Project title:	To identify pre-harvest, harvest and post-harvest management practices capable of reducing losses of pumpkins during storage
Project number:	FV 439
Project leader:	Debbie Rees, Produce Quality Centre, Natural Resources Institute (NRI), University of Greenwich
Report:	Annual report, April 2015
Previous report:	None
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Location of project:	Natural Resources Institute
Industry Representative:	David Murfitt, Oakley Farms
Date project commenced:	15 September 2014
Date project completed (or expected completion date):	28 February 2017

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

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AUTHENTICATION

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

Dr Debbie Rees

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Signature .....  . Date ...21st May 2015

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GROWER SUMMARY

Headlines

- Pumpkin varieties differ in their keeping qualities. Further studies in this project will identify the key factors affecting the storage potential of pumpkins.
- US growers' perceptions are that the stalk provides an entry route for rotting pathogens and that this is greater where stalks are damaged by infection with mildew. A field trial will be conducted this season to determine the impact of spraying against mildew on post-harvest pumpkin losses.

Background

The UK market for decorative (carving) pumpkins, currently estimated at £14-15M per year, is growing at a rate of 20% annually, and the market for culinary (edible) pumpkins is growing at an even faster rate from a much lower sales base. However, the levels of pumpkin losses are estimated to be 15-20% of the initially harvested crop which equates to an annual loss of £2-3M. This project seeks to identify the causes of losses and test practices to reduce these losses.

There is currently very little information on the relative importance of different causes of loss and the impact of pre-harvest, harvest and post-harvest management practices on these losses. This project is working with UK growers to understand the current situation through detailed and structured observations on-farm. Recommendations provided to and practices used by growers in the USA will be reviewed, both through the literature and by direct consultation. By studying a range of decorative and culinary varieties, the characteristics associated with good storage potential will be identified.

Summary

Overall project Aim

To identify pre-harvest, harvest and post-harvest management practices capable of reducing losses of both edible and carving pumpkins during storage.

Specific project objectives are:

<u>Year 1</u>

1. To collate and disseminate information on management of the pumpkin crop in the US, and associated research relevant to the UK industry.

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2. To determine and rank the main forms of post-harvest loss (Tissue breakdown, latent infection, post-harvest infection, harvest maturity) currently affecting pumpkins in the UK.

3. To determine and rank the key factors affecting the storage potential of pumpkins in the UK (harvest maturity, mineral nutrition, harvesting/post-harvest practices, storage environment/practices.)

All years

4. To determine the varietal characteristics that affect storage potential (including size, skin thickness, pericarp thickness, dry matter content)

Year 2

5. To identify and test pre-harvest management practices to improve storage potential.

6. To identify and test harvest/post-harvest management practices to improve storability, including the identification of maturity indicators to predict storage potential at harvest.

To collate and disseminate information on management of the pumpkin crop in the US, and associated research relevant to the UK industry.

A review of information obtained from the scientific literature and extension information is presented separately from this report.

Key points of information obtained from discussion with Mark Dillinger of Tozer US are as follows:

- The perception of US growers is that the pumpkin stalk provides an important route into the fruit for postharvest rotting pathogens, and that this is greater where stalks have been damaged by infection with mildew. There are two US practices that would reduce this; firstly US growers aim to keep the foliage as long as possible and actively spray to manage the powdery mildew with a range of actives and will also apply a potassium bicarbonate every 7 days as part of the spray program, and secondly they leave as long a handle as possible, by tearing the vine at the attachment point and letting this wound which is smaller seal up naturally.
- The stalk colour is a sign of good fruit quality, a dark green stalk will mean that there is no powdery mildew present. Powdery mildew present when the fruit is growing also leads to the stalk twisting when it is forming and encourages breakdown at the point the stalk joins to the fruit. US pumpkin breeders aim to select for varieties with improved attachment of the stalk to the fruit, as a means of reducing entry of pathogens. Figure A illustrates varieties with good and bad attachment characteristics.

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- US grower will not lift a fruit from the field until it has initially cured (they use a slap test and if a hollow echo then ready if a dull thud then not). They are also using the colour as a good guide as to fruit maturity as if the orange has not got any depth to it then the fruit has not yet started to ripen.
- US growers consider a decent nutrition program essential for the fruits to store. They use a nutrition program is made up from a combination of base dressing top dressing and foliar feed. Colour is a good indication of nutrition. If a good fungicide and nutrition program are used then the fruit will recover from and seal over any wounds on the fruit skin reducing breakdown issues.

Figure A. Pumpkin fruit from varieties with good stalk attachment (LH picture) and poor stalk attachment (RH picture).

Preliminary storage trial conducted to compare four key varieties

Table A shows the data obtained from a single bin of each of Mars, Terraflyn Magician and Gomez assessed after approximately one month of storage under cover. Pumpkins were assessed as saleable or unsaleable. In almost all cases where a pumpkin was defined as unsaleable, it was due to rotting. Although, in this preliminary trial there was only one bin per variety and therefore a statistical analysis cannot be carried out, there was a considerable different in % losses with Gomez having more than four times the loss compared to Mars.

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Table A. An assessment of pumpkins within a single bin of each of four varieties following one month's storage under cover under ambient conditions during October/November 2014 in Kent.

Variety	#saleable pumpkins	#nonsaleable pumpkins	Total # pumpkins	% unsaleable	% soft stalk
Mars	132	3	135	**2.2**	87.9
Terra Fin	156	7	163	**4.3**	59.0
Magician	115	11	126	**8.7**	70.9
Gomez	187	19	206	**9.2**	39.8

Growers perceptions of pumpkin varieties

A questionnaire on varietal behaviour was circulated to pumpkin growers. Responses relating to keeping quality indicated that growers consistently regard Mars as a good storer, but are less clear about Terra Fin and Magician. This is consistent with the findings of the preliminary storage trial. However, the two respondents who grew Gomez regarded this as a good storer, whereas this variety had the highest percentage of unsaleable pumpkins in our trial.

Levels of loss this year were quoted as ranging from 7 – 35% in the field and 5 – 35% during storage.

Preliminary post-harvest characterisation of varieties

This year a preliminary assessment of the post-harvest characteristics of a range of varieties was carried out. To our knowledge no such characterisation of UK varieties exists. The aim is to find out which characteristics relate to keeping qualities so that this information can be used for varietal selection, and also improvement of crop management. Key varietal characteristics assessed are set out in Figures B (skin strength, flesh firmness and whole pumpkin firmness). Values for moisture and sugar content, fruit dimensions, flesh and skin colour and mineral content were also collected.

Our first year of analysis, in what was a particularly poor season due to an early maturing crop, represents an initial benchmark which we can compare to future seasons. However, our initial observations indicate that there is a wide range of traits in the pumpkin cultivars that are statistically significant including skin strength, flesh firmness and overall fruit firmness among varieties (Figure B). Likewise there is a wide range in moisture content from 89 – 96%. Not surprisingly there is a strong negative correlation between moisture

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content, whole fruit firmness (r = -0.77) and flesh firmness (r = -0.88), and with skin strength (r = -78)

Varieties with high moisture content tend to have lower sugar concentration per fresh weight essentially indicating a dilution effect with water uptake into the fruit.

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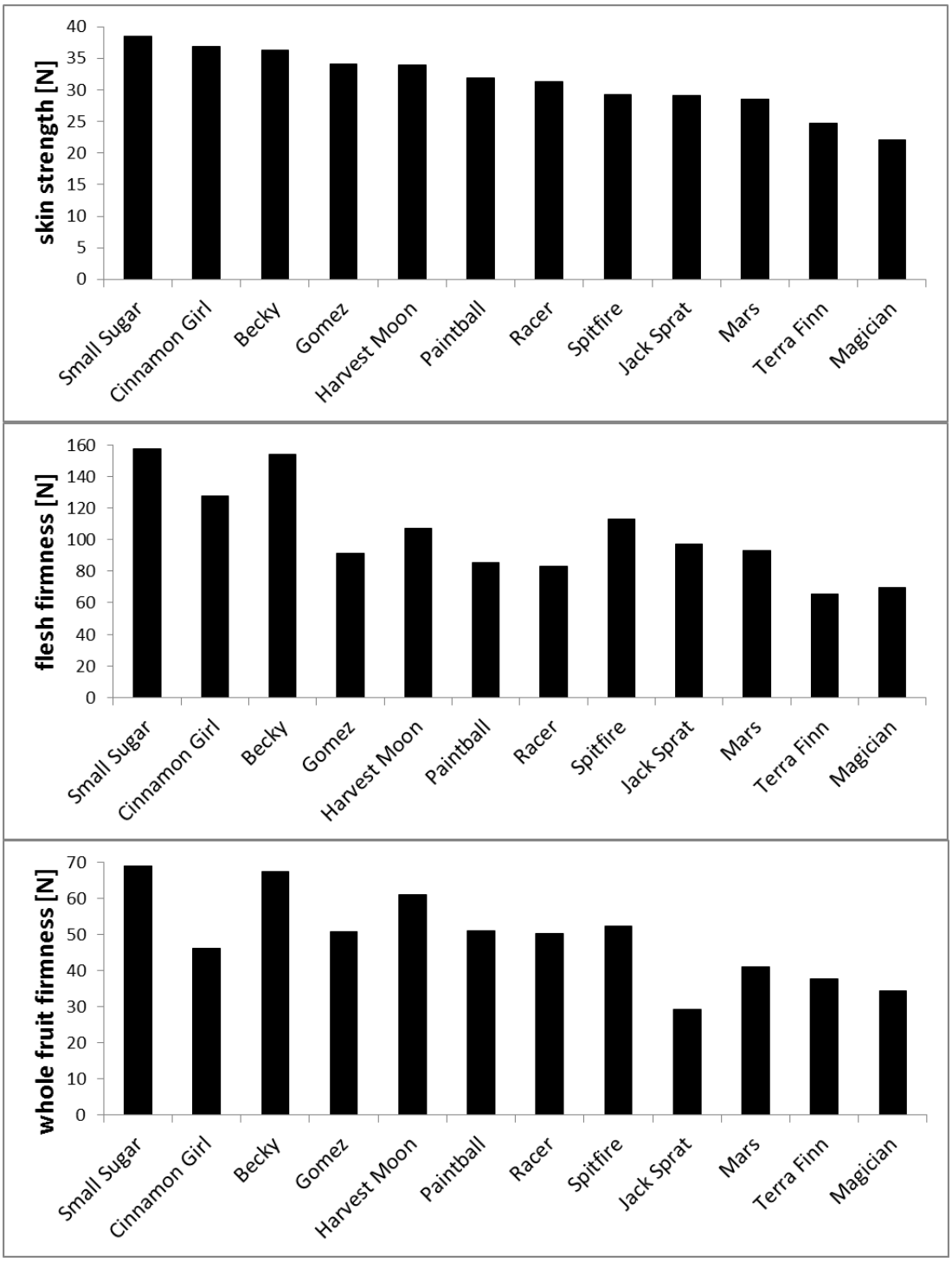

Figure B. skin strength, flesh firmness, whole fruit firmness measured by TA.XT plus Texture Analyser. Each data point is the mean for four measurements on 3-5 pumpkins. Varietal effect was significant ($p<0.001$) for all three characteristics with Least Significant Difference ($p<0.05$) of 6.7, 35.0, 16.9 respectively.

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Rot samples collected and analysed

Samples of rotting pumpkins were collected from the field and also from the storage trial conducted at Dan Mackelden, and were analysed to identify the rotting pathogens. The main pathogens identified were *Botrytis cinerea*, *Phoma cucurbitacearum*, *Rhizopus stolonifera*, *Colletotrichyn coccodes*, *Fusarium acuminatum*, *Mucor hiemalis*. Diagnostic photographs of these rots are shown in Appendix 1.

The proportion of rots identified is given in Figure C, together with a summary of the weighting of the rots for samples from East Anglia and the South East. However, this data should be treated with great caution as the samples were collected for identification purposes and were not proportional to the incidents observed. Nevertheless the notable difference between the two regions is probably an indication of a real difference.

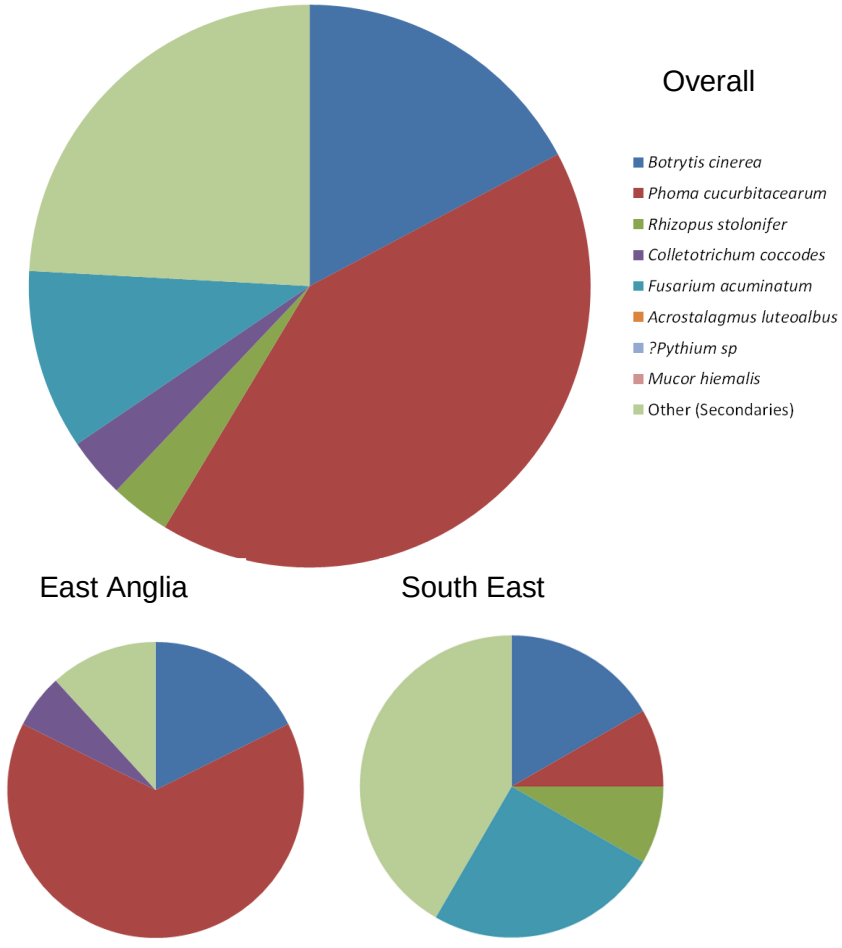

Figure C. The rots identified as a proportion of all samples analysed, and separated into those collected in East Anglie and in the South East. This data is an indication of incidence

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only, as samples were collected for identification purposes and not for quantification of incidence.

Particular attention was paid to the pumpkin stalk, which has been implicated as a route of the entry of rotting pathogens. The main pathogens isolated from the stalks were *Acrostalagmus luteoalbus*, *Fusarium acuminatum* and *Botrytis cinerea.* Using the current methodology it is not possible to determine whether powdery or downey mildew are present, as these are obligate biotrophic pathogens and can therefore not be grown on artificial media. We have been informed (Mark Dellinger personal communication) that a twisted stalk is diagnostic of infection. However, it will be necessary to make observations in the field about the prevelance of these two pathogens.

Samples were also taken from the border between stalk and fruit. The pathogens isolated from 19 samples are illustrated in Figure D. The most prevalent in this limited survey was *Fusarium acuminatum*, which may suggest that this pathogen enters through the stalk.

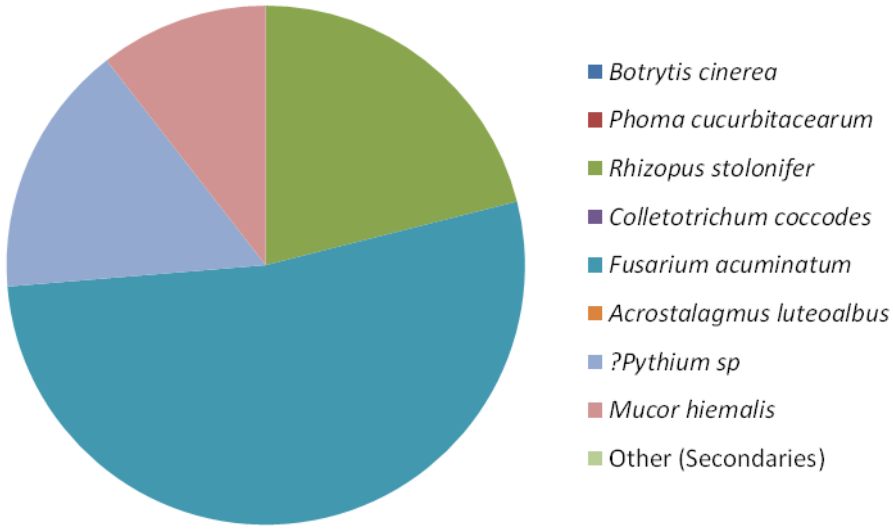

Figure D. Rotting pathogens isolated from the border between stalk and fruit for 19 samples of pumpkin fruit.

Future plans

The data presented in this report are mostly of a preliminary nature, as they have been collected from a single season only, and a season that was unusual as the pumpkin fruit maturation was so early. However, the findings so far have helped to clarify the priorities for season 2.

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1. A review of the relevant information available within the scientific literature and extension services outside the UK (especially from the US) will be presented separately from this report. Peter Waldock will visit US 3-9 October, after which the review will be updated.
2. On the basis of information obtained on growers' practices in the US, a trial will be set up, hosted by Oakley farms, to determine the effect of spraying against Mildew in terms of reducing losses due to post-harvest/post-cutting rots. The trial will include three varieties; Racer, Mars and Harvest Moon, with one acre per variety (0.5 acres with treatment, and 0.5 acre control). The chemical programme to be used is still to be decided, but the potato blight forecast model will be used to determine timing of applications. In the absence of mildew it will be necessary to use chemicals to trigger canopy senescence at an appropriate time.
3. A programme of field observations during crop development will be conducted on selected fields, focusing on cultivars Racer, Mars and Harvest Moon. The purpose is to investigate factors affecting relative incidence of key pathogens in different regions. An understanding of the epidemiology of the main pathogens will help to inform future control strategies. The observations will include recording of aborted fruit and rots, and information on nearby crops. A draft crop walker's guide has been developed by East Malling (Appendix 2.)
4. Observations of harvest and storage conditions will be undertaken, including assessment of levels of loss when stores dismantled.
5. The survey of varietal post-harvest characteristics will continue in 2015, and will be linked to storage trials of the same varieties. In this second season it will be useful to have control over the harvest maturity.

Financial Benefits

Too early in the project to predict benefits

Action Points

None at this stage of the project

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SCIENCE SECTION

Introduction

The market for carving pumpkins, currently estimated at £14-15M per year is growing at a rate of 20% annually, and the market for culinary pumpkins at a similar rate albeit from a lower base. The levels of loss during storage are unclear, but are estimated to be 15-20% equating to an annual loss of £2-3M for decorative pumpkins alone. The overall aim of this project is to improve the uniformity and quality of pumpkins and reduce losses, thereby providing a significant increase in profitability for the UK pumpkin industry.

Carving pumpkins need to be stored and cured for approximately 6 weeks from harvest, usually in mid-September, until the end of October. It would be commercially advantageous to store culinary pumpkins until Thanksgiving (third week in November), equivalent to 9-10 weeks or longer if possible.

In the UK, storage is currently in uncovered windrows in the field, windrows within greenhouses, or in bins within stores (usually without refrigeration). Usually no specific temperature or humidity control is used, but in some cases there is forced airflow which will reduce the build-up of condensation. No ventilation within windrows is used.

Although losses are high there is little reliable information either on the main forms of loss (physiological, latent infection, post-harvest infection) or on the key factors (mineral nutrition, harvesting/post-harvest practices, storage environment/practices) affecting losses.

Growing region and variety

It has been observed that losses can vary by region, with lower storage losses reported for the variety Racer grown on the South coast compared to those under cultivation in East Anglia and it has been suggested that warmer temperatures improves curing (skin hardening and healing) and / or that it prevents night-time condensation (dews that can increase the risk of rots). Likewise it is known that storage potential varies by variety; Mars is a variety with a higher flesh content and with longer storage potential than similar sized pumpkins with thinner flesh (pericarp). However, there has been no detailed study relating phenotypical characteristics with storage potential.

Pre-harvest disease

Powdery and Downy mildew can lower yield and cause rots/plant loss in the field, respectively. Varietal resistance to Downey mildew is being bred for and is associated with fruit that retain dark green stems, Work has been done in the US on the impact of Downy

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mildew on crop storage and the recommendations are to run a spray program up until the point of harvest.

US storage strategies

In the US more importance is given to storage conditions than in the UK, presumably indicating a greater value of the US crop. The UK pumpkin industry can potentially benefit greatly by exploiting US knowledge. For example in some states it is recommended that pumpkins are stored on shelves with no contact between neighbouring fruits. Removing soil from the outside of the pumpkin is considered good practice and other sanitation measures including washing fruits in drenching tanks prior to storage will reduce infection potential if the inoculum in the water flume can be controlled. Chlorine drenching can be an effective only when soil contamination is removed prior to drenching.

Ethylene

US research indicates that ethylene should be avoided during storage. Exposure to ethylene will degreen squash with green rinds. Ethylene will also cause abscission of the stem, especially in less mature fruit.

Chilling injury

Pumpkins are chilling sensitive below 10°C, but the effects are slow to occur, such that storage for several months at 10°C may cause some chilling injury. Thus for carving pumpkins short exposure to temperatures lower than 10°C is unlikely to cause damage, but nevertheless sub-clinical damage may occur where fruits are subject to lower-temperatures (<10°C). Chilling injury may become a significant factor for the eating quality of culinary pumpkins due to the potentially longer storage periods. The challenge to extend the season for culinary pumpkins beyond November will require more sophisticated storage technology such as ethylene removal or use of SmartFresh (1-MCP) and better control over post-harvest diseases through the use of sanitising agents (ozone, hydrogen peroxide misting).

Curing/skin set

Curing or skin set can be a significant factor in improving the storage potential of fruit. In the US growers are advised to harvest at sufficient maturity, for example after senescence of the leaves, when the pumpkin skins have set (thickened and hardened). It has been noted that if disease kills the vines prematurely, there is a risk that the fruit will be harvested immature. US storage practices are designed to allow curing, thereby further strengthening the skin and healing harvest wounds, and so reducing the risk of pathogen invasion. It is

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therefore common practice by some growers to cure pumpkins for 10 to 20 days at 20 - 25°C with good ventilation (e.g. four air exchanges per day). Storage humidity is set 65-85% to reduce weight loss but prevent moisture and rotting.

Overall project Aim

To identify pre-harvest, harvest and post-harvest management practices capable of reducing losses of both edible and carving pumpkins during storage.

Specific project objectives are:

Year 1

1. To collate and disseminate information on management of the pumpkin crop in the US, and associated research relevant to the UK industry.
2. To determine and rank the main forms of post-harvest loss (Tissue breakdown, latent infection, post-harvest infection, harvest maturity) currently affecting pumpkins in the UK.
3. To determine and rank the key factors affecting the storage potential of pumpkins in the UK (harvest maturity, mineral nutrition, harvesting/post-harvest practices, storage environment/practices.)

All years

4. To determine the varietal characteristics that affect storage potential (including size, skin thickness, pericarp thickness, dry matter content)

Year 2

5. To identify and test pre-harvest management practices to improve storage potential .
6. To identify and test harvest/post-harvest management practices to improve storability, including the identification of maturity indicators to predict storage potential at harvest.

The pumpkin harvest was unusually early in 2014, and so had already started in most places before the project start date of 15th September. For this reason it was not possible to carry out the range of field observations originally intended, nor to set up the range of storage trials originally intended.

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Materials and methods

To collate and disseminate information on management of the pumpkin crop in the US, and associated research relevant to the UK industry.

Information has been collated from the scientific literature, and from publically available extension information, primarily from the United States. This has formed the basis of a review that will be presented separately from this report. Mark Dellinger (Tozer seeds US, Pennsylvania) visited UK 6-10 October 2014, during which time he gave a presentation to the Tozer Pumpkin day on Wednesday 8th October at Cobham. He also provided information during discussions with Peter Waldock and Debbie Rees.

Preliminary storage trial conducted to compare four key varieties

Preliminary storage trial conducted to compare four key varieties

A bin of each of four pumpkin varieties; Mars, Terraflynn, Magician and Gomez were stored by Dan Mackleden under cover, with no temperature control. The bins were assessed on 4th November for incidence of rots, and state of stalks. Samples were taken for identification of rotting pathogens.

Growers perceptions of pumpkin varieties

A questionnaire was circulated at the end of a meeting of the Cucurbit Growers Association, to determine growers' perceptions of fourteen pumpkin varieties using a 1-3 score for size, keeping quality, colouring up and overall performance. Growers were also asked about storage, and levels of loss.

Preliminary post-harvest characterisation of varieties

At least four pumpkins were provided by Tozer seeds, Dan Meckelden, Oakley Farms or Barfoots of twelve pumpkin varieties; Mars, Becky, Cinnamon Girl, Jack Sprat, Small Sugar, Racer, Magician, Paint Ball, Terra Fin, Spitfire, Gomez, Harvest Moon. These were stored outside under ambient conditions prior to characterisation.

<u>Characterisation protocol</u>

Each pumpkin was photographed. Skin colour was measured using Minolta colour meter (L*a*b* colour space) at 4 points around the fruit equator.;

Whole fruit firmness was measured using a TA.XT plus Texture Analyser (Stable Micro Systems, UK) equipped with a convex-tip probe; 8-mm diameter. The probe recorded resistance whilst travelling 8.0 mm at a speed of 0.83 mm s^{-1} and the maximum force (N)

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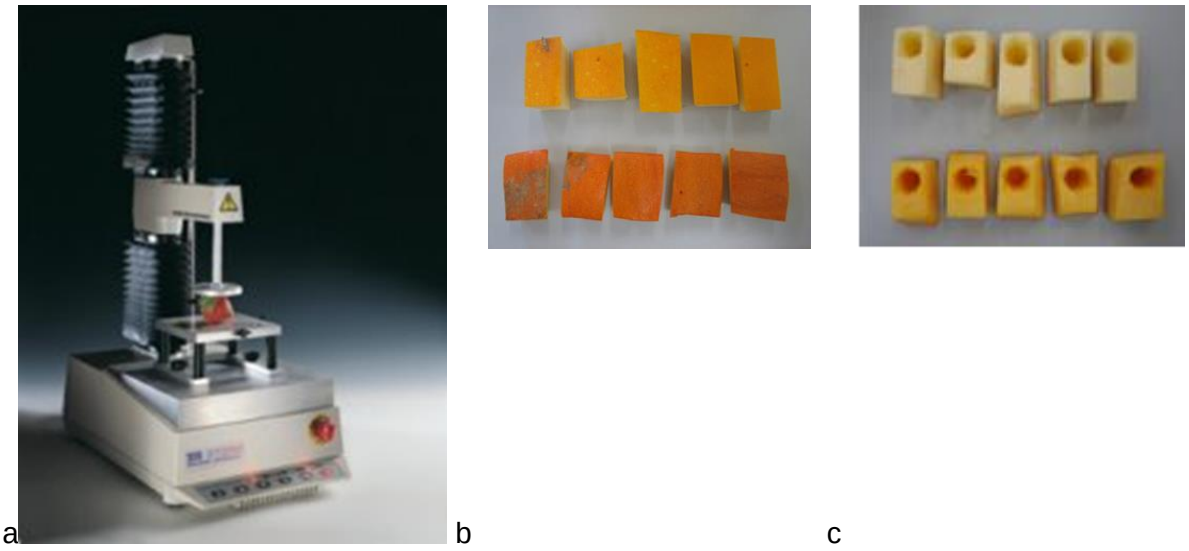
recorded. For whole fruit firmness and for mesocarp (skin removed) firmness, and a 50 kg load cell.

Samples were collected from a pumpkin cut into two halves longitudinally. An equatorial strip (about 5 cm thick) was cut out and photographed to record the internal structure. The diameter of the pumpkin and thickness of flesh (pericarp) were both measured. Skin strength was measured on four cut sections of the equatorial strip using a TA.XT plus Texture Analyser (Stable Micro Systems, UK) equipped with a 2-mm diameter probe (puncture test) and a 50 kg load cell. The probe was driven 5.0 mm at a speed of 0.83 mm s^{-1} and the maximum force (N) recorded. Flesh firmness was measured on four sections from the flesh side using an 8 mm probe using the same parameters

Samples of flesh from opposite eighths of the pumpkin were frozen in liquid nitrogen and stored at -20 °C for subsequent mineral analysis and sugar analysis. Another sample was taken, weighed and dried in an oven to calculate dry matter content.

One pumpkin for each variety was assessed on each day over five days, so that five pumpkins were assessed for each variety.

Mineral content was analysed by FAST and will included N, Ca, K, B, Fe, Mg, Mn, P, Zn, and Cu.



a b c

Figure 1. a) TA.XT plus Texture Analyser (Stable Micro Systems, UK) used to carry out texture measurements. Cut sections used for b) skin strength and c) flesh firmness assessment.

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Rot samples collected and analysed

Samples of rotting pumpkins were taken to East Malling Research for identification of rotting pathogens. Samples were taken from the leading edge of the rotten tissue and plated onto potato dextrose agar (PDA). Growing cultures were then identified under the microscope by morphology. In specific cases molecular techniques (sequencing phylogenetically informative regions) were used.

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Results

To collate and disseminate information on management of the pumpkin crop in the US, and associated research relevant to the UK industry.

A review of information obtained from the scientific literature and extension information is presented separately from this report.

Key points of information obtained from discussion with Mark Dillinger of Tozer US are as follows:

- US growers consider 4 categories of pumpkin; Bush, Small vine, Medium vine, Large vine. They grow varieties that have between 90 to 120 days to maturity, compared to the UK varieties that mostly mature in 90 days. Although spacing has historically been around 5500 per acre a number of US growers have been year on year reducing the density with some of the large Vine down as low as 1200 per acre. This means they will get 2 to 3 fruits per plant (UK is 1 or less on the larger grades)
- Mark Dillinger's perception is that the pumpkin stalk provides an important route into the fruit for postharvest rotting pathogens, and that this is greater where stalks have been damaged by infection with mildew. There are two US practices that would reduce this; firstly US growers aim to keep the foliage as long as possible and actively spray to manage the powdery mildew with a range of actives and will also apply a potassium bicarbonate every 7 days as part of the spray program, and secondly they leave as long a handle as possible, by tearing the vine at the attachment point and letting this wound which is smaller seal up naturally.
- The stalk colour is a sign of good fruit quality, a dark green stalk will mean that there is no powdery mildew present. Powdery mildew present when the fruit is growing also leads to the stalk twisting when it is forming and encourages breakdown at the point the stalk joins to the fruit. US pumpkin breeders aim to select for varieties with improved attachment of the stalk to the fruit, as a means of reducing entry of pathogens. Figure 2 illustrates varieties with good and bad attachment characteristics.
- US grower will not lift a fruit from the field until it has initially cured (they use a slap test and if a hollow echo then ready if a dull thud then not). They are also using the colour as a good guide as to fruit maturity as if the orange has not got any depth to it then the fruit has not yet started to ripen.

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- US growers consider a decent nutrition program essential for the fruits to store. They use a nutrition program is made up from a combination of base dressing top dressing and foliar feed. Colour is a good indication of nutrition. If a good fungicide and nutrition program are used then the fruit will recover from and seal over any wounds on the fruit skin reducing breakdown issues.
- Hydrogen peroxide concentrate at 34% and injected at 1% into the water for the final wash spray line on the washer is common practice.

Figure 2. Pumpkin fruit from varieties with good stalk attachment (LH picture) and poor stalk attachment (RH picture).

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Preliminary storage trial conducted to compare four key varieties

Table 1 shows the data obtained from a single bin of each of Mars, Terraflyn Magician and Gomez assessed after approximately one month of storage under cover. Pumpkins were assessed as saleable or unsaleable. In almost all cases where a pumpkin was defined as unsaleable, it was due to rotting. Although, in this preliminary trial there was only one bin per variety and therefore a statistical analysis cannot be carried out, there was a considerable different in % losses with Gomez having more than four times the loss compared to Mars. The temperature and humidity within the bins is shown in Figure 4; temperature dipped below 10°C on only a couple of occasions and humidity was generally between 80 and 100%. In addition to saleability the state of the stalk was assessed as firm or soft.

A B

C D

Figure 3. Bins of pumpkins assessed for quality at the end of one month of storage under cover. A B Gomez, C D

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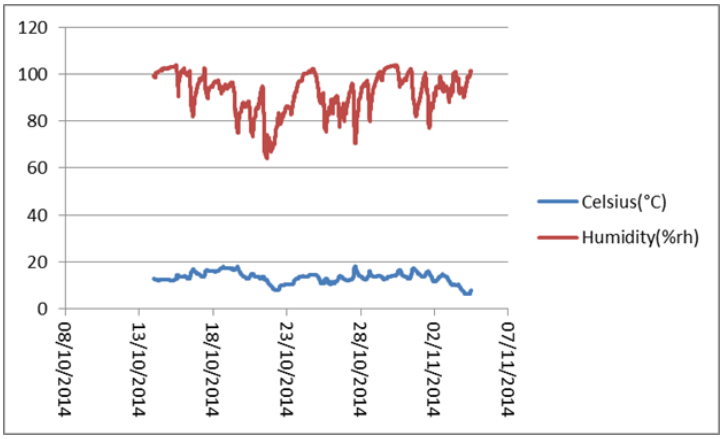

Figure 4. Temperature and humidity data recorded within a pumpkin bin during storage under cover under ambient conditions during October/November 2014 in Kent.

Table 1. An assessment of pumpkins within a single bin of each of four varieties following one month's storage under cover under ambient conditions during October/November 2014 in Kent.

Variety	#saleable pumpkins	#nonsaleable pumpkins	Total # pumpkins	% unsaleable	% soft stalk
Mars	132	3	135	**2.2**	87.9
Terra Fin	156	7	163	**4.3**	59.0
Magician	115	11	126	**8.7**	70.9
Gomez	187	19	206	**9.2**	39.8

Growers perceptions of pumpkin varieties

A questionnaire on varietal behaviour was circulated to pumpkin growers. Table 2 summarises the answers obtained from five respondents. Responses relating to keeping quality indicated that growers consistently regard Mars as a good storer, but are less clear about Terra Fin and Magician. This is consistent with the findings of the preliminary storage trial. However, the two respondents who grew Gomez regarded this as a good storer, whereas this variety had the highest percentage of unsaleable pumpkins in our trial.

Levels of loss this year were quoted as ranging from 7 – 35% in the field and 5 – 35% during storage.

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Table 2: AHDB Horticulture Pumpkin storage project grower questionnaire.

Variety	Seed house	Size	Keeping quality	Colouring up	Overall performance
Mars	Tozer	2,2,2,2	3,3,3,3	2,2,2,2	2,3,2,2
Becky	Tozer	2.5,2	3,3	2,3	2,2
Cinnamon girl - Pie Star variant	Tozer				
Jack Sprat - Pie Star variant	Tozer				
Small Sugar	Tozer	2	2	3	2
Racer	Tozer	1,2,2,2	2,2,2,2	2,2,2,2	2,2,2,2
Harvest Moon	Monsanto	2,2,2	2,2,2	2,2,2	2,3,2
Paintball / Orange Smoothie	Pro Veg	2,2	3	3,2	3,2
Terra Fin	Sakata	2,2,1	2,3,2	2,2,2	2,3,2
Flynn	Sakata	3,1,2	2,1,2	2,1,2	2,1,1
Spitfire	Clause	2,2,2	2,2,2	3,2,2	2,2,2
Gomez	Clause	1,2	3,3	1.5,1	2,3
Sorcerer	Clause				
Magician	Clause	3,3,3,3	2,1,3,1	3,2,3,1	2,1,2,1
other					
other					
other					

Size	1	Undersize	Colouring up	1	very late
	2	As expected		2	As usual
	3	oversize		3	Early colour up

Keeping quality	1	Did not keep	Overall performance	1	Poor, will not grow again
	2	Some losses		2	Acceptable, would grow again
	3	Stored very well		3	Excellent, a star performer

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Preliminary post-harvest characterisation of varieties

This year a preliminary assessment of the post-harvest characteristics of a range of varieties was carried out. To our knowledge no such characterisation of UK varieties exists. The aim is to find out which characteristics relate to keeping qualities so that this information can be used for varietal selection, and also improvement of crop management. Figure 5 shows photographs of representative pumpkins for the twelve varieties characterised in this first year of trials. The varietal characteristics assessed are set out in Figures 6 (skin strength, flesh firmness and whole pumpkin firmness), Figure 7 (moisture content and sugar content), Table 3 (fruit dimensions), Table 4 (flesh and skin colour), Table 5 mineral content.

As this is only a single year of data, and we do not yet have data on keeping quality to relate this to, there are only limited conclusions that can be made. However, we did observe a wide statistically significant range in skin strength, flesh firmness and overall fruit firmness among varieties (Figure 6). Likewise there is a wide range in moisture content (Figure 7). Not surprisingly there is a strong negative correlation between moisture content, whole fruit firmness (r = -0.77) and flesh firmness (r = -0.88), and with skin strength (r = -78)

Varieties with high moisture content tend to have lower sugar concentration per fresh weight (Figure 7), essentially indicating a dilution effect with water uptake into the fruit.

Figure 5. Twelve pumpkin varieties assessed for postharvest characteristics

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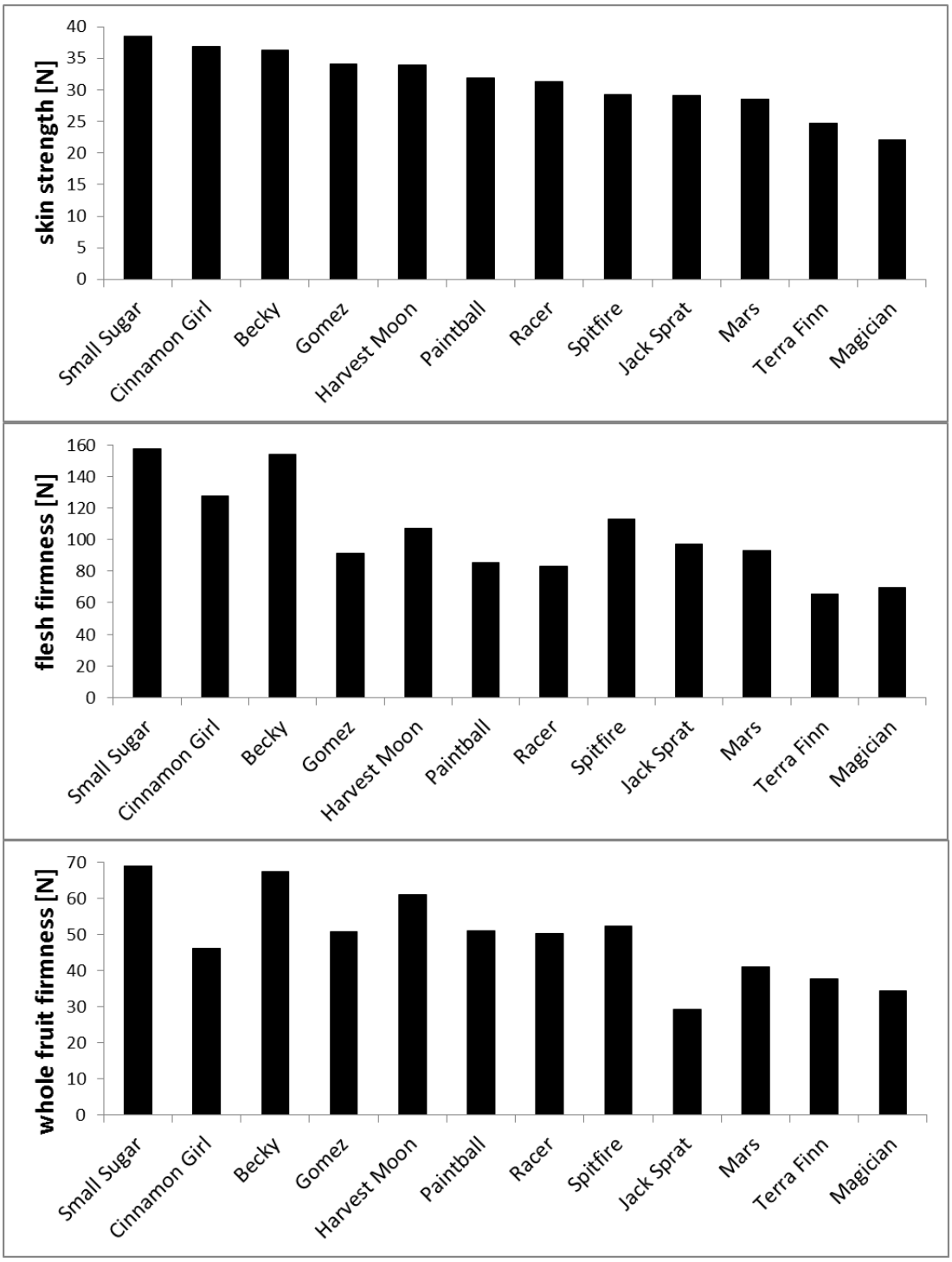

Figure 6. skin strength, flesh firmness, whole fruit firmness measured by TA.XT plus Texture Analyser. Each data point is the mean for four measurements on 3-5 pumpkins. Varietal effect was significant ($p<0.001$) for all three characteristics with Least Significant Difference ($p<0.05$) of 6.7, 35.0, 16.9 respectively.

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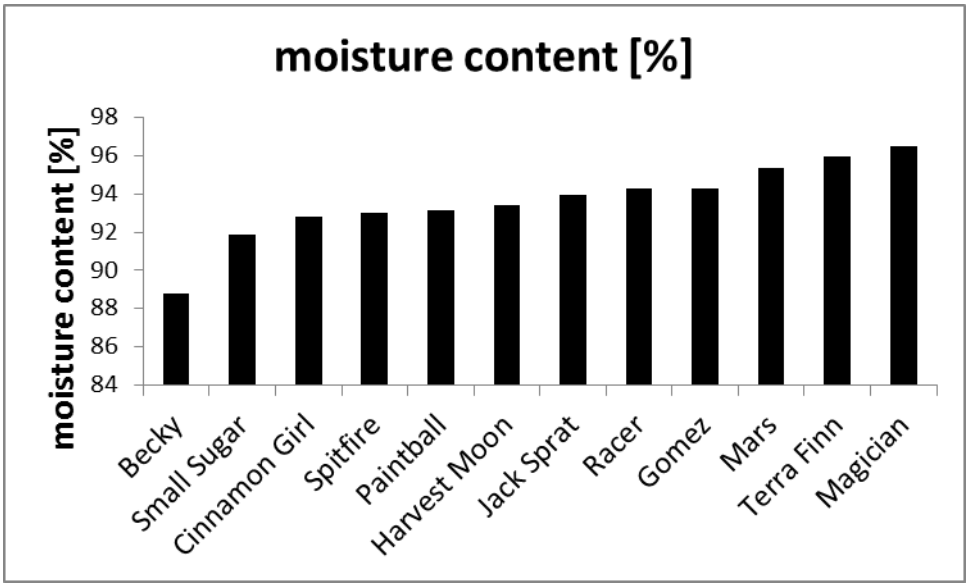

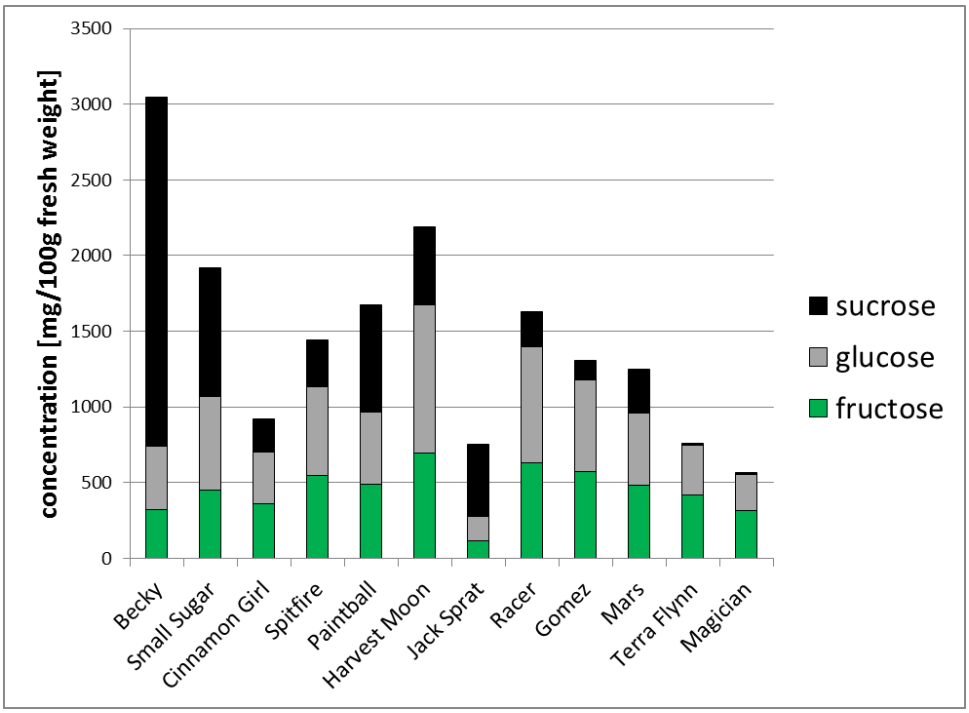

Figure 7. Moisture content and sugar content of twelve pumpkin varieties. Each data point is the mean of measurements on 3-5 pumpkins per variety.

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Table 3. Dimensions of pumpkins from twelve varieties, measured as indicated in the diagram below

	Diameter [cm]	Height [cm]	Flesh thickness [cm]
Becky	16.0	11.2	2.4
Cinnamon Girl	16.7	11.5	1.8
Gomez	19.5	17.1	3.0
Harvest Moon	25.3	21.7	3.5
Jack Sprat	14.5	12.4	1.5
Magician	23.7	19.3	2.9
Mars	20.3	15.1	2.4
Paintball	18.7	15.0	2.2
Racer	24.5	17.4	3.5
Small Sugar	16.5	12.6	2.4
Spitfire	21.2	14.3	2.6
Terra Finn	22.9	18.0	2.5
Varietal effect	P<0.001	P<0.001	P<0.001
Least significant Difference	3.2	2.7	05

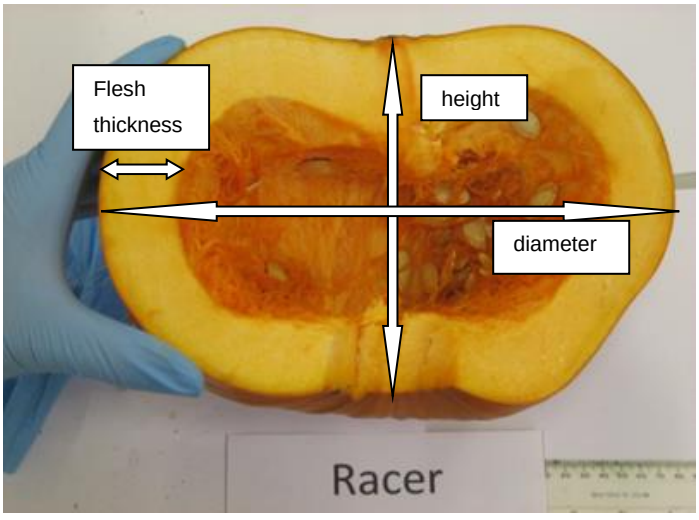

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Table 4. Colour of skin and flesh of twelve pumpkin varieties

	skin			flesh		
	L*	a*	b*	L*	a*	b*
Becky	56.4	28.4	49.4	65.7	23.6	76.4
Cinnamon Girl	58.1	29.8	54.0	71.5	7.6	64.5
Gomez	53.3	28.6	45.6	73.6	8.8	57.2
Harvest Moon	56.0	30.0	50.0	66.4	12.4	56.3
Jack Sprat	61.4	30.6	58.7	68.2	17.9	68.5
Magician	56.8	29.3	51.1	73.2	5.0	48.3
Mars	56.5	27.8	50.5	71.5	6.9	48.8
Paintball	58.7	27.9	54.7	70.1	10.4	54.9
Racer	52.9	27.5	44.4	65.4	13.5	57.1
Small Sugar	56.8	26.5	49.6	69.0	15.7	72.1
Spitfire	56.7	33.8	51.5	74.5	7.4	63.1
Terra Finn	59.6	28.5	55.9	71.1	2.7	49.9
Varietal effect	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Least significant Difference	3.6	2.1	5.7	5.0	5.5	11.0

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Table 5. Mineral analysis of pumpkin fruit from twelve varieties

Variety	N	Ca	K	Mg	P	Cu	Fe	Mn	Zn	B
	mg/100g fresh weight					mg/Kg fresh weight				
Becky	219	40.6	518	21.81	74.14	0.57	8.19	0.89	2.14	4.00
Cinnamon Girl	233	24.8	480	19.53	55.78	0.49	8.15	0.44	1.63	3.26
Gomez	175	29.3	245	15.06	25.96	0.58	4.18	0.44	1.78	2.78
Harvest Moon	205	32.2	269	16.54	48.30	0.39	4.06	0.87	1.65	1.92
Jack Sprat	188	42.6	714	17.21	71.55	0.58	6.71	0.32	1.22	3.06
Magician	112	31.6	177	12.26	18.33	0.35	8.91	0.65	1.25	1.42
Mars	117	24.4	256	11.83	29.02	0.41	6.19	0.53	1.53	1.57
Paintball	150	25.8	386	17.22	61.56	0.38	4.08	0.66	1.16	2.40
Racer	181	31.7	230	16.10	37.49	0.40	7.11	0.85	1.93	2.20
Small Sugar	119	28.5	556	19.35	55.17	0.53	5.69	0.71	1.66	3.08
Spitfire	137	19.3	486	18.70	62.49	0.55	4.33	0.75	1.72	2.69
Terra Finn	91	46.8	217	12.73	14.37	0.40	2.85	0.45	1.30	1.68

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Rot samples collected and analysed

Samples of rotting pumpkins were collected from the field and also from the storage trial conducted at Dan Mackelden, and were analysed to identify the rotting pathogens. The main pathogens identified were *Botrytis cinerea*, *Phoma cucurbitacearum*, *Rhizopus stolonifera*, *Colletotrichyn coccodes*, *Fusarium acuminatum*, *Mucor hiemalis*. Diagnostic photographs of these rots are shown in Appendix 1.

The proportion of rots identified is given in Figure 8, together with a summary of the weighting of the rots for samples from East Anglia and the South East. However, this data should be treated with great caution as the samples were collected for identification purposes and were not proportional to the incidents observed. Nevertheless the notable difference between the two regions is probably an indication of a real difference.

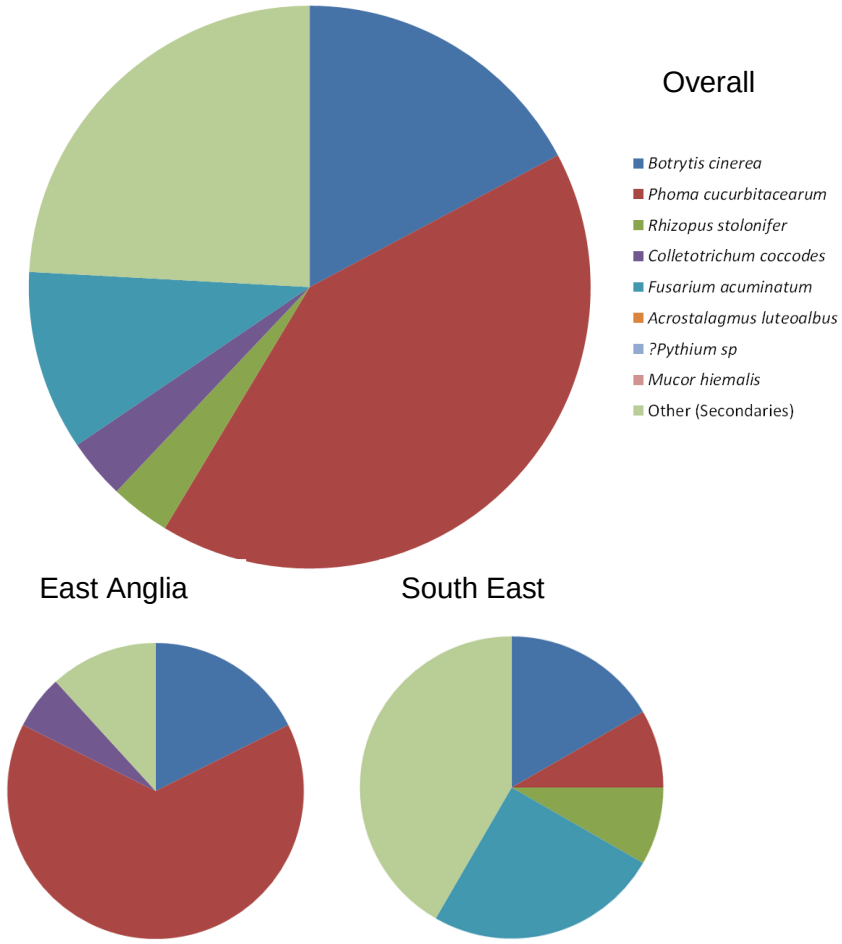

Figure 8. The rots identified as a proportion of all samples analysed, and separated into those collected in East Anglie and in the South East. This data is an indication of incidence only, as samples were collected for identification purposes and not for quantification of incidence.

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Particular attention was paid to the pumpkin stalk, which has been implicated as a route of the entry of rotting pathogens. The main pathogens isolated from the stalks were *Acrostalagmus luteoalbus*, *Fusarium acuminatum* and *Botrytis cinerea.* Using the current methodology it is not possible to determine whether powdery or downy mildew are present, as these are obligate biotrophic pathogens and can therefore not be grown on artificial media. We have been informed (Mark Dellinger personal communication) that a twisted stalk is diagnostic of infection. However, it will be necessary to make observations in the field about the prevalence of these two pathogens.

Samples were also taken from the border between stalk and fruit. The pathogens isolated from 19 samples are illustrated in Figure 9. The most prevalent in this limited survey was *Fusarium acuminatum*, which may suggest that this pathogen enters through the stalk.

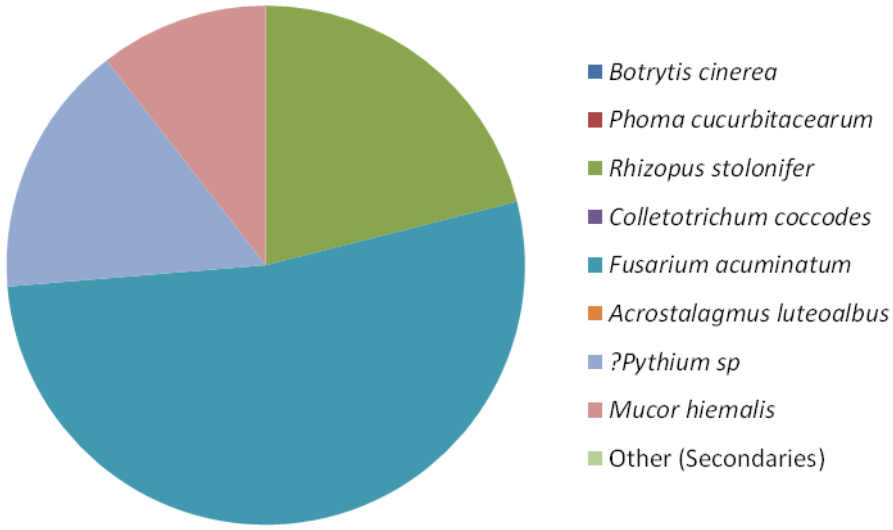

Figure 9. Rotting pathogens isolated from the border between stalk and fruit for 19 samples of pumpkin fruit.

Discussion

2014 was a very difficult year for pumpkin growers. The warm summer resulted in early fruit maturation, and forced the growers to keep the crop for longer than usual before marketing. As a result the level of losses in the field and in stores was high. The losses quoted in questionnaires returned were 7-35% in the field and 5-35% in stores.

The project has started to collate information from outside the UK, primarily the US. One of the most interesting observations is that US growers perceive that the presence of mildew in the field can increase rots of the fruit, by causing damage to the stem due to infection of

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cut stems. The levels of postharvest rots were particularly high in the UK this year. It has therefore been decided that there would be value during 2015 in conducting a trial to determine the potential to reduce losses through spraying against mildew.

As the project started in September, and the harvests were very early in 2014, it was not possible to have a thorough set of observations in the field. We will rely on 2015 to start to understand the pathogen load and to confirm the pathogen incidence.

Despite initial observations we cannot come to any firm conclusions yet about the impact of varietal characteristics on susceptibility to rots and storability. We need to confirm stability between seasons. However, there is a huge range in dry matter content, and it will be very interesting to determine what impact this has on storability. The general perception is that low dry matter for crops is associated with poor storability. However, there have been observations for root crops such as sweet potato and potato that within a species the opposite is true, so careful observations will be necessary.

Conclusions

The data presented in this report are mostly of a preliminary nature, as they have been collected from a single season only, and a season that was unusual as the pumpkin fruit maturation was so early. However, the findings so far have helped to clarify the priorities for season 2.

1. A review of the relevant information available within the scientific literature and extension services outside the UK (especially from the US) will be presented separately from this report. Peter Waldock will visit US 3-9 October, after which the review will be updated.
2. On the basis of information obtained on growers' practices in the US, a trial will be set up, hosted by Oakley farms, to determine the effect of spraying against Mildew in terms of reducing losses due to post-harvest/post-cutting rots. The trial will include three varieties; Racer, Mars and Harvest Moon, with one acre per variety (0.5 acres with treatment, and 0.5 acre control). The chemical programme to be used is still to be decided, but the potato blight forecast model will be used to determine timing of applications. In the absence of mildew it will be necessary to use chemicals to trigger canopy senescence at an appropriate time.
3. A programme of field observations during crop development will be conducted on selected fields, focusing on Racer, Mars and Harvest Moon. The purpose is to investigate factors affecting relative incidence of key pathogens in different regions.

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An understanding of the epidemiology of the main pathogens will help to inform future control strategies. The observations will include recording of aborted fruit and rots, and information on nearby crops. A draft crop walker's guide has been developed by East Malling (Appendix 2.)

4. Observations of harvest and storage conditions will be undertaken, including assessment of levels of loss when stores dismantled.
5. The survey of varietal post-harvest characteristics will continue in 2015, and will be linked to storage trials of the same varieties. In this second season it will be useful to have control over the harvest maturity.

Knowledge and Technology Transfer

A presentation was made on these results to the Outdoor Cucurbits Group on 13th January 2015.

Acknowledgements

We would like to acknowledge Dan Mackleden for hosting and assisting in the storage trial, Oakley Farms and Barfoots for allowing us to observe their fields and stores and providing samples, Curson, Tozer Seeds and Clause Seeds for providing samples.

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