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FINAL REPORT

Improvement in the storage and shelf-life of plums by the use of 1-MCP

Undertaken for the HDC

CONTENTS

EAST MALLING RESEARCH

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Authentication

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

.....D S Johnson
Signature

Date .....

Grower summary

Headlines

Pre-storage treatment with 1-methylcyclopropene ('SmartFresh™') substantially delayed the ripening of Marjorie's Seedling plums after storage but had little effect on the ripening of Opal or Victoria plums.

Background and expected deliverables

Plums are an important fruit crop in the UK with a production of 13,000 tonnes in 2002, valued at £6.4 M and over 15,000 tonnes in 2003 (Defra statistics). However, while imports of plums increased 4-fold over a 3-year period (1998-2001) the market share for home-produced plums has declined to 7-8%. Most UK plums are marketed in August and September but there is a large and increasing demand by the major retailers for consistent supplies of high quality UK plums for the fresh market from July through to November and beyond.

The greatest extension of storage life of English plums is usually achieved from storage at a temperature of 1^{o}C although a number of factors influence the actual storage life for any given cultivar. Periods of storage for different cultivars vary from 1 to 7 weeks but for the main cultivars currently grown in the UK, i.e. Victoria and Marjorie's Seedling, the expected storage life is 3-4 weeks. In order to prolong storage life plums need to be picked when firm but beginning to colour. Fruit picked too immature may not ripen normally and product quality at the point of sale may be inadequate. On the other hand fruit that is already softening and sweetening at harvest is likely to have a reduced storage potential.

The ethylene inhibitor 1-MCP (1-Methylcyclopropene) is currently applied post-harvest to a number of fruit crops to slow the natural ripening processes thereby improving shelf-life and often extending the storage period. Early results with 1-MCP on both European and Japanese plums (*Prunus domestica* and *Prunus salicina*) obtained in Canada and Spain indicated the potential for delaying softening and extending storage; in South Africa 1-MCP is approved for use on 'Songold' plums and has prolonged air storage by 14 days and shelf life by a further 7 days.

The overall aim of the project is to achieve continuity in the supply of English plums to retailers and particularly to extend the season for late maturing cultivars such as Victoria and Marjorie's Seedling. Present recommendations are to select only good quality plums at the firm ripe stage and, after allowing them to cool overnight, put them into store at 1^{o}C. Storage is limited by the onset of flesh browning and the development of fungal rots and some re-grading of fruit may be necessary after storage to remove any rots that may have developed.

In keeping with their climacteric nature plums ripen rapidly when exposed to warm temperatures and may soften rapidly and become 'bladdery' which is a common cause of market rejection. Rot development during marketing may also be problematic and consequently both the time and temperature during distribution and marketing should be minimised in order to maintain quality and prevent decay.

- The specific objective of the study was to evaluate the effects of 1-MCP ('SmartFresh™') on some physiological and quality parameters during the storage and subsequent shelf-life of 3 cultivars of plum (Opal, Victoria and Marjorie's Seedling) harvested at different maturity (colour) stages.

- It was envisaged that on completion of the project it would be possible to assess the impact of 'SmartFresh™' application on the storage and marketing of UK plums and treatment parameters would have been defined as regards cultivars and stage of maturity for the most efficacious response.

- The work was expected to lead to the development of treatment protocols for 'SmartFresh™' use on English plums and to result in a SOLA application.

Summary of project and main conclusions

Summary

Three plum (*Prunus domestica L.*) cultivars: 'Opal', 'Victoria' and 'Marjorie's Seedling' were harvested on 22 July, 24 August and 3 September 2004 respectively. In 2005 Victoria were picked on 17 and 24 August and 'Marjorie's Seedling' on 31 August and on 2 September.

Fruit was assigned to one of 3 maturity categories based mainly on the total area of red colour. Sorting on the basis of the extent of red coloration generally proved to be a satisfactory means of assessing fruit maturity in that background colour and firmness (by squeezing) generally related to red colour. Two samples of 10 fruit from each maturity stage were used for immediate assessment of quality.

'SmartFresh™' (625 parts per billion of 1-MCP) was applied to half the number of trays for each maturity stage for a period of 24 hours commencing on the day of harvest. Fruit was cooled to 1^{o}C during the course of 'SmartFresh™' application. All samples were stored at 1^{o}C for 4 weeks ('Opal') or 6 weeks (Victoria and Marjorie's Seedling). Additionally in 2005 Marjorie's Seedling plums were stored at 3^{o}C. Quality of fruit was assessed on fruit removed from store and again after a further 3, 4 or 7 days at 20^{o}C. Informal tasting of the fruit was carried out on most occasions and any comments were noted. The carbon dioxide production (respiration) and ethylene production of fruits was measured immediately ex-store and after 4 days at 20^{o}C.

Conclusions

For all plum varieties tested (Opal, Victoria and Marjorie's Seedling) maturity stage was a major factor determining the quality of fruit stored at 1^{o}C and after a further period at 20^{o}C to simulate marketing of the fruit. As expected storage life was restricted by the development of fungal rots and flesh browning.

Selecting fruit for storage on the basis of the degree of red coloration proved to be a successful strategy for minimising decay and the development of flesh browning. Results suggest that storage of plums should be limited to fruit with a maximum of 50% colour. Further coloration of fruits will occur when fruit is returned to warmer

conditions after storage although the concentration of soluble solids will not increase from harvest values and is a disadvantage of picking less-coloured fruit.

Although there were some effects of 'SmartFresh™' on the physiology of stored Opal fruit any effects on quality changes were generally slight particularly when compared with the effects of maturity stage. There is little justification for treatment of Opal plums due to its limited storage life.

Similarly, there were inconsistent effects of 'SmartFresh™' on the physiology and quality changes of stored Victoria fruit. Greater responses of Victoria to 'SmartFresh™' were expected in view of positive responses obtained in preliminary trials carried out in 2003 (Tully et al., 2005). These authors reported improved firmness of fruit stored at 1°C and during shelf-life following treatment with 'SmartFresh™' (650 ppb a.s.). In 2004 and 2005 the incidence of browning tended to be less in fruit treated with 'SmartFresh™' but it is unclear whether this effect would be sufficient to justify commercial application. No attempt was made to judge the commercial significance of the browning recorded in the plums and it is probable that some degree of browning is acceptable and may be indistinguishable from the changes in flesh appearance that is normally associated with ripening. In the event of a SOLA application being granted for the use of 'SmartFresh™' on plums further commercial trials would quantify any benefits of 'SmartFresh™' for Victoria fruit.

The ripening (colouring and softening) of Marjorie's Seedling plums following cold storage was slowed significantly by the application of 'SmartFresh™' prior to storage and the development of flesh browning was reduced. These effects support the results obtained in preliminary trials in 2003 (Tully et al., 2005). The prospect for improved quality and more controlled ripening of Marjorie's Seedling plums is of particular importance to the UK plum industry since later marketing would provide an opportunity to exploit fully the marketing of Victoria plums by avoiding an overlap between varieties. Although Marjorie's Seedling responded to 'SmartFresh™' treatment irrespective of maturity stage the generally higher incidence of rotting and flesh browning in stage 3 fruit would encourage the treatment and storage of fruit with a maximum of 50% colour. Storage of plums at 3°C as opposed to the recommended 1°C was detrimental to storage life and quality despite pre-treating the fruit with 'SmartFresh™'.

Financial benefits

It appears that the treatment of Marjorie's Seedling plums with 'SmartFresh™'will help to maintain quality in store and slow the ripening of fruit during marketing and provide higher quality fruit to the consumer.

Being able to store Marjorie's Seedling plums until the marketing of Victoria plums is completed is a major opportunity to control the supply of English plums to the market and to maximise returns to the grower.

Action points for growers

- Growers should note the importance of avoiding fruit that are too coloured when contemplating extended storage of plums.

- Prompt marketing and cool chain distribution is advised in order to prevent rot development and maintain firmness in plums following cold storage.

- There is no label recommendation for the application of ‘SmartFresh™’ to plums in the UK but it is intended to pursue a SOLA for this use.

References

Tully, M.S., Hanney, S.J. and Bishop, C.F.H. (2005). The effect of 1-methylcyclopropene on the storage potential of UK cultivar plum (*Prunus domestica*). Acta Hort. 682, 1579.

Science Section

Introduction

Plums are an important fruit crop in the UK with a production of 13,000 tonnes in 2002, valued at £6.4 M and over 15,000 tonnes in 2003 (Defra statistics). However, while imports of plums increased 4-fold over a 3-year period (1998-2001) the market share for home-produced plums has declined to 7-8%. Most UK plums are marketed in August and September but there is a large and increasing demand by the major retailers for consistent supplies of high quality UK plums for the fresh market from July through to November and beyond.

The greatest extension of storage life of English plums is usually achieved from storage at a temperature of 1^{o}C although a number of factors influence the actual storage life for any given cultivar (Kidd and West, 1936). Periods of storage for different cultivars vary from 1 to 7 weeks but for the main cultivars currently grown in the UK, i.e. Victoria and Marjorie's Seedling, the expected storage life is 3-4 weeks. In order to prolong storage life plums need to be picked when firm but beginning to colour. Fruit picked too immature may not ripen normally and product quality at the point of sale may be inadequate. On the other hand fruit that is already softening and sweetening at harvest is likely to have a reduced storage potential.

The ethylene inhibitor 1-MCP (1-Methylcyclopropene) is currently applied post-harvest to a number of fruit crops to slow the natural ripening processes thereby improving shelf-life and often extending the storage period. Early results with 1-MCP on both European and Japanese plums (*Prunus domestica* and *Prunus salicina*) obtained in Canada and Spain indicated the potential for delaying softening and extending storage; in South Africa 1-MCP is approved for use on 'Songold' plums and has prolonged air storage by 14 days and shelf life by a further 7 days.

Aims of the project

The overall aim of the project is to achieve continuity in the supply of English plums to retailers and particularly to extend the season for late maturing cultivars such as Victoria and Marjorie's Seedling. Present recommendations are to select only good quality plums at the firm ripe stage and, after allowing them to cool overnight, put them into store at 1^{o}C. Storage is limited by the onset of flesh browning and the development of fungal rots and some re-grading of fruit may be necessary after storage to remove any rots that may have developed. In keeping with their climacteric nature plums ripen rapidly when exposed to warm temperatures and may soften rapidly and become 'bladdery', which is a common cause of market rejection. Rot development during marketing may also be problematic and consequently both the time and temperature during distribution and marketing should be minimised in order to maintain quality and prevent decay.

The specific objective of the study was to evaluate the effects of 1-MCP ('SmartFresh^{TM}') on some physiological and quality parameters during the storage and subsequent shelf-life of 3 cultivars of plum (Opal, Victoria and Marjorie's Seedling) harvested at different maturity (colour) stages.

It was anticipated that on completion of the project it would be possible to assess the impact of 'SmartFresh™' application on the storage and marketing of UK plums and to define treatment parameters in relation to cultivars and stage of maturity for the most efficacious response. The work was expected to lead to the development of treatment protocols for 'SmartFresh™' use on English plums that would form the basis of a SOLA application.

Outline of results from year 1

Three plum (*Prunus domestica L.*) cultivars: 'Opal', 'Victoria' and 'Marjorie's Seedling' were harvested on 22 July, 24 August and 3 September 2004 respectively. Individual 'Opal' and 'Victoria' plums were picked and assigned to one of 3 maturity categories based mainly on the total area of red colour. Least mature (stage 1) fruits were those with the first sign of red colour and the most mature (stage 3) had 80-100% of their surfaces coloured red. Those placed into the intermediate maturity (stage 2) category had about 50% red colour. The same categorisation was implemented for 'Marjorie's Seedling' but this was carried out post picking on a bulk consignment comprised of mixed maturities. Sorting on the basis of the extent of red coloration generally proved to be a satisfactory means of assessing fruit maturity in that background colour and firmness (by squeezing) generally related to red colour. Two samples of 10 fruit from each maturity stage were used for immediate assessment of quality. This included measurement of red and green colour using a Hunter colour meter and measurement of firmness non-destructively using a digital hardness tester and destructively using a Lloyd materials testing machine. Each was cut for an examination of internal quality and juice from all fruits in each sample was combined and used for measurement of soluble solids concentration.

'SmartFresh™' was applied to half the number of trays (40 fruit per tray) for each maturity stage for a period of 24 hours commencing on the day of harvest. Plums were loaded into a gas-tight polypropylene storage container of 360 L nominal capacity in a controlled temperature (CT) room at 1°C and treated with 625 ppb (parts per billion) of the active substance (a.s.) 1-MCP. Fruits not treated with 'SmartFresh™' were stored in a separate CT room at the same temperature (1°C).

All samples were stored at 1°C for 4 weeks ('Opal') or 6 weeks (Victoria and Marjorie's Seedling). Quality of fruit was assessed on fruit removed from store and again after a further 7 days at 20°C. The carbon dioxide production (respiration) and ethylene production of fruits was measured each week at storage temperature (1°C).

<u>Opal</u>

All fruit coloured well during ripening at 20°C regardless of maturity stage at harvest. However, the skins of the fruits cracked badly during ripening and tended to exude juice. No doubt these effects promoted the development and spread of fungal rots. It is clear that Opal plums are suitable for short-term storage only. After 4 weeks at 1°C the flesh of all fruits was translucent and brown

The effects of maturity stage were as follows:

- Generally rot incidence increased with a more advanced maturity stage.

- Differences in objective measurements of colour were related to maturity stage at harvest and these differences were maintained during storage.
- Lower firmness associated with higher maturity stage at harvest was maintained during storage.
- After 7 days at 20^{o}C fruits had softened to the same extent regardless of maturity stage. However, after only 3 days at 20^{o}C the effects of maturity stage were highly significant. It is clear that in 7 days all fruits reached a basal level of firmness. Shorter periods are required after storage to preserve benefits accrued from picking at earlier maturity stages.
- Soluble solids concentrations generally increased with maturity stage

The effects of 'SmartFresh™' were as follows:

- Stage 1 and to a lesser extent stage 2 fruits treated with 'SmartFresh™' were slightly less affected by flesh browning than untreated fruits of comparable maturity stages although this result is of academic interest only.
- Overall there was no effect of 'SmartFresh™' treatment on rot incidence.
- There were no apparent effects of 'SmartFresh™' treatment on colour measurements.
- There was no significant effect of 'SmartFresh™' on hardness or firmness of fruits kept at 1^{o}C.
- 'SmartFresh™' reduced softening in fruit stored for 7 or 14 days and subjected to a further 7 days at 20^{o}C. However, the effects of 'SmartFresh™' were less on fruits at a higher maturity stage.
- There were no significant effects of 'SmartFresh™' on soluble solids content.

Opal plums are suitable for short-term storage only and storage should be restricted to fruit picked with 50% or less of red colour. The time from removal of fruit from store until sale and consumption should be sufficient to encourage ripening and further colour development but should be short enough to avoid the problems of rot development. It is clear that to maintain firmness the primary requirement is to reduce post-storage time and temperature and to avoid storing stage 3 fruit. Although there were some effects of 'SmartFresh™' on the physiology of stored fruit any effects on quality changes were generally slight particularly when compared with the effects of maturity stage. There is little justification for treatment of Opal plums with 'SmartFresh™' due to its limited storage life.

Victoria

The incidence of rotting in Victoria plums stored for 6 weeks at 1^{o}C remained low (5% or less) but increased to unacceptably high levels when fruit was subjected to a further 7 days at 20^{o}C. However, rotting at 20^{o}C was generally avoided by reducing the simulated marketing period to 4 days and restricting cold storage to 31 days and to fruit of maturity stages 1 and 2. The results emphasise the importance of storing less coloured fruit and controlling the time and temperature during the marketing phase in order to avoid problems with rot development.

The effects of maturity stage were as follows:

- Average (5 ex-store and 4 ex-SMP (simulated marketing period) inspections) rot incidences for maturity stages 1, 2 and 3 were 4.5, 7.7 and 17.9% respectively.
- Flesh browning was apparent in stage 1 fruit after 6 weeks of storage and in stage 2 and 3 fruit after only 4 weeks. Browning developed in fruits stored for 3 weeks and subjected to a further 7 days SMP regardless of maturity stage at harvest.
- Fruits at a more advanced stage of maturity at harvest exhibited a higher rate of respiration and ethylene production
- Differences in objective measurements of colour were related to maturity stage at harvest and these differences were maintained during storage.
- Initial maturity-related differences in colour ex-store were no longer evident after 7 days of ripening at 20^{o}C suggesting that a basal colour had been reached.
- Hardness (Shore) and firmness (N) at harvest declined with increased maturity based on the amount of red coloration on the fruit at the time of picking.
- The decline in hardness or firmness in fruit from maturity stage 1 to 2 (10% to 50% red) was small in comparison with that between maturity stage 2 and 3 (50% to 90% red). This pattern of maturity effects on the texture of fruit was generally maintained during storage and subsequent SMP.
- The concentration of soluble solids in the fruit was generally unaffected by maturity

The effects of 'SmartFresh™' were as follows:

- The overall effect of 'SmartFresh™' was to reduce rot incidence from 14.1% to 5.9% (average of 5 ex-store and 4 ex-SMP inspections).
- The incidence of browning tended to be less in fruit treated with 'SmartFresh™' but the effect was insufficient to extend the storage life.
- 'SmartFresh™' had no effect on fruit respiration or ethylene production and consequently effects on quality parameters were not expected.
- There were no apparent effects of 'SmartFresh™' treatment on colour measurements ex-store or after 7 days at 20^{o}C.
- There was no consistent benefit of 'SmartFresh™' on the texture of stored fruit. However on 2 occasions the hardness (Shore) of stage 2 and stage 3 fruit was higher where 'SmartFresh™' had been applied and on one occasion the firmness (N) of stage 3 fruit was higher where 'SmartFresh™' had been applied.
- The concentration of soluble solids in the fruit was generally unaffected by 'SmartFresh™' treatment.

Previous work has shown that at 1^{o}C the storage life of Victoria plums is limited to 3 weeks by the onset of flesh browning. In this study fruit picked at stages 2 and 3 developed browning during the fourth week of storage while those picked at stage 1 were generally free of browning after 5 weeks. However, browning appeared in fruit at all maturity stages when stored for 2 weeks and subjected to a further 7 days at 20^{o}C. Although the simulated marketing temperature and period may be regarded as

severe the result generally endorses earlier work suggesting that without intermittent warming treatments the storage of Victoria plums is limited to 2-3 weeks. No attempt was made to judge the commercial significance of the browning recorded in the plums and it is probable that some degree of browning is acceptable and may be indistinguishable from the changes in flesh appearance that is normally associated with ripening. 'SmartFresh™' did not influence the time of onset of flesh browning and therefore did not prolong storage life. There were no effects of 'SmartFresh™' on the physiology of stored fruit and few effects on quality changes. Consequently there is little justification for treatment of Victoria plums with 'SmartFresh™' and the emphasis for achieving longer storage with minimal wastage should be on picking at the correct maturity stage and minimising the time and temperature for distribution and marketing.

Marjorie's Seedling

The incidence of rotting in Marjorie's Seedling plums stored for 38 days at 1^{o}C remained low (2.4% or less) but increased to unacceptably high levels when fruit stored for 24 days or more was subjected to a further 7 days at 20^{o}C. However, similar to results obtained for Victoria plums, rotting at 20^{o}C was generally avoided by reducing the simulated marketing period to 3 days.

The effects of maturity stage were as follows:

- Flesh browning occurred infrequently in stage 1 fruit stored for up to 38 days but was more evident in stage 2 and 3 fruit although symptoms were generally considered as slight.
- After 38 days of storage stage 3 fruit had a higher rate of ethylene production.
- Differences in objective measurements of colour were related to maturity stage at harvest and these differences were maintained during storage.
- Initial maturity-related differences in colour ex-store were less evident after 7 days of ripening at 20^{o}C but maturity effects on 'b' values remained significant.
- Hardness (Shore) and firmness (N) at harvest declined with increased maturity based on the amount of red coloration on the fruit at the time of picking and this pattern of maturity effects on the texture of fruit was generally maintained during storage but differences were lost during a simulated marketing period.
- Soluble solids concentrations in the fruit increased with maturity stage.

The effects of 'SmartFresh™' were as follows:

- There was no consistent effect of 'SmartFresh™' on the incidence of rotting.
- The internal condition of fruit stored for 35 days was good and noticeably better in fruit treated with 'SmartFresh™'.
- After 31 and 38 days of storage ethylene production was significantly lower in fruit treated with 'SmartFresh™'.
- After 38 days respiration rate of stage 1 fruit was lower where 'SmartFresh™' had been applied and where average respiration rates during storage were compared the effect of 'SmartFresh™' was extended to stage 2 fruit. On the

basis of the effects of 'SmartFresh™' on the physiological parameters effects on quality parameters were expected.

- There were no apparent effects of 'SmartFresh™' treatment on colour measurements made on fruit immediately after storage and this was confirmed from visual observation of the fruit.
- There were significant effects of 'SmartFresh™' treatment on 'a' and 'b' colour measurements after 7 days at 20°C and visual observation confirmed that 'SmartFresh™'-treated fruit appeared less ripe particularly those from maturity stage 1.
- There was generally no consistent benefit of 'SmartFresh™' on the texture of stored fruit although after 38 days there was a small but significant benefit of 'SmartFresh™' on the hardness of fruit at maturity stages 1 and 2.
- Unlike Opal and Victoria there were marked effects of 'SmartFresh™' in slowing the rate of softening of fruit subjected to a simulated marketing period. The effects of 'SmartFresh™' were more pronounced on destructive firmness measurements (penetrometer) than on non-destructive measurements (Shore) of hardness. The effects of 'SmartFresh™' were small after only 3 days at 20°C compared with 7 days at 20°C indicating that 'SmartFresh™' controlled the rapid softening during the later stages of ripening at 20°C which can be problematic in the marketing of plums and can result in 'bladdery' fruit appearing in the market-place.
- Soluble solids content was unaffected by 'SmartFresh™' treatment.

The ripening of Marjorie's Seedling plums following cold storage was slowed significantly by the application of 'SmartFresh™' prior to storage and fruits picked at maturity stages 1 and 2 were virtually free of flesh browning when stored for up to 42 days and subjected to a further 3 or 7 days at 20°C. Rotting at 20°C could not be controlled unless the post storage period was restricted to 3 days but it is expected that this period could be extended if a lower temperature could be provided during ripening after storage. The prospect for improved quality and more controlled ripening of Marjorie's Seedling plums is of particular importance to the UK plum industry since later marketing would provide an opportunity to exploit fully the marketing of Victoria plums by avoiding an overlap between varieties. Although Marjorie's responded to 'SmartFresh™' treatment irrespective of maturity stage the generally higher incidence of rotting and flesh browning in stage 3 fruit would encourage the treatment and storage of fruit with a maximum of 50% colour.

Targets for year 2

1. To continue to evaluate the effects of 'SmartFresh™' on some physiological and quality parameters during the storage and subsequent shelf-life of Victoria and Marjorie's Seedling plums harvested at different maturity (colour) stages.
2. To compare the effects of 'SmartFresh™' on Marjorie's Seedling plums stored at 1°C and 3°C.

Materials and Methods

Victoria plums were picked on 17 and 24 August and 'Marjorie's Seedling' plums were picked on 31 August and on 2 September 2006. All fruit came from the same

commercial farm in West Kent. Individual Victoria fruits were picked and assigned to one of 3 maturity stages based mainly on the total area of red colour. Least mature (stage 1) fruits were those with the first sign of red colour (approx. 10%) and the most mature (stage 3) had 80-100% of their surfaces coloured red. Those placed into the intermediate maturity (stage 2) category had about 50% red colour. Sorting on the basis of the extent of red coloration generally proved to be a satisfactory means of assessing fruit maturity in that background colour and firmness (by squeezing) generally related to red colour. Fruits of each maturity stage were selected at random to form the required number of 10-fruit samples for each experiment. Replicate size was 10 fruit i.e. 1 punnet. Fruit from the first pick of Marjorie's Seedling were assigned to 3 maturity stages as described for the Victoria. The second pick of Marjorie's Seedling were of mixed maturity i.e. normal commercial standards.

Two samples of 10 fruit from each maturity stage were used for immediate assessment of quality. This included measurement of red and green colour using a Hunter colour meter and measurement of firmness non-destructively using a digital hardness tester. Each was cut for an examination of internal quality and juice from all fruits in each sample was combined and used for measurement of soluble solids concentration. Details of the methods used for quality assessment are described below.

Harvest evaluation parameters

Colour. The colour of each fruit in a sample was measured using a 'Hunter ColorFlex' instrument. The 'a' value was used as a measure of redness (the higher the value the redder the fruit) and the 'b' value as a measure of yellowness (the higher the value the more yellow the fruit). The 'L' value was also measured which provides an indication of the degree of whiteness in the colour (100, white and 0, black).

Fruit firmness (non-destructive). One measurement (Shore) was made on each of 10 fruit in a sample using a digital hardness tester (Bareiss) fitted with a 0.1 cm^2 test anvil. Measurements were made in the equatorial region of the fruit.

Soluble solids concentration. Juice was extracted from each fruit by squeezing and soluble solids concentration (%) was measured using a digital refractometer (Atago Ltd).

'SmartFresh™' was applied to half the number of trays for each maturity stage for a period of 24 hours commencing on the day of harvest. Plums were loaded into a gas-tight polypropylene storage container of 360 L nominal capacity in a CT room at 1^oC and treated with 625 ppb (parts per billion) of the active substance (a.s.) 1-MCP. In order to release the active substance the appropriate amount of 'SmartFresh™' (0.36g per 360L container) was placed in a 250 mL screw-top bottle and 5 mL of deionised water added. After agitation the bottle was placed in the treatment container and after removal of the cap the treatment container was sealed for the duration (24 h) of the treatment. Treatment chambers were equipped with fans to circulate the atmosphere. Fruits not treated with 'SmartFresh™' were stored in a separate CT room at the same temperature (1^oC).

After treatment with 'SmartFresh™' for the prescribed period the container was opened and the fruit was allowed to ventilate in normal air for a few hours prior to transfer to storage containers. The same type of container was used for 'SmartFresh™' application and for storage. All samples were stored at 1°C for up to 6 weeks. Additionally the Marjorie's Seedling picked on the second occasion was stored for a similar period in air at 3°C. Quality of fruit was assessed on fruit removed from store and again after a further 7 days at 20°C.

On removal of the fruit any apparent visual differences were recorded and each fruit was examined for the presence of fungal rots. Digital photographs were also taken of fruit immediately ex-store. Two punnets of fruit of each maturity stage were removed and placed into a room at 20°C for 4 days (simulated marketing period or SMP). Quality assessment was similar on fruit immediately ex-store or after a 4-day SMP and included measurements of colour (red and background), firmness (non-destructive) and soluble solids as described above for fruit at harvest. Careful attention was paid to the examination of internal quality and the extent of any internal browning of the flesh. Informal tasting of the fruit was carried out on most occasions and any comments were noted.

The carbon dioxide production (respiration) and ethylene production of fruits from each pick was measured on one occasion immediately ex-store and again after 4 days at 20°C. Punnets of fruit from each maturity stage / treatment were sealed for a few hours into plastic containers with air-tight lids. A sample of the atmosphere from each container was taken by syringe (0.5ml) and injected into a gas chromatograph fitted with an alumina column and FID detector. Results were expressed as parts per billion (ppb) of ethylene. The concentration of carbon dioxide was measured by circulating the atmosphere through an infra-red gas analyser (Analytical Development Company Ltd) and expressed as mg kg^{-1} hr^{-1}. Production rates were calculated using the measured concentrations of ethylene and carbon dioxide, the fruit mass and the time during which the containers remained sealed.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using GENSTAT 7 statistical software. The overall effects of treatments can be compared using the standard errors of the difference between means (s.e.d.) and degrees of freedom (d.f.) given in the tables.

Results and Discussion

Victoria

Fruit physiology (Tables 1 and 2)

Ethylene production of cold-stored fruit from both picks increased progressively with maturity stage but there was no significant reduction following the application of 'SmartFresh™'. Effects of maturity stage on ethylene production were lost in fruit ripened at 20°C for 4 days. 'SmartFresh™' reduced ethylene production in the first pick of fruit subjected to 4 days at 20°C. Respiration rate of cold-stored fruit from pick 1 increased progressively with maturity stage and was reduced in fruit from

maturity stages 1 and 2 by 'SmartFresh™' application. With some evidence of effects of 'SmartFresh™' on fruit physiology, albeit somewhat inconsistent, there was some expectation of effects on fruit quality during storage.

Rotting (Table 3)

The incidence of rotting generally increased with time in store and in fruit exposed to 20°C for 4 days (Table 3). Fruit picked on the second occasion generally developed more rotting and this is likely to be due to the occurrence of rain during the intervening week between picks. As expected the incidence of rotting was variable within the experiment due to the small number of fruits per replicate (punnet) and the opportunity for spread by contact. On average there was a significant increase in rotting associated with a more advanced maturity stage but no affect of 'SmartFresh™' (Tables 15 and 16).

Colour (Tables 5-9, 13 and 14)

The skin colour (hue) of the exposed and shaded sides of the fruit was measured and analysed. The reporting of objective colour measurements is complex (McGuire, 1992) and requires some explanation so that marketers can interpret results provided in the tables of results. The coordinate L is a measure of the colour's lightness whilst negative 'a' indicates a hue of bluish-green and a positive 'a' indicates a hue of red-purple. A positive 'b' indicates yellow and a negative 'b' blue. The more useful characteristics are the hue angle (h°) which integrates the effects of 'b' and 'a' and the chroma (C) which is analogous to the intensity of the colour.

It was reported previously (Year 1 report) that ripened plums had lower 'L values (darker), higher 'a' values (more red and less green) and lower 'b' values (more blue and less yellow). Similar effects were found in the 2005 experiments and additionally in 2005 the hue angle was found to decrease with ripening. Generally there were highly significant effects of maturity stage on the colour of plums at harvest and during storage and the SMP. On average the more mature fruits were darker (lower 'L'), less green (higher 'a' on green side), more blue (lower 'b') and had a lower hue angle and chroma. Effects of 'SmartFresh™' on colour were generally restricted to the first pick of fruit but effects were small in comparison with maturity stage and were inconsistent (Tables 15 and 16).

Hardness (Table 10)

Maturity stage at harvest had a major affect on the hardness (Shore) of the fruit in store. On average the firmness difference between stage 3 and stage 2 fruit was about twice that between stage 2 and stage 1 fruit (Tables 15 and 16). This result emphasises the need to be highly selective when harvesting Victoria plums for storage and to choose only fruits that are firm but beginning to colour (Kidd and West, 1936). There was only one occasion when 'SmartFresh™' improved hardness (pick 1 fruit stored for 3 weeks inclusive of a SMP) but on average there was no effect on fruit from either pick.

Soluble solids (Table 11)

Soluble solids increased with maturity stage and particularly between stages 2 and 3. There was little change in soluble solids concentration during storage or SMP and there were no consistent effects of 'SmartFresh™' treatment (Tables 15 and 16).

Flesh browning (Table 12)

As expected flesh browning became worse with time in store and increased markedly with maturity stage. Pick 2 fruit were generally more susceptible to browning than those from pick 1 and may be related to the rainfall experienced in the intervening week between picks (Kidd and West, 1936).There were some anomalies in the data which may be associated with the difficulties of assessing whether the fruit flesh was normally translucent or brown. For example stage 2 and 3 fruit from the second pick stored for 2 weeks were considered to be browning but a week later no browning was recorded despite the inclusion of a SMP. Browning developed rapidly during the SMP and emphasises the need to keep the fruit as cool as possible during distribution to retail outlets and to minimise the time taken to distribute fruit. A complete cool-chain would be optimum for maintaining quality in the fruit but cool shelf space is often a premium during the summer months. Despite the difficulties in assessing whether the fruit flesh is brown or translucent as in normally ripening fruit there was a general improvement in flesh appearance as a result of 'SmartFresh™' treatment (Tables 15 and 16).

Table 1. Effect of 'SmartFresh™' (625 ppb 1-MCP) on ethylene production (µL kg^{-1} h^{-1}) of Victoria plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
2	1	0.53	0.38	0.58	0.81	3.77	3.93	0.447
2	2	1.04	0.47	2.35	1.20	4.88	3.95	0.848
		Includes 4-day simulated marketing period at 20°C						
3	1	8.76	5.92	11.75	7.21	8.08	7.03	1.972
3	2	5.80	6.06	5.18	4.23	5.80	3.79	1.329

Table 2. Effect of 'SmartFresh™' (625 ppb 1-MCP) on respiration rate (mg CO_2 kg^{-1} h^{-1}) of Victoria plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
2	1	11.76	10.39	12.63	11.61	12.21	12.37	0.304
2	2	15.76	15.39	14.34	13.85	14.59	14.67	0.485
		Includes 4-day simulated marketing period at 20°C						
3	1	12.85	12.11	12.60	11.93	12.32	12.10	0.763
3	2	18.87	17.85	16.53	16.00	19.66	16.52	1.657

Table 3. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the incidence (%) of rotting in Victoria plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
2	1	0	0	0	0	0	0	-
4	1	1.0	0	0	0	5	10.0	6.45
6	1	0	0	5.0	0	5.0	5.0	5.00
2	2	0	6.2	20.0	0	5.6	5.6	8.18
4	2	0	0	0	15.0	22.2	22.2	7.03
6	2	6.2	5.6	0	20.0	35.0	16.7	11.15
		Includes 4-day simulated marketing period at 20°C						
3	1	15.0	0	10.0	0	20.0	25.0	15.81
5	1	0	0	21.4	5.0	20.0	5.0	14.25
7	1	15.0	5.0	5.0	5.0	15.0	35.0	10.8
3	2	0	37.5	20.0	12.5	25.0	30.0	16.46
5	2	0	0	5.0	70.0	44.4	55.6	19.77
7	2	75.0	50.0	75.5	75.0	93.8	72.2	17.88

Table 4. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the 'L' value (red side) of Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	37.1	-	32.3	-	24.6	-	0.48
2	1	30.4	35.1	28.5	30.4	24.6	24.1	1.78
4	1	33.5	33.4	28.4	28.8	22.3	21.5	1.25
Harvest	2	40.3	-	33.7	-	29.1	-	0.82
2	2	38.5	38.0	32.4	31.6	26.9	26.0	0.97
4	2	34.3	31.2	29.4	28.4	24.6	23.9	0.66
		Includes 4-day simulated marketing period at 20°C						
3	1	26.8	27.2	24.4	24.6	22.5	22.2	1.05
5	1	25.9	28.1	23.1	26.0	21.6	23.1	1.32
3	2	26.4	27.6	25.5	24.1	23.5	24.0	1.36

Table 5. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the 'a' value (red side) of Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	8.0	-	12.1	-	11.4	-	1.04
2	1	14.6	10.6	12.9	13.7	13.0	12.6	1.15
4	1	11.2	12.9	14.1	16.1	12.2	10.5	1.13
Harvest	2	3.8	-	9.4	-	11.2	-	0.75
2	2	5.9	6.8	10.8	10.6	11.7	11.5	1.59
4	2	11.0	12.68	12.8	12.0	10.4	10.1	1.07
		Includes 4-day simulated marketing period at 20°C						
3	1	13.2	14.5	12.3	12.2	10.3	9.6	0.62
5	1	11.8	13.3	7.5	10.9	7.0	7.2	1.39
3	2	13.8	13.8	12.1	11.4	10.3	11.8	1.06

Table 6. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the 'b' value (red side) of Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	11.7	-	8.2	-	2.9	-	0.40
2	1	8.5	11.7	7.6	8.6	4.9	4.7	1.13
4	1	10.4	10.1	7.4	7.1	3.8	3.2	0.63
Harvest	2	14.2	-	9.3	-	5.7	-	1.38
2	2	13.5	13.0	6.9	8.7	4.6	3.9	0.57
4	2	10.4	7.6	5.4	5.2	2.0	2.5	0.73
		Includes 4-day simulated marketing period at 20°C						
3	1	6.0	5.5	4.3	4.2	2.8	2.7	0.33
5	1	3.3	3.5	1.0	1.5	0.9	0.5	0.78
3	2	5.5	5.5	4.7	2.6	2.7	2.5	0.90

Table 7. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the 'L' value (green side) of Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	50.9	-	49.1	-	44.6	-	0.58
2	1	48.6	48.3	47.2	45.2	43.4	38.5	0.71
4	1	47.0	48.4	46.0	46.4	35.7	33.6	1.57
Harvest	2	49.7	-	47.3	-	44.9	-	1.74
2	2	47.5	48.0	45.8	44.8	38.0	38.6	0.95
4	2	45.5	45.4	43.8	42.3	35.9	33.4	1.55
		Includes 4-day simulated marketing period at 20°C						
3	1	34.8	33.4	32.4	33.0	27.1	25.6	1.15
5	1	35.4	34.1	31.5	29.7	25.2	25.6	1.30
3	2	32.2	33.2	31.2	32.9	28.7	27.3	1.52

Table 8. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the 'a' value (green side) of Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	-6.6	-	-6.2	-	-1.2	-	0.28
2	1	-4.9	-4.9	-3.4	-2.7	1.0	4.8	1.08
4	1	-3.7	-3.4	-2.2	-1.9	5.4	7.0	1.07
Harvest	2	-6.7	-	-4.7	-	-0.8	-	2.09
2	2	-4.7	-4.7	-1.8	-0.2	5.2	5.5	1.40
4	2	-2.9	-2.9	-0.1	-0.7	6.7	8.3	1.68
		Includes 4-day simulated marketing period at 20°C						
3	1	9.6	11.6	10.9	11.5	12.7	12.6	1.42
5	1	11.3	10.5	8.9	10.2	8.5	7.4	1.21
3	2	11.6	10.2	14.6	11.5	13.8	13.3	1.07

Table 9. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the 'b' value (green side) of Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	20.9	-	21.6	-	17.5	-	0.11
2	1	20.7	20.8	19.6	18.9	16.5	13.6	0.46
4	1	19.1	18.9	18.6	18.1	11.9	9.6	0.85
Harvest	2	20.9	-	18.2	-	17.1	-	1.22
2	2	19.4	19.1	17.8	16.8	12.1	12.6	0.96
4	2	18.5	17.7	16.5	15.8	10.6	8.6	1.01
		Includes 4-day simulated marketing period at 20°C						
3	1	10.7	9.4	10.1	9.2	6.9	5.4	0.58
5	1	8.1	8.3	6.6	5.0	2.8	1.5	1.12
3	2	8.8	8.6	9.1	8.4	7.2	6.5	0.98

Table 10. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the hardness (Shore) of Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	68.3	-	62.0	-	34.7	-	2.53
2	1	56.6	55.1	48.5	40.2	36.3	33.4	5.26
4	1	49.8	52.2	44.6	47.6	37.8	30.0	7.33
6	1	44.6	49.2	37.2	44.3	-	-	4.54
Harvest	2	74.1	-	56.2	-	46.8	-	6.09
2	2	53.9	51.4	45.6	42.0	34.5	32.6	2.65
4	2	56.1	50.8	46.0	42.5	28.6	29.7	3.38
6	2	32.0	34.0	8.0	23.6	-	-	2.11
		Includes 4-day simulated marketing period at 20°C						
3	1	22.7	29.8	22.7	24.6	16.2	15.0	1.53
5	1	37.8	38.0	30.8	30.1	17.9	16.1	2.56
3	2	32.2	29.7	23.7	23.9	17.4	18.2	3.59

Table 11. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the concentration of soluble solids (% Brix) in Victoria plums stored in air at 1°C. (Use 3 degrees of freedom (d.f.) for testing harvest means).

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
Harvest	1	10.6	-	12.0	-	15.0	-	-
2	1	13.9	13.9	14.6	14.5	15.1	16.4	0.33
4	1	13.3	13.6	13.9	14.2	15.5	15.8	0.28
6	1	13.0	13.3	14.1	13.8	15.9	16.0	0.64
Harvest	2							
2	2	13.0	12.4	13.8	14.0	14.4	14.4	0.21
4	2	13.6	13.4	14.6	13.4	16.1	14.7	0.50
6	2	12.2	13.3	12.5	12.6	14.5	13.8	1.19
		Includes 4-day simulated marketing period at 20°C						
3	1	13.1	13.7	13.7	13.6	15.4	15.2	0.33
5	1	13.4	12.5	13.4	13.3	16.4	13.5	0.63
7	1	13.6	12.9	12.7	14.2	13.4	16.1	0.95
3	2	12.4	12.2	13.0	13.4	14.0	14.5	0.70
5	2	13.0	13.2	13.2	13.6	14.3	15.8	0.44

Table 12. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the incidence (%) of flesh browning in Victoria plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
2	1	0	0	0	0	0	0	-
4	1	0	5.0	0	0	0	0	-
6	1	20.0	15.0	25.0	15.0	60.0	45.0	17.52
2	2	0	0	5.0	10.0	58.3	11.1	8.52
4	2	6.2	18.8	35.0	35.0	33.3	44.4	10.46
6	2	38.1	18.8	55.0	43.8	75.0	75.0	22.92
		Includes 4-day simulated marketing period at 20°C						
3	1	0	0	70.0	45.0	89.4	71.7	-
5	1	60.0	40.0	95.0	55.0	100.0	60.0	10.80
7	1	100.0	100.0	100.0	100.0	87.9	92.9	4.31
3	2	0	0	0	0	0	0	-
5	2	25.0	6.2	25.0	5.0	44.4	11.1	9.04

Table 13. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the hue angle (h°) of the red side of Victoria plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
2	1	30.3	48.0	30.4	32.2	20.5	20.5	5.41
4	1	43.0	37.9	28.0	23.8	17.4	17.1	2.97
2	2	66.3	62.5	32.6	39.3	21.4	19.0	3.37
4	2	43.5	30.6	22.8	23.5	11.1	14.2	1.82
		Includes 4-day simulated marketing period at 20°C						
3	1	24.4	21.0	19.3	18.7	15.3	15.7	1.76
5	1	15.3	14.9	7.3	8.0	7.6	3.5	3.47
3	2	21.7	21.6	21.2	12.4	14.4	11.9	3.39

Table 14. Effect of 'SmartFresh™' (625 ppb 1-MCP) on the hue angle (h°) of the green side of Victoria plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	Treated	Control	Treated	Control	Treated	(6 d.f.)
		Cold storage at 1°C						
2	1	103.3	103.3	99.6	98.0	86.6	70.7	3.45
4	1	101.0	100.2	96.7	96.1	65.3	54.1	4.98
2	2	103.7	103.8	95.7	90.5	66.8	66.5	5.74
4	2	98.7	99.4	90.5	92.2	57.5	46.0	7.31
		Includes 4-day simulated marketing period at 20°C						
3	1	48.1	38.9	43.2	38.6	28.6	23.4	4.47
5	1	35.5	38.4	36.8	26.0	18.4	11.2	4.90
3	2	37.1	40.3	32.0	36.1	27.7	26.1	2.60

Table 15. Average effects of maturity stage and 'SmartFresh™' on quality (rotting, colour, firmness (Shore), soluble solids and flesh browning) of Victoria plums picked on the first occasion in 2005. Colour (Hunter L a b, Hue angle (h^o) and Chroma (C) measured on the red and green (Grn) side of the fruit)

	Stage			F Sig.	SED	'SmartFresh™'		F Sig.	SED
	1	2	3			No	Yes		
%Rots	2.9	4.3	12.1	**	1.64	7.6	5.3	n.s.	1.33
Red L	30.0	26.8	22.8	***	0.38	26.0	27.0	**	0.31
Red a	12.8	12.5	10.3	***	0.39	11.7	12.0	n.s.	0.32
Red b	7.4	5.2	2.9	***	0.29	5.1	5.3	n.s.	0.24
Red h^o	29.3	21.0	14.7	***	1.54	21.6	21.8	n.s.	1.26
Red C	15.0	13.7	10.8	***	0.24	12.9	13.4	*	0.19
Grn. L	41.2	38.9	31.8	***	0.40	37.8	36.8	*	0.33
Grn. a	3.3	3.9	7.4	***	0.34	4.5	5.2	*	0.28
Grn. b	14.5	13.3	8.5	***	0.24	12.6	11.6	***	0.19
Grn. h^o	71.1	66.9	44.8	***	1.70	63.6	58.3	**	1.39
Grn. C	17.3	16.0	12.6	***	0.50	15.6	15.0	n.s.	0.41
Shore	42.8	36.1	25.3	***	1.81	35.2	34.3	n.s.	1.48
%SS	13.3	13.8	15.4	***	0.16	14.1	14.2	n.s.	0.13
%Brown	28.3	42.1	50.6	***	1.97	44.9	35.8	***	1.61

Table 16. Average effects of maturity stage and 'SmartFresh™' on quality (rotting, colour, firmness (Shore), soluble solids and flesh browning) of Victoria plums picked on the second occasion in 2005. Colour (Hunter L a b, Hue angle (h^o) and Chroma (C) measured on the red and green (Grn) side of the fruit)

	Stage			F Sig.	SED	'SmartFresh™'		F Sig.	SED
	1	2	3			No	Yes		
Rots	15.0	26.1	35.7	*	5.47	23.8	27.4	n.s.	4.47
Red L	32.7	28.6	24.8	***	0.37	29.1	28.3	*	0.30
Red a	10.7	11.6	11.0	n.s.	0.45	11.0	11.2	n.s.	0.37
Red b	9.2	5.6	3.0	***	0.24	6.18	5.71	*	0.19
Red h^o	41.0	25.3	15.3	***	1.28	28.3	26.1	n.s.	1.04
Red C	14.9	13.0	11.4	***	0.36	13.1	13.1	n.s.	0.29
Grn. L	42.0	40.1	33.6	***	0.39	38.7	38.4	n.s.	0.31
Grn. a	1.1	3.9	8.8	***	0.51	4.7	4.5	n.s.	0.41
Grn. b	15.3	14.1	9.6	***	0.50	13.3	12.7	n.s.	0.40
Grn. h^o	80.5	72.8	48.4	***	2.00	67.7	66.8	n.s.	1.63
Grn. C	17.3	16.4	13.7	***	0.54	16.2	15.4	n.s.	0.44
Shore	45.7	37.3	26.8	***	1.49	37.5	35.6	n.s.	1.22
%SS	12.8	13.4	14.6	***	0.23	13.6	13.6	n.s.	0.18
%Brown	11.3	21.4	35.3	***	4.66	26.7	18.6	n.s.	3.80

Marjorie's Seedling

'SmartFresh™' treatment and maturity stage

Fruit physiology (Tables 17 and 18)

Fruit respiration and ethylene production at 1°C tended to increase with maturity stage although the effects just failed to reach significance at the 5% level of probability. 'SmartFresh™' reduced the respiration rate of fruits in store but surprisingly there were no significant effects on ethylene production.

Rotting (Table 19)

There was insufficient rotting to determine any treatment effects.

Colour (Tables 20-29)

It seems appropriate that the interpretation of the objective colour measurements provided for the experiments on Victoria (see above) are repeated here to aid the reader of the report. The skin colour (hue) of the exposed and shaded sides of the fruit was measured and analysed. The reporting of objective colour measurements is complex (McGuire, 1992) and requires some explanation so that marketers can interpret results provided in the tables of results. The measured coordinates are L is a measure of the colour's lightness whilst negative 'a' indicates a hue of bluish-green and a positive 'a' hue of red-purple. A positive 'b' indicates yellow and a negative 'b' blue. The more useful characteristics are the hue angle (h^o) which integrates the effects of 'b' and 'a' and the chroma (C) which is analogous to the intensity of the colour.

Increased maturity was generally associated with a lower 'L', 'a' and 'b' on the red side of the fruit which contributed a change in the overall colour as indicated by effects on the hue angle. The intensity of colour (Chroma) was less for fruit at a more advanced stage of maturity. On the green side of the fruit increased maturity was associated with a decline in 'L' and 'b' values and was therefore similar to affects recorded on the red side of the fruit. However, 'a' values on the green side increased i.e. became less green with maturity stage and storage time. The hue angle results indicated that there was less change in colour on the green side of fruits than on the red side but, similar to effects on the red side, the intensity of colour (Chroma) on the green side was less on fruits at a more advance maturity stage.

Fruits treated with 'SmartFresh™' had a lighter colour (higher 'L') after storage and a 4-day simulated marketing period. Treated fruits also retained a greener background colour (lower 'a') and 'SmartFresh™' delayed the colour changes associated with ripening and helped maintain a higher intensity of colour. As anticipated most of these effects on colour attributes were more pronounced in fruit subjected to a 4-day simulated marketing period since ripening progresses slowly in fruit held at 1°C.

Hardness (Table 30)

The hardness of fruit generally declined with time in store. Although hardness at harvest and after 2 weeks of storage declined with more advanced stage of maturity thereafter there was no significant effect of maturity stage. 'SmartFresh^{TM}'-treated fruit were generally harder than the untreated and the effect remained evident until the termination of storage after 6 weeks.

Soluble solids (Table 31)

The concentration of soluble solids in the fruit increased with maturity stage and tended to decline slightly during storage. On two occasions only higher soluble solids was associated with 'SmartFresh^{TM}' application.

Flesh browning (Table 32)

With the exception of fruit of maturity stage 3 the incidence of flesh browning was low in fruit stored for up to 6 weeks. However flesh browning was particularly evident where fruit was stored for 6 or 7 weeks and subjected to a 4-day simulated marketing period. After 7 weeks (including a 4-day simulated marketing period) there was less flesh browning in fruits that had been treated with'SmartFresh^{TM}'.

'SmartFresh^{TM}' treatment and storage temperature

Fruit physiology (Tables 33 and 34)

Fruit stored at 3^{o}C as opposed to the recommended 1^{o}C exhibited a higher rate of respiration and ethylene production although these differences were not sustained after a 4-day simulated marketing period. 'SmartFresh^{TM}' application tended to reduce ethylene production in fruit stored for 5 weeks inclusive of a 4-day simulated marketing period and reduced respiration rate of fruit stored for 3 weeks.

Rotting (Tables 35)

Rotting was virtually absent in fruit stored for up to 7 weeks with or without a 4-day simulated marketing period.

Colour (Tables 36-45)

The effects of the higher storage temperature on colour parameters were generally similar to those associated with more advanced maturity stage described in the first experiment on Marjorie's Seedling (see above). Thus on the red side of the fruit the higher storage temperature resulted in a lower 'b' and lower hue value and on the green side less negative 'a', lower b and chroma and higher hue values. These effects were not necessarily evident at each examination and commonly were more evident after a 4-day simulated marketing period.

'SmartFresh^{TM}' application resulted in greener fruit (more negative 'a' values) after a 4-day simulated marketing period but had little effect on other colour parameters. This is in contrast with the results of the first experiment were there was generally a wider

effect of 'SmartFresh™' on colour parameters. The reduced effect of 'SmartFresh™' in experiment 2 may relate to the treatment of fruit of mixed maturities since it is clear from the results of experiment 1 that effects of 'SmartFresh™' are likely to be greatest on least mature fruit.

Hardness (Table 46)

As expected fruit stored at 3°C were generally softer than those stored at the recommended temperature of 1°C. There were no significant effects of 'SmartFresh™' on hardness of fruit and again this may reflect the fact that the samples were comprised of a high proportion of fruit that were too mature to respond to the treatment. In general for climacteric fruits it is necessary to treat at an immature or pre-climacteric stage in order to achieve the greatest response from ethylene inhibiting effect of 'SmartFresh™'.

Soluble solids (Table 47)

There were no significant effects of storage temperature or 'SmartFresh™' treatment on the soluble solids concentration in the fruit.

Flesh browning (Table 48)

With the exception of untreated fruit 3°C the incidence of flesh browning was low in fruit stored for up to 6 weeks. However flesh browning was particularly evident where fruit was stored for 5 or 7 weeks including a 4-day simulated marketing period. After 7 weeks (including a 4-day simulated marketing period) there was more flesh browning in fruits stored at the higher temperature and after 5 and 7 weeks (including a 4-day simulated marketing period) there was a marked reduction in flesh browning where fruit had been treated with 'SmartFresh™'.

Table 17. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on ethylene production (µL kg^{-1} h^{-1}) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(6 d.f.)
		Cold storage at 1°C						
2	1	0.07	0.09	0.08	0.07	0.09	0.10	0.011
		Includes 4-day simulated marketing period at 20°C						
3	1	2.00	1.53	2.02	1.69	2.10	1.97	0.277

Table 18. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on respiration rate (mg CO_2 kg^{-1} h^{-1}) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(6 d.f.)
		Cold storage at 1°C						
2	1	8.12	7.04	8.82	7.11	8.54	8.06	0.340
		Includes 4-day simulated marketing period at 20°C						
3	1	12.68	11.81	15.80	12.42	13.22	13.54	2.398

Table 19. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the incidence (%) of rotting in Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
2	1	0	0	10.0	0	5.6	0	6.60 (6)
4	1	-	-	0	0	0	5.6	3.93 (4)
6	1	10.0	0	5.0	0	5.0	5.6	6.36 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	0	0	0	0	0	0	-
5	1	-	-	0	0	16.7	5.6	12.42 (4)
6	1	-	-	5.0	0	-	-	5.00 (4)
7	1	-	-	0	0	0	0	-

Table 20. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the 'L' value (red side) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		32.2	-	26.9	-	25.1	-	1.04 (3)
2	1	29.9	28.8	29.7	26.9	24.4	23.7	1.47 (6)
4	1	-	-	25.2	28.6	24.5	25.0	1.43 (4)
5	1	-	-	25.2	24.7	-	-	0.59 (2)
6	1	27.2	25.9	25.6	25.1	22.8	24.5	0.25 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	24.2	28.3	23.7	24.4	22.7	23.4	0.80 (6)
6	1	-	-	23.8	24.0	-	-	0.52 (2)

Table 21. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the 'a' value (red side) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		3.4	-	8.6	-	6.4	-	0.77 (3)
2	1	6.3	6.3	6.4	8.2	5.7	5.9	1.86 (6)
4	1	-	-	9.3	8.7	7.5	8.0	1.36 (4)
5	1	-	-	8.5	7.7	-	-	0.45 (2)
6	1	10.7	9.0	8.0	8.2	5.5	6.7	0.79 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	7.5	6.1	6.0	7.5	4.7	5.9	0.75 (6)
6	1	-	-	6.9	7.5	-	-	0.59 (2)

Table 22. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the 'b' value (red side) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		7.4	-	2.3	-	0.3	-	0.73 (3)
2	1	4.9	6.0	4.4	3.4	0.2	0.8	1.47 (6)
4	1	-	-	2.2	5.6	-0.5	0.3	0.97 (4)
5	1	-	-	1.5	1.5	-	-	0.46 (2)
6	1	2.6	3.2	1.0	1.2	0.3	1.2	0.86 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	2.1	4.8	1.7	3.1	0.2	0.6	0.63 (6)
6	1	-	-	0.2	0.9	-	-	0.13 (2)

Table 23. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the 'L' value (green side) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		42.8	-	42.1	-	38.9	-	2.10 (3)
2	1	40.6	41.2	39.3	38.1	36.0	38.9	0.76 (6)
4	1	-	-	40.2	40.4	36.1	37.5	1.23 (4)
5	1	-	-	38.5	39.0	-	-	0.17 (2)
6	1	37.9	40.3	38.0	39.2	34.2	37.9	1.20 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	33.3	38.1	32.7	36.4	29.7	34.4	1.20 (6)
6	1	-	-	35.9	35.9	-	-	0.30 (2)

Table 24. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the 'a' value (green side) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		-7.2	-	-6.3	-	-4.6	-	0.62 (3)
2	1	-5.6	-7.0	-5.6	-4.9	-1.9	-4.3	0.76 (6)
4	1	-	-	-4.9	-5.5	-1.7	-3.0	1.55 (4)
5	1	-	-	-5.4	-5.8	-	-	0.54 (2)
6	1	-3.2	-6.5	-4.6	-5.9	-2.2	-4.8	1.01 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	0.9	-4.4	1.3	-3.4	3.2	-0.1	1.20 (6)
6	1	-	-	-2.5	-3.6	-	-	0.67 (2)

Table 25. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the 'b' value (green side) of Marjorie's Seedling plums stored in air at 1°C

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		14.3	-	13.3	-	12.2	-	0.94 (3)
2	1	13.9	14.2	12.2	12.7	11.0	12.3	0.69 (6)
4	1	-	-	12.6	13.7	10.4	10.4	1.52 (4)
5	1	-	-	12.9	12.7	-	-	0.24 (2)
6	1	11.0	14.1	12.4	13.4	9.6	12.5	0.69 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	8.0	11.9	7.5	10.8	5.5	9.4	1.20 (6)
6	1	-	-	10.0	10.2	-	-	0.08 (2)

Table 26. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the hue angle (red side) of Marjorie's Seedling plums stored in air at 1°C

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		65.2	-	15.1	-	2.0	-	7.00 (3)
2	1	38.9	43.5	36.3	22.8	-1.2	6.6	15.60 (6)
4	1	-	-	12.2	32.5	-3.5	2.6	4.62 (4)
5	1	-	-	10.2	11.0	-	-	3.32 (2)
6	1	13.4	19.4	7.0	7.9	1.8	9.7	7.54 (4)
		Includes 4-day simulated marketing period at 20°C						
3	1	15.7	38.0	15.9	22.2	2.3	5.6	3.84 (6)
6	1	-	-	1.9	6.7	-	-	1.21 (2)

Table 27. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the hue angle (green side) of Marjorie's Seedling plums stored in air at 1°C

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		116.9	-	115.4	-	110.7	-	1.07 (3)
2	1	112.0	116.4	114.5	111.0	99.4	109.2	3.25 (6)
4	1	-	-	111.3	111.8	97.2	105.9	7.37 (4)
5	1	-	-	112.7	114.4	-	-	1.63 (2)
6	1	106.1	114.6	110.2	113.7	103.2	110.7	3.60 (4)
		Includes 4-day simulated marketing period at 20°C						
3	1	83.6	110.4	78.5	107.2	58.2	90.8	11.39 (6)
6	1	-	-	103.9	109.1	-	-	3.33 (2)

Table 28. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the Chroma (red side) of Marjorie's Seedling plums stored in air at 1°C

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		8.2	-	8.9	-	6.5	-	0.67 (3)
2	1	8.0	8.7	8.3	8.9	5.8	6.0	1.23 (6)
4	1	-	-	9.6	10.4	7.6	8.0	1.51 (4)
5	1	-	-	8.6	7.8	-	-	0.46 (2)
6	1	11.0	9.6	8.1	8.3	5.6	6.8	0.86 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	7.8	7.7	6.3	8.1	4.7	5.9	0.86 (6)
6	1	-	-	6.9	7.6	-	-	0.59 (2)

Table 29. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the chroma (green side) of Marjorie's Seedling plums stored in air at 1°C

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		16.0	-	14.8	-	13.1	-	1.09 (3)
2	1	14.9	15.8	13.4	13.6	11.2	13.1	0.78 (6)
4	1	-	-	13.5	14.8	10.7	10.9	1.67 (4)
5	1	-	-	14.0	13.9	-	-	0.44 (2)
6	1	11.5	15.5	13.2	14.7	9.9	13.4	0.94 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	8.2	12.7	7.7	11.3	6.5	9.4	0.89 (6)
6	1	-	-	10.3	10.8	-	-	0.27 (2)

Table 30. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the hardness (Shore) of Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		74.1	-	56.2	-	46.8	-	6.09 (3)
2	1	57.9	59.1	55.0	58.2	49.9	51.2	2.05 (6)
4	1	-	-	48.5	54.2	50.8	52.1	1.01 (4)
5	1	-	-	28.6	27.4	-	-	2.80 (2)
6	1	27.7	33.1	26.4	34.2	27.0	31.3	0.86 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	47.1	52.1	45.3	51.2	45.5	50.7	1.60 (6)
5	1	-	-	17.5	22.9	19.1	24.9	2.75 (4)
6	1	-	-	23.8	23.1	-	-	0.25 (2)
7	1	-	-	31.0	29.8	27.6	38.1	3.50 (4)

Table 31. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the concentration of soluble solids (% Brix) in Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest		14.4	-	16.4	-	17.9	-	1.57 (3)
2	1	15.1	15.4	14.8	16.2	16.6	17.0	0.49 (6)
4	1	-	-	15.6	15.2	16.2	16.6	0.67 (4)
5	1	-	-	14.6	15.4	-	-	0.96 (2)
6	1	13.8	14.0	15.2	15.6	16.2	16.6	0.60 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	14.3	13.7	15.3	15.4	16.7	16.5	0.44 (6)
5	1	-	-	15.7	15.2	16.0	16.1	0.58 (4)
6	1	-	-	14.6	15.4	-	-	0.15 (2)
7	1	-	-	14.4	15.1	15.6	16.4	0.54 (4)

Table 32. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) on the incidence (%) of flesh browning in Marjorie's Seedling plums stored in air at 1°C.

		Maturity Stage 1		Maturity Stage 2		Maturity Stage 3		SED
Weeks	Pick	Control	SF	Control	SF	Control	SF	(d.f.)
		Cold storage at 1°C						
Harvest								
2	1	0	0	0	0	0	0	-
4	1	-	-	0	10.0	7.1	22.2	11.72 (4)
5	1	-	-	-	-	-	-	-
6	1	10.0	0	5.6	5.0	31.7	25.0	18.49 (6)
		Includes 4-day simulated marketing period at 20°C						
3	1	0	5.0	0	0	5.6	5.6	5.38 (6)
5	1	-	-	15.0	5.0	0	11.1	5.00 (4)
6	1	-	-	30.0	5.0	-	-	11.18 (2)
7	1	-	-	50.0	25.0	65.0	35.0	9.35 (4)

Table 33. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on ethylene production (µL kg^{-1} h^{-1}) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
3	2	0.21	0.36	0.16	0.51	0.050
		Includes 4-day simulated marketing period at 20°C				
5	2	5.93	4.67	4.61	4.25	0.577

Table 34. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on respiration rate (mg CO_2 kg^{-1} h^{-1}) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
3	2	6.30	7.70	5.22	6.43	0.367
		Includes 4-day simulated marketing period at 20°C				
5	2	13.74	12.83	13.22	11.52	1.646

Table 35. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the incidence (%) of rotting in Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	0	0	0	0	-
4	2	0	0	0	0	-
6	2	5.0	0	0	0	3.54
		Includes 4-day simulated marketing period at 20°C				
3	2	0	0	0	0	-
5	2	0	0	25.0	10.0	19.04
7	2	0	0	0	0	-

Table 36. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the 'L' value (red side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	27.5	27.0	29.1	27.4	1.49
4	2	26.5	26.0	26.6	26.9	1.29
6	2	25.6	25.2	25.7	26.3	0.52
		Includes 4-day simulated marketing period at 20°C				
3	2	27.0	25.7	25.4	26.6	0.44

Table 37. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the 'a' value (red side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	7.6	9.1	7.1	7.8	1.30
4	2	9.0	9.2	8.9	7.5	0.74
6	2	9.1	11.1	8.9	9.0	1.09
		Includes 4-day simulated marketing period at 20°C				
3	2	7.5	7.0	6.5	7.2	0.54

Table 38. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the 'b' value (red side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	4.2	3.2	5.1	3.4	0.99
4	2	3.7	1.5	3.4	2.8	0.88
6	2	2.2	2.2	1.9	1.6	0.68
		Includes 4-day simulated marketing period at 20°C				
3	2	2.6	-0.1	1.2	0.7	0.78

Table 39. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the 'L' value (green side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	40.9	40.1	40.6	41.9	0.82
4	2	41.4	40.8	41.2	42.6	1.11
6	2	39.8	38.5	40.0	40.7	1.30
		Includes 4-day simulated marketing period at 20°C				
3	2	35.7	33.1	36.9	36.1	1.86

Table 40. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the 'a' value (green side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	-6.6	-5.6	-6.1	-6.3	0.65
4	2	-5.5	-3.7	-6.3	-5.7	1.01
6	2	-4.9	-2.3	-5.3	-3.1	0.38
		Includes 4-day simulated marketing period at 20°C				
3	2	-0.7	3.8	-1.9	-0.6	1.27

Table 41. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the 'b' value (green side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	14.2	14.2	14.3	14.6	0.58
4	2	14.0	12.9	14.3	13.2	1.32
6	2	13.8	12.3	13.8	13.5	0.41
		Includes 4-day simulated marketing period at 20°C				
3	2	9.7	6.7	10.0	9.1	0.81

Table 42. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the hue value (red side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	29.1	19.7	35.7	23.9	8.73
4	2	22.0	8.9	20.9	20.6	5.31
6	2	13.5	11.2	11.5	10.0	3.11
		Includes 4-day simulated marketing period at 20°C				
3	2	19.3	-0.8	10.4	5.8	6.71

Table 43. Effect of 'SmartFresh™' (625 ppb 1-MCP) and storage temperature on the hue value (green side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	114.8	111.5	113.0	113.3	1.58
4	2	111.5	105.8	113.7	113.2	2.95
6	2	109.3	100.9	111.2	102.9	1.86
		Includes 4-day simulated marketing period at 20°C				
3	2	93.9	60.8	100.2	93.5	8.08

Table 44. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the Chroma (red side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	8.7	9.7	8.8	8.6	0.96
4	2	9.7	9.3	9.5	8.0	0.80
6	2	9.3	11.3	9.1	9.2	1.19
		Includes 4-day simulated marketing period at 20°C				
3	2	8.0	7.0	6.7	7.2	0.40

Table 45. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the Chroma (green side) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	15.7	15.3	15.5	15.9	0.76
4	2	15.1	13.5	15.6	14.4	1.51
6	2	14.6	12.5	14.8	13.8	0.38
		Includes 4-day simulated marketing period at 20°C				
3	2	9.7	7.9	10.3	9.1	0.94

Table 46. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the hardness (Shore) of Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	54.9	49.8	54.4	48.3	2.18
4	2	51.2	45.0	51.2	46.2	1.74
6	2	30.2	28.0	29.0	28.0	1.35
		Includes 4-day simulated marketing period at 20°C				
3	2	45.7	42.3	41.6	41.6	2.26
5	2	16.0	13.3	16.9	13.8	1.74
7	2	40.0	35.0	41.2	34.8	2.86

Table 47. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the concentration of soluble solids (% Brix) in Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
Harvest	2					
2	2	11.2	14.2	12.4	12.8	1.11
4	2	12.8	13.0	12.6	10.9	0.64
6	2	13.8	12.6	12.5	11.6	1.63
		Includes 4-day simulated marketing period at 20°C				
3	2	11.6	12.3	12.7	12.2	1.12
5	2	13.2	13.1	13.7	13.2	0.47
7	2	11.6	13.2	13.2	12.4	0.77

Table 48. Effect of 'SmartFresh™' (SF) (625 ppb 1-MCP) and storage temperature on the incidence (%) of flesh browning in Marjorie's Seedling plums.

		Control		SF		SED
Weeks	Pick	1°C	3°C	1°C	3°C	(4 d.f.)
2	2	-	-	-	-	-
4	2	0	0	0	10.0	-
6	2	5.0	25.0	5.0	5.0	7.07
		Includes 4-day simulated marketing period at 20°C				
3	2	0	0	10.0	0	7.07
5	2	25.0	25.0	5.0	5.0	7.07
7	2	25.0	45.0	10.0	20.0	5.00

Conclusions

For all plum varieties tested (Opal, Victoria and Marjorie's Seedling) maturity stage was a major factor determining the quality of fruit stored at 1°C and after a further period at 20°C to simulate marketing of the fruit. As expected storage life is restricted by the development of fungal rots and of flesh browning. Selecting fruit for storage on the basis of the degree of red coloration proved to be a successful strategy for minimising decay and the development of flesh browning. Results suggest that storage of plums should be limited to fruit with a maximum of 50% colour. Further

coloration of fruits will occur when fruit is returned to warmer conditions after storage although the concentration of soluble solids will not increase from harvest values and is a disadvantage of picking less-coloured fruit.

Although there were some effects of 'SmartFresh^{TM}' on the physiology of stored Opal fruit any effects on quality changes were generally slight particularly when compared with the effects of maturity stage. There is little justification for treatment of Opal plums due to its limited storage life.

Similarly, there were inconsistent effects of 'SmartFresh^{TM}' on the physiology and quality changes of stored Victoria fruit. Greater responses of Victoria to 'SmartFresh^{TM}' were expected in view of positive responses obtained in preliminary trials carried out in 2003 (Tully et al., 2005). These authors reported improved firmness of fruit store at 1^{o}C and during shelf-life following treatment with 'SmartFresh^{TM}' (650 ppb a.s.). In 2004 and 2005 the incidence of browning tended to be less in fruit treated with 'SmartFresh^{TM}' but it is unclear whether this effect would be sufficient to justify commercial application. No attempt was made to judge the commercial significance of the browning recorded in the plums and it is probable that some degree of browning is acceptable and may be indistinguishable from the changes in flesh appearance that is normally associated with ripening. In the event of a SOLA application being granted for the use of 'SmartFresh^{TM}' on plums further commercial trials would quantify any benefits of 'SmartFresh^{TM}' for Victoria fruit.

The ripening of Marjorie's Seedling plums following cold storage was slowed significantly by the application of 'SmartFresh^{TM}' prior to storage. This effect supports the results obtained in preliminary trials in 2003 (Tully et al., 2005). The prospect for improved quality and more controlled ripening of Marjorie's Seedling plums is of particular importance to the UK plum industry since later marketing would provide an opportunity to exploit fully the marketing of Victoria plums by avoiding an overlap between varieties. Although Marjorie's responded to 'SmartFresh^{TM}' treatment irrespective of maturity stage the generally higher incidence of rotting and flesh browning in stage 3 fruit would encourage the treatment and storage of fruit with a maximum of 50% colour. Storage of plums at 3^{o}C as opposed to the recommended 1^{o}C was detrimental to storage life and quality despite pre-treating the fruit with'SmartFresh^{TM}'.

Responses of plums to treatment with 1-MCP are known to vary with variety and marked yearly variations in efficacy for any particular variety have been noted which do not appear related to ripeness at harvest (Skog et al., 2003).

Technology transfer

EMRA Plum Walk held at EMR on 4 August 2005. Update of work in progress by David Johnson.
Report of the presentation made at the EMRA Plum Walk published by Brian Lovelidge in the Grower, 11 August 2005.
Poster and fruit exhibits at the National Fruit Show 2005.
Article prepared for HDC News due for publication in July 2006.

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