasect C and Amistar treated broccoli heads were down-graded at the initial assessment compared to untreated controls. During storage Azoxystrobin-treated broccoli retained the blue/green background for longer during storage and both Permasect and Amistar treated broccoli had fewer heads of broccoli subject to senescence during the initial stages of shelf-life (Table 1.5).

Conclusions

Ethylene build up in confined spaces such as store rooms is sufficient to accelerate deterioration during shelf-life.

SmartFresh^{TM} application may have benefit in extending product quality- identifying most appropriate timing for application(s) is still to be determined.

Growers should be aware that some crop-protection agents used for pest and disease control have secondary effects on shelf-life quality of broccoli

Technology transfer

Brassica Grower Association meeting 17January 2012; Article for HDC News May 2012

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