Grower Summary

CP 083

Minimising post-harvest losses in radish through an understanding of pre and post-harvest factors that influence root splitting

Final 2014

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GROWER SUMMARY

Headline

- Rainfall, temperature and relative humidity during growth and/or at harvest all affect the rates of splitting in commercially grown radishes. Splitting rates at harvest were correlated with substrate moisture content at the radish growth stage 41.
- Post-harvest splitting susceptibility can be decreased by reducing hypocotyl water content and increasing temperature during handling.

Background

Splitting is a problem for radish growers as rates can be up to 30%, exceeding supermarket tolerances which are typically about 10%. It usually occurs pre-harvest or shortly post-harvest (1-2 days) during storage. To remove the split radish prior to packing, batches have to be sorted by hand, a process which is costly and time consuming. Despite these problems, little is known about the environmental and physiological conditions which result in split radishes. Identification of the factors affecting splitting or splitting susceptibility may allow the development of field production, harvesting and handling practices which minimise the issue.

Summer radishes (*Raphanus sativus*), which are predominantly grown in the UK as opposed to winter radishes grown more commonly in Asia, have a rapid growth cycle. In the field they can take less than 4 weeks from drilling to harvest. Previous field scale research into splitting in larger, slower growing winter radish types has shown that both irrigation frequency (Wan and Kang 2005) and quantity (Kang and Wan 2005) affect splitting at harvest, suggesting that water availability and irrigation management are an important influence on splitting in summer radishes. The timing of water availability or periods of stress as a result of drying down may also affect splitting rates, which was shown in carrots by Salter and Goode 1967 and Sorensen and Harker 2000.

Irrigation and water availability during growth may affect hypocotyl water contents at harvest. Marcelis reports that increased salinity (which consequently decreases water availability) during growth results in lower percentages in the water contents of the radish hypocotyl at harvest (Marcelis *et al.* 1997). Likewise, the post-harvest practice of e.g washing radishes can lead to water absorption, resulting in changes to hypocotyl water contents. Increased hypocotyl water contents could lead to more post-harvest splits as the turgor pressure increases. Literature has it that the failure force (the force required to split a carrot with a

metal wedge driven into it at a constant speed) is negatively correlated with tissue turgor and water potential (McGarry 1993, 1995). There have been no reported investigations into the effects of hypocotyl water content on splitting susceptibility in summer radishes.

The temperature of the radish hypocotyls during harvest and post-harvest processes may also have an effect on splitting susceptibility. In a review of the effects of temperature on a range of fruits and vegetables, which did not include radishes, Bourne (1982) showed that for the majority of the crops tested, an increase in temperature was associated with decreasing failure force suggesting that produce is less susceptible to damage at high temperatures. Bajema *et al.* (1998) also found a decrease in compressive failure strain and tissue toughness with increasing temperature in potatoes. In this investigation the effects of turgor were investigated and a similar pattern was observed. The similarities between the effects of temperature and turgor led the investigators to conclude that the same mechanism must explain both the effects of temperature and turgor (Bajema *et al.* 1998).

The aim of this research was to identify the pre- and post-harvest factors affecting splitting in radish hypocotyls. The specific objectives were to investigate:

- the splitting trends in commercial radishes;
- the splitting susceptibility of different cultivars;
- the effects of water availability during growth on splitting;
- the effects of hypocotyl water content on post-harvest splitting susceptibility;
- the effects of hypocotyl temperature on post-harvest splitting susceptibility and to;
- establish a key for the development stages of radish.

Summary

Objective 1: Investigating splitting trends in commercial produce

Commercial quality assessment data for the cultivar ‘Celesta’ from 2012, 2013 and 2014 was analysed for correlations between splitting and weather. Analysis showed a significant effect of rainfall during growth, temperature during growth and at harvest and relative humidity during growth and at harvest. Temperature both during growth and at harvest tended to be negatively correlated with splitting suggesting lower temperatures were associated with increased splitting. Rainfall during growth and relative humidity during growth and at harvest were both positively correlated with splitting indicating higher levels of rainfall or higher relative humidity were associated with increased splitting.

In 2014 additional measurements were made. The number of split radishes measured by the quality assessment team at G's was correlated with the number of split radishes which arrived at Harper Adams University (HAU). The number of radishes which were split on arrival at HAU was highly correlated with the number of radishes which split as a result of impact texture analysis. Impact texture analysis was conducted by dropping the radishes from a height of 1.4 m onto a metal plate, which is the maximum height radishes are dropped from under commercial harvest conditions when they are dropped into the metal trailer. Correlation between the number of radishes which were split on arrival at HAU and the number of radishes which split after dropping indicated this as an accurate, rapid and repeatable way of testing splitting susceptibility. Splitting which occurred as a result of impact texture analysis was significantly correlated with relative water content suggesting relative water content may affect splitting susceptibility. Splitting observed by G's was significantly correlated with weather during growth and at harvest. Again a negative correlation was observed between splitting and temperature suggesting low temperatures result in more splitting and a positive correlation was observed between precipitation and relative humidity with splitting suggesting high levels of rainfall and relative humidity increase splitting.

Results from this investigation suggest the weather conditions associated with splitting are cold, wet weather during growth with a high relative humidity. These conditions are expected to result in radishes with a high relative water content and turgor pressure. In support of this theory, analysis at HAU showed radishes which were more susceptible to splitting as a result of being dropped had higher relative water contents.

Objective 2: To establish a key for the development stages of radish

A key was established for the growth stages of radishes and growth stage 41 was identified (see Table 1).

Table 1: Example pictures of whole radish and free-hand cross-sections of radishes at key growth stages. Principle growth stages 1 and 4 occur simultaneously.

Days post drilling	Growth Stage	Whole plant	Cross section of hypocotyl
2	01: Radicle emerged from seed		
5	10: Cotyledons completely unfolded; true leaf initial visible (diameter 1.2 mm)		
13	11: 1st true leaf or pair of true leaves unfolded (diameter 1.9 mm)		
15	11/41(start): 1st true leaf or pair of true leaves unfolded / The exodermis and outer cortex rupture and slough away exposing the periderm. The hypocotyl begins to expand (diameter 2.4 mm)		
17	12/41(end): 2nd true leaf or pair of true leaves unfolded / The exodermis and outer cortex rupture and slough away exposing the periderm. The hypocotyl begins to expand (diameter 3.5 mm)		

Growth stage 41 marks the start of rapid hypocotyl expansion. During this growth stage the exodermis and outer cortex rupture and slough away exposing the periderm. Growth stage 41 is important as it is splitting of the periderm which is a problem therefore, all splitting must occur after this point.

Timings for growth of the cultivar *Raphanus sativus* 'Rudi' were determined and growth stage 41, which can be identified non-destructively, was found to occur between days 15 and 17 under glasshouse conditions (Figure 1).

Figure 1 Growth stage 41 can be identified non-destructively

Objective 3: To investigate the splitting susceptibility of different radish cultivars

Cultivars were shown to have different splitting susceptibilities. Of the cultivars tested 'Rudi' displayed the most splitting at harvest and 'Celesta' showed the least. A non-significant trend was observed linking the thickness of the periderm with the splitting susceptibility. The cultivars with a thinner periderm tended to split less and within the same cultivar the radishes with a thicker periderm also split more.

Objective 4: To investigate the effects of water availability during growth on splitting

High volumetric water content during growth was shown to result in high levels of splitting in the cultivars ‘Rudi’, ‘Celesta’ and ‘Saxa 2’.

Splitting was found to correlate with volumetric water content (VWC) on day 17 which was shown in objective 2 to be the time when growth stage 41 occurs. High levels of water at this point resulted in high levels of splitting.

Marketable yield was greatest for radishes which received a drying down period from day 8 to day 17 and then irrigation to harvest.

Objective 5: To investigate the effects of hypocotyl water content on post-harvest splitting susceptibility

High hypocotyl water contents were shown to result in radishes being more susceptible to damage from dropping, puncture and compression. As hypocotyl water content increased the force required to cause a fracture in the periderm as a result of crushing or puncture decreased and a sharp increase was observed in the number of radishes which split as a result of a 1.4 m drop at hypocotyl water contents at or in excess of 96.5 %. Hypocotyl water contents in excess of 95.6 % have been found at harvest in trials carried out for Objective 4 and in commercial radishes (data not shown). The compression force required to fracture a radish was shown to be affected by the size of the radish, larger radishes were more resistant to compression damage, therefore smaller radishes are more likely to split when packed together.

Objective 6: To investigate the effects of hypocotyl temperature on post-harvest splitting susceptibility

As radish temperature decreased splitting susceptibility measured by dropping increased. The greatest amount of splitting, 65%, was observed at the lowest temperature, 5.6°C, and the least amount of splitting, 0%, was observed at the highest temperature, 39.0°C. These results suggest radishes are more susceptible to splitting at lower temperatures.

Financial Benefits

UK radish producers encounter frequent problems with post-harvest splitting in radish which has a significant commercial impact in terms of product wastage. Identification and removal of splits is both time consuming and wasteful and is not always successful which results in depot rejection and further cost. The direct impact on the consumer is not known, but it is

thought that the split radishes and drying/deterioration of the split surfaces may also deter sales.

Action Points

1. Avoid high soil moisture contents during growth. High water contents during growth resulted in more splitting in all cultivars tested.
2. In particular do not irrigate plants for the period from day 7 to growth stage 41. Water requirement at this stage is less than later in development and excessive water prior to growth stage 41 increases the number of splits at harvest.
3. Ensure plants have adequate water in later growth. Increased irrigation in the final 10 days increases yield but does not increase splitting.
4. Avoid having very high hypocotyl water contents post-harvest as radishes are more prone to splitting as a result of puncture, compression or dropping at high hypocotyl water contents.
5. A preference should be made for larger radishes as these are more resistant to splitting when crushed.
6. Avoid having low temperatures during post-harvest handling as radishes are more prone to splitting as a result of dropping at low temperatures.
7. Cultivar selection was shown to have a significant effect on splitting susceptibility. Radishes with a thicker periderm tended to split more.