Project Report

Bruising sensitivity at harvest

Ref: R252

Final Report: January 2007

Fraser. Milne: *SAC*

2007

Project Report 2007/2

Additional copies of this report and a list of other publications can be obtained from:

Publications
British Potato Council
4300 Nash Court
John Smith Drive
Oxford Business Park South
Oxford
OX4 2RT

Tel: 01865 782222
Fax: 01865 782283
e-mail: publications@potato.org.uk

Most of our reports, and lists of publications, are also available at *www.potato.org.uk*

1. Contents

2. Summary for growers

2.1 Project aims

The aim of the project was to examine the effect of soil moisture content and crop maturity at haulm destruction, on changes in sensitivity to tuber bruising at harvest. The work did not aim to resolve the underlying reasons (biochemical or physiological) for any observed changes in bruising sensitivity but was designed to determine if the grower has any control on the sensitivity to bruising at harvest and to evaluate if there any trade-offs that may occur for other important quality factors such as skin set and dry matter content.

2.2 Work undertaken

The study consisted of replicated field trials using two prominent potato varieties, Maris Piper and Marfona, in years one and two respectively with the addition of Lady Rosetta in the third year. The crop was subjected to two different soil moisture levels at haulm destruction. Soil moisture levels were manipulated by the use of irrigation and rain shelters 2-3 weeks before haulm destruction. Measurements of tuber sensitivity to bruising were made at various harvest dates. The experiments attempted to separate the effects of soil moisture and crop maturity on sensitivity to bruising. Quality factors such as skin set and dry matter were also measured.

2.3 Summary and key findings

Tuber sensitivity to bruising does not stay at a constant level at harvest time and can change in the same crop by several orders of magnitude depending on environmental factors and time of harvest after defoliation. It has also been found that sensitivity to bruising can change very rapidly as shown by a greatly reduced incidence of bruising when impacted 4 hours after harvest compared to being impacted at harvest. Tubers harvested before or soon after defoliation have a much lower bruising level than the same crop harvested three to five weeks after defoliation.

- <u>Soil moisture content at haulm destruction and bruising sensitivity</u>.
  The overall results from the three years shows that in some varieties there is a definite risk of more bruising from soils that are dry at haulm destruction. The magnitude of the effect varies with variety and was most noticeable with Maris Piper and Lady Rosetta. The response of Marfona was inconsistent and unpredictable so no conclusion could be reached. However the presumption that dry soils are *always* more prone to bruising compared to wet soils does not appear to be true either as several comparisons showed no difference. Each year there was always an occasional dataset where the trend described above was nearly reversed with the wet treatment exhibiting greater bruising than the dry treatment. The reason for this has not been positively identified but appears to occur when the soil becomes saturated above field capacity after defoliation. While soil moisture content at haulm destruction appears to influence sensitivity to bruising

at harvest, the effect is not consistent. This leads us to consider whether soil moisture is influencing tuber sensitivity directly (such as an effect on turgor) or whether it is altering some other factors that we are not measuring. This maybe why, on some occasions, tubers from the wet soil plots are more prone to bruising. The experiment has shown that we now have a consistent method of manipulating tuber sensitivity to bruising (M. Piper & Rosetta) which we did not have before. This will allow the production of samples to test the key factors involved in sensitivity changes in tuber bruising with reduced amount of variation.

- <u>The effect of haulm destruction on bruising sensitivity</u>. There was a consistent trend of very low to non-existent bruising at defoliation (green top) and a very large increase in bruising at harvest three to five weeks after defoliation. The trend was consistent in all varieties and statistically significant in all trials. The reason for this has not been identified. Understanding why this happens could help reduce bruising at harvest. This phenomenon could also be used as a means of the production of differentially sensitive tubers for tests.

- <u>Skin Set</u>. A consistent trend emerged with skin set. The drier soil resulted in a more rapid tuber skin set than tubers from the wet soils. The tubers from the wet soil plots had poorer skin set, for a longer period of time after defoliation than from the drier soil. A compromise may need to be reached if crops are to be lifted soon after defoliation, as extra water will slow down skin set but could reduce bruising.

- <u>Timing of impacts</u>. Tests on the effect of the time between harvesting and when the tubers were impacted showed that there was far less bruising if impacted 24 hours after harvest compared to impacted within 20 minutes of harvest. An intermediate time of 4 hours also showed a large difference in the amount of bruising occurring. This has major implication when testing crops for sensitivity to bruising as a predictor to harvester damage. Further work needs to be carried out to detect why this occurs, as it has implications for possible practical solutions in crops that are difficult to harvesting due to bruising sensitivity.

    - <u>Respiration</u>. Studies on respiration (CO_2) levels at harvest showed that respiration rates increased considerably a short time after harvest. However, in the preliminary studies we did not find a correlation with CO_2 produced and bruising sensitivity.

2.4 Recommendations

- Some varieties (Maris Piper, Lady Rosetta) have been found to be more prone to bruising when defoliated in dry soil conditions. When growing varieties that are prone to bruising, try to avoid the soil reaching a large moisture deficit at defoliation by the use of irrigation. Great care is required however, as too much irrigation (wet soil) could lead to a delayed skin set and difficulty at harvesting, especially if there is additional rainfall.
  No exact data are available at present as to what is the best SMD to aim for, but as a rough guide with current knowledge, aim for ~30mm SMD at defoliation, but be

flexible as it will depend greatly on local conditions, soil type and expected rainfall. These recommendations supplement rather than replace other recommendations.

- Assessing the bruising sensitivity of crops before harvesting can allow better management of the crop and give prior warning of possible harvesting problems. Test tubers by dropping or impacting them with a realistic size of impact that would occur on a harvester, and not with excessive force. A suitable range is, 200-300mm drop on to hard surface (0.4-0.5J energy). Lower impact is required for large bakers.

- Bruising levels were found to be lowest at defoliation and much higher after a normal post defoliation interval before harvest. Where there is a history of bruise sensitive crops from a particular farm/location, check whether there is an option to market the crop without set skin. This would allow the crop to be lifted “green top” or soon after defoliation and potentially reduce bruising levels.

3. Experimental section

3.1 Introduction

Results from a previous survey carried out by HRI for BPC ("BRUCE" project) indicated that soil moisture at haulm destruction might influence bruising at harvest. Several agronomists had also reported this association (Nelson D).

The aim of this project was to examine the effect of soil moisture content and crop maturity at haulm destruction on changes in sensitivity to tuber bruising at harvest. The project consisted of field trials and laboratory tests.

The field trials involved three prominent potato varieties, Maris Piper, Marfona and Lady Rosetta, subjected to different soil moisture levels at haulm destruction. Soil moisture levels were manipulated using irrigation and rain shelters. Measurements of soil moisture, tuber bruising sensitivity, skin set and tuber dry matter were made at various harvest dates.

3.2 Materials and methods

3.2.1 Material and methods - 2004

The trial site was at Drem in East Lothian on a sandy silt loam soil. The crop was grown using standard crop agronomy practices unless otherwise stated.

The trial consisted of two potato varieties, Maris Piper and Marfona, planted as 8 blocks of four plots consisting of two varieties and two treatments (32 plots). Experiments were conducted at two haulm destruction dates (Trial 1 & Trial 2) giving 4 replications per treatment per trial. Each trial received identical treatments until 2 weeks before haulm destruction. At that time each block was split into paired plots of wet (soil moisture was kept high) and dry (soil moisture was kept low) treatments for the two varieties. Paired plots of one variety were matched to a paired plot of the second variety such that the wet and dry treatments were contiguous.

TABLE 1 KEY DATES FOR TRIALS 1 & 2, 2004

Trial	Date treatments Imposed	Haulm destruction date	Harvest dates
1	28 July	11 August	11 August 31 August 7 September 14 September
2	20 August	3 September	3 September 24 September 1 October

The varieties grown were Maris Piper and Marfona.
The crop was planted on the 14 April 2004.
The fertiliser applied to the trial was 200:120:252 kg/ha N:P:K.
Plot size was 5m x 1.83m.

Haulm destruction was achieved two weeks after imposing the soil moisture treatments by chopping the haulm at 50mm above the ridge.
Covers remained on for 5 days after haulm destruction.

3.2.2 Material and methods - 2005

The trial site was at Drem in East Lothian on a sandy loam soil. The crop was grown using standard agronomy practices unless otherwise stated.

The trial consisted of two potato varieties, Maris Piper and Marfona, planted as 12 blocks of four plots consisting of two varieties and two treatments (48 plots). Experiments were conducted at two haulm destruction dates (Trial 1 & Trial 2) giving 6 replications per treatment per trial. Each trial received identical treatments until 2 weeks before haulm destruction. At that time each block was split into paired plots of wet (soil moisture was kept high) and dry (soil moisture was kept low) treatments for the two varieties. Paired plots of one variety were matched to a paired plot of the second variety such that the wet and dry treatments were contiguous.

TABLE 2 KEY DATES FOR TRIALS 1 & 2, 2005

Trial	Date treatments Imposed	Haulm destruction date	Harvest dates
1	5 August	18 August	18 August 8 September 15 September 22 September 29 September
2	22 August	6 September	6 September 27 September 4 October 10 October

Maris Piper was planted on 5th May and Marfona on 13th May 2005.
The fertiliser applied to the trial was 188:113:244 kg/ha N:P:K plus 66kg/ha SO_3.
Plot size was 5m x 1.83m.

Haulm destruction was achieved two weeks after imposing the soil moisture treatments by chopping the haulm at 50mm above the ridge.

3.2.3 Materials and methods - 2006

The trial site was at Drem in East Lothian on a sandy loam over sandy silt loam soil. The crop was grown using standard agronomy practices unless otherwise stated.

Trial 1 consisted of two potato varieties, Maris Piper and Marfona, planted as 6 blocks of four plots consisting of two varieties and two treatments (28 plots).

Trial 2 consisted of three potato varieties, Maris Piper Marfona and Lady Rosetta, planted as 9 blocks of four plots consisting of two varieties and two treatments (36 plots).

Experiments were to be conducted at two haulm destruction dates (Trial 1 & Trial 2) giving 6 replications per treatment per trial. Each trial would receive identical treatments until 2 weeks before haulm destruction. At that time each block would be split into paired plots of wet (soil moisture was kept high) and dry (soil moisture was kept low) treatments for the two varieties. Paired plots of one variety were matched to a paired plot of the second variety such that the wet and dry treatments were contiguous.

While attempting to install covers on the plots for Trial 1 on the 31 July heavy rain occurred (43 mm) resulting in the field becoming water logged. The consequence of the saturated ground was that the ground would not dry out sufficiently in a two-week period to give reasonable differences. As we had only one set of covers it was decided to put the covers on the second trial early as it would take 3 weeks to pull out enough water to show a difference. Haulm destruction for trial 2 was scheduled for a more typical harvest period and also contained the extra variety Lady Rosetta. Trial 1 was used for testing the *Blackspot Protect* kit.

TABLE 3 KEY DATES FOR TRIALS 1 & 2, 2006

Trial	Date treatments Imposed	Haulm destruction date	Harvest dates
1	No treatment Due to heavy rain at time of treatment	18 Aug	Used for *Blackspot Protect* test and timing of impact tests.
2	7 August	25 August	25 August 19 September 25 September 2 Oct

Maris Piper was planted on 28th April, Marfona and Lady Rosetta on 8th May 2006. The fertiliser applied to the trial was 188:113:132 kg/ha N:P:K plus 66kg/ha SO_3. Plot size was 5m x 1.83m.

Haulm destruction was achieved approximately three weeks after imposing the soil moisture treatments by chopping the haulm at 50mm above the ridge.
Covers remained on for 4 days after haulm destruction.

Comparison of impactors and timing of impact

Tubers were hand dug and randomly subdivided to produce sub-samples. Samples for "at harvest" measurements were impacted within 20 minutes of harvest. The other samples were carefully handled into crates and kept out of direct sunlight at ambient temperature until the time of impact. The sample size was 25 tubers.

Respiration

Respiration measurements were made by measuring CO_2 produced on a sub-sample of 10 tubers of even sizes (55-65mm) taken from a 35-tuber sample (25 impacted, 10 for respiration testing). They were then placed in a "Seal Tight" plastic tub (volume 5L) immediately on lifting and left undisturbed for 30 min. Sampling from the container was carried out by pump to a dual wavelength infrared gas analyser [IRGA] carbon dioxide sensor (Edinburgh Instruments). The container lid was then removed and reapplied for the next sampling time. Respiration was calculated based on duration of lid closure, weight of tubers, carbon dioxide gas concentration before and after lid closure and gas volume in the container. The IRGA instrument had a resolution of 1ppm CO_2 and temperature compensation built in. Atmospheric pressure was monitored but not compensated for due small differences.

3.2.4 Common methodology

The soil moisture treatments were applied by covering the 'dry' plots with rain covers measuring 6m by 5.5m. For the wet plots, tape irrigation was installed to allow selective irrigation. The rain shelters were constructed of tubular steel pipe covered with a translucent PVC sheet with open ends to allow airflow (Figure 17). The irrigation tape used was "Evaflow" drip. This was selected for its uniformity and even water distribution at 2cm intervals and its capability of running at low pressure. Flow rates were 0.2 l/min per metre.

Hand dug tuber samples were collected at haulm destruction and at 3 weeks, 4 weeks, and 5 weeks post haulm destruction and tested for bruising sensitivity. Dry matter and skin set were measured at 3weeks post haulm destruction. A 25-tuber sample was used for bruising sensitivity and another 20-tuber sample for skin set from each plot.

Bruising sensitivity

A SAC pendulum was used to impart an impact to a tuber for bruise sensitivity testing (Figure 18). The pendulum gave an impact (0.4 J) the equivalent of a drop of a distance of 200mm on to a hard surface by a tuber of average shape (not long oval) that would pass through a 60-65mm square mesh riddle (tuber of approx. 200grams). This value was chosen as it represents a typical impact that can occur on a harvester. If the crop bruises at this level then it will be very likely to bruise on the harvester. Conversely if it does not bruise at this level, careful setting of the harvester should ensure low tuber bruising of the crop.

A representative sample of 25 good quality, 55-65mm tubers was collected from at least four plants. Green, abnormally shaped or diseased tubers were rejected. Impact tests on tubers were carried out in the field soon after digging.

Tubers were orientated in the pendulum so that the anvil would strike squarely onto the tuber on the stolon-end approximately 20mm from the stolon attachment point. After impact, tubers were then placed in crates (to avoid any additional impacts or compression damage) and transported back to the laboratory. On the same day as impacting they were placed in a “hot box” for 16 hours at 33^{o}C. After the 16 hours the sample was reduced to room temperature for 2 hours before being examined for bruises by peeling.

A bruised tuber was defined as one showing a dark discolouration at the point of impact 3-8 mm below the skin. Tubers that exhibited a white bruise (cell damage resulting in starch leakage) but no dark discolouration were not classed as bruised. Tubers with tissue splits and no discolouration would also not be classed as bruised (no tuber splitting was found).

Bruised tubers were classified into an area bruised less the 5 mm in diameter and an area greater than 5 mm diameter. Only the tubers with bruises greater than 5mm in diameter are reported here, as they are the main concern to the industry.

Crop Cover

The progress of haulm development was measured using a grid (915x1000mm). This was placed over the crop such that the width (915mm) aligned with the drill width. The grid is divided into 100 squares and the number of squares that covered leaves rather than bare ground was recorded. Senescence measurement was carried out at the same time, and visually assessed as leaves in a particular square that showed yellowing.

Method of skin set assessment

All samples were hand dug and handled gently until processed.

A sample of 20 tubers of 50-65mm size was placed in the SAC scuffing barrel and then the barrel rotated for a set number of turns. The tubers were then removed and categorised into five groups depending on the area of skin removed. Results are presented as the ‘percentage area skinned of the sample’ which is calculated using the average area skinned for each group multiplied by the number of tubers in each group.

TABLE 4 THE FIVE GROUPS USED FOR SCUFFING ASSESSMENTS.

Area skinned	Mid point
nil	0
<1%	0.5
1-5%	3.0
5-12.5%	8.75
12.5-25%	18.75
> 25%	62.5

As a guide to interpreting the results, a crop with only 50% of the tubers skinned and where all that are skinned have less than 1% area effected (average pre-pack standards for set skin) would result in a percentage area skinned of 0.25%.

Soil moisture measurement
Soil core samples were collected from each plot at haulm destruction and oven dried to provide accurate soil moisture content measurement. The sampling site was 250-300mm depth below ridge, offset by 100mm from the centre of ridge to centre of the bed.

Statistical analysis
Statistical analysis on bruising results was by GLM as recommended by Chris Theobald of BioSS, using GenStat 8th edition.

In performing an initial test on the bruise data, it was clear that the familiar analysis of variance (ANOVA) was not appropriate, as this requires the data to satisfy several criteria. ANOVA was not suitable on a least two points: normality and homogeneity of variance.

Data had a binomial distribution not a normal distribution hence failed the first test. Because it is a proportion, the spread is different at the two extremes of data compared to the middle, so it failed the homogeneity of variance test.

The most appropriate test for this type of data is to use a generalised linear model (GLM). Generalized linear models extend the ordinary regression framework to situations where the data does not follow a normal distribution, or where a transformation (known as the *link function*) needs to be applied before a linear model can be fitted.

(For more information see Dobson, A.J. (1990). *An Introduction to Generalized Linear Models*, Chapman & Hall, London. McCullagh, P. & Nelder, J.A. (1989). *Generalized Linear Models (second edition)*, Chapman & Hall, London.).

GLM allows the use of the full set of data and a much higher degree of freedom and therefore more confidence in the result. The main hypothesis being tested in the project was that there was a difference in sensitivity to bruising in crops from the different soil moisture at haulm destruction. So the first test was wet soil versus dry soil followed by variety, then timing of assessments.

3.3 Results

3.3.1 Results of Trial 1, 2004

Soil moisture measurements

Rainfall and irrigation data for the wet and dry plots for the two trials are provided in Table 5. The soil moisture deficit [SMD] at the time of haulm destruction was determined by oven drying core samples. At haulm destruction, the soil moisture deficit in the ‘wet’ treatments was zero with a 74mm deficit in the dry treatments (Table 10). The condition of the crop at haulm destruction is shown in Table 11.

TABLE 5 RAINFALL AND IRRIGATION DATA, 2004

(mm water)

		Trial 1				Trial 2		
		Dry Plots	Wet Plots			Dry Plots	Wet Plots	
09-May								
10-May		24	24			24	24	
17-May		0	0			0	0	
24-May		0	0			0	0	
31-May		1.5	1.5			1.5	1.5	
07-Jun		4.5	4.5			4.5	4.5	
14-Jun		0	0			0	0	
21-Jun		0	0			0	0	
28-Jun		90	90			90	90	
05-Jul		30	30			30	30	
12-Jul		2.32	2.32			2.32	2.32	
19-Jul		5.22	5.22			5.22	5.22	
26-Jul		15.08	15.08			15.08	15.08	
30-Jul		Rain covers on	30	Irrigation				
06-Aug			34.8			34.8	34.8	
09-Aug			38.76			38.76	38.76	
11-Aug	HD		0					
	Sum	172.6	276.1					
	Diff			103.5				
16-Aug			13.68			13.68	13.68	
20-Aug		46.74	46.74			46.74	46.74	
27-Aug		20.8	20.8			Rain covers on	20.8	
31-Aug		4.8	4.8				4.8	
03-Sep		0	0		HD		0	
					Sum	306.6	332.2	
					Diff			25.6
06-Sep		8	8				8	
09-Sep		0	0				0	
23-Sep		1.6	1.6			1.6	1.6	
30-Sep		8	8			8	8	

TABLE 6 SOIL MOISTURE AT HAULM DESTRUCTION

Soil moisture at haulm destruction determined by oven dried core samples (soil type, sandy silt loam)

	Water (m^3m^{-3})	SMD @ 0.7m ($0 = 0.310\ m^3m^{-3}$)
Dry soil plots	0.205	74
Wet soil plots	0.310	0

The dry plots would fail a *Syngenta Smart test.*

TABLE 7 CROP CONDITION AT HAULM DESTRUCTION ON 11TH AUG 2004

	Marfona	Maris Piper
Percentage crop cover	80%	100%
Percentage senescence	20%	nil

Effect of soil moisture on bruising

As can be seen from Figure 1, both Marfona and Maris Piper had very low levels of bruising at the time of haulm destruction irrespective of moisture regime. However, 3 weeks after haulm destruction the bruising sensitivity increased, most noticeably in Maris Piper but also in Marfona. There was also a major effect of the moisture regime with Maris Piper, which was significant at 3 weeks and 4 weeks post desiccation. With Marfona, the graph shows a smaller increase in bruising sensitivity with the dry regime.

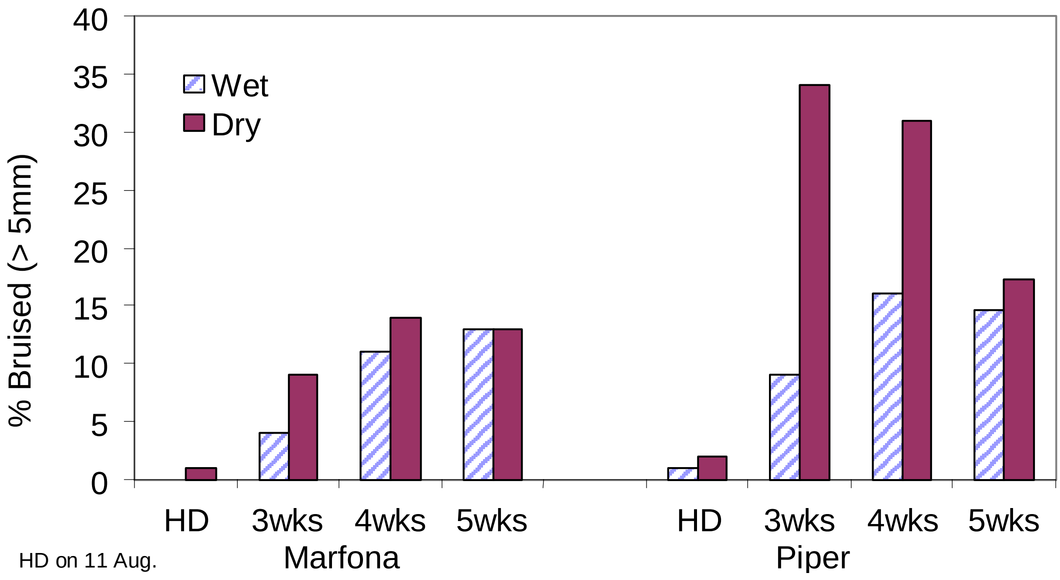

FIGURE 1 THE EFFECT OF SOIL MOISTURE AT HAULM DESTRUCTION ON BRUISING, TRIAL 1

Dry plots were covered on 28th July and haulm destruction took place on 11th August.
SMD wet plots = 0 mm, dry plots = 74 mm. (HD = haulm destruction).
Soil temperatures were 16.3^{o}C at HD, 15.7 ^{o}C at +3wks, 15.4 ^{o}C at +4wks, and 14.8 ^{o}C at +5 wk.

Statistical Analysis

As previously mentioned statistical analysis was carried out by GLM.

The main hypothesis being tested was that there was a difference in bruise sensitivity in crops from different soil moisture content at haulm destruction.

The factors to be investigated in the analysis were - Treatment (dry or wet), timing of the harvest (at haulm destruction [HD] and 3, 4 or 5 weeks later), variety (Marfona or M. Piper). The first level listed is treated as the reference level for each factor.

TABLE 8 STATISTICAL ANALYSIS OF BRUISING, TRIAL 1, 2004

A model was fitted to the response (bruises more than 5mm) with all five factors, giving the following summary analysis of deviance, parameter estimates (on the logistic scale) and approximate significance probabilities: plot effects are omitted from the table.

Source	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Regression	12	136.80	11.400	11.40	<.001
Residual	50	73.56	1.471		
Total	62	210.36	3.393		

Parameter	estimate	s.e.	t(*)	t pr.
Constant	-4.734	0.556	-8.51	<.001
Treatment Dry vs. Wet	-0.849	0.374	-2.27	0.023
Timing HD vs. +3wk	2.820	0.523	5.39	<.001
Timing HD vs. +4wk	3.132	0.519	6.03	<.001
Timing HD vs. +5wk	2.846	0.526	5.41	<.001
Variety Marfona vs. Piper	0.807	0.174	4.65	<.001

Treatment, timing, and variety all show significant effects. Tubers from the dry soil plots, all three later sampling times and Maris Piper all give higher bruising responses than the reference.

[Guide, for a significant difference "t pr." value should be less than 0.05 (95% confidence level)]

Skin set

From the results on skin set taken 3 weeks after haulm destruction (Table 9), it is clear that excess moisture slows down skin set, with both Marfona and Maris Piper showing poorer skin set in wet conditions. The wet treatment of Marfona with a value of 0.48 would not present a problem for harvesting but 2.54 for Maris Piper would certainly result in scuffing on the harvester. The skin set results are an assessment of a changing variable; a definitive value is unlikely to be achieved until the change has stopped.

TABLE 9 SKIN SET AND TUBER DRY MATTER

Percentage area skinned after treatment in SAC scuffing barrel, Trial 1

	Marfona				Maris Piper			
	At haulm destruction		3wk after HD		At haulm destruction		3wk after HD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Wet soil plots	27.15	0.64	0.48	0.23	34.45	2.44	2.54	0.19
Dry soil plots	17.26	5.45	0.04	0.01	29.65	5.13	0.06	0.01
% Tuber dry matter								
Wet soil plots	15.7		15.1		18.5		18.2	
Dry soil plots	15.7		15.9		19.5		19.4	

[Guide; area skinned should be less than 0.25 for packing quality]

3.3.2 Results of Trial 2, 2004

Soil moisture measurements

The soil moisture content was determined by oven dried core samples at haulm destruction. The results show that the difference in soil moisture between the two treatments was 32mm (Table 10).

TABLE 10 SOIL MOISTURE AT HAULM DESTRUCTION, 2004

Soil moisture at haulm destruction determined by oven dried core samples
(soil type, sandy silt loam)

	Water (m^3m^{-3})	SMD @ 0.7m (0 = 0.310 m^3m^{-3})
Dry soil plots	0.274	25
Wet soil plots	0.318	-7

Dry plots were wet and would pass a *Syngenta Smart test*. Wet plots were very wet.

The crop cover and senescence of the crop at haulm destruction in the second trial are shown in Table 11.

TABLE 11 CROP AND SOIL CONDITIONS AT HAULM DESTRUCTION 3RD SEPT. 2004

	Marfona	Piper
Crop cover	10%	40%
Senescence	100% (stems brown)	80%

Effect of soil moisture on bruising

The results presented in Figure 2 show a higher level of bruising at haulm destruction compared to that found in trial 1. However, overall the differences between treatments are not as conclusive as in trial 1, three weeks post haulm destruction.

In trial 1 there was a significant difference between treatments of dry versus wet (t pr. 0.023 trial 1. bruises >5mm), whereas in trial 2 there was no significant difference between treatments (t pr. 0.500 trial 2 bruise >5 mm).

In this trial there was not the same SMD between treatments (see above) and the moisture content in the soil profile was not as evenly distributed due to the way moisture was removed. Moisture was removed by surface evaporation rather than by root uptake, as the haulm was senesced. There was also a much higher degree of variability between the plots. The analyses by BioSS are shown in Table 12.

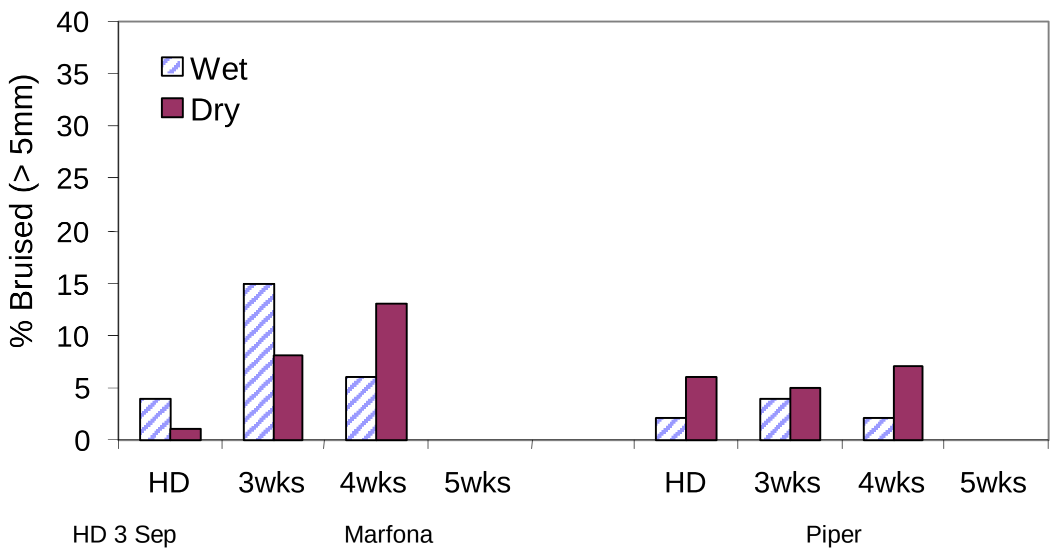

FIGURE 2 THE EFFECT OF SOIL MOISTURE AT HAULM DESTRUCTION ON BRUISING, TRIAL 2

Dry plots were covered on 20 August and haulm destruction took place on 3 Sept.
SMD wet plots = -7mm, dry plots = 25 mm
Soil temperatures were 15.4^{o}C at HD, 14.0 ^{o}C at +3wks, 13.2 ^{o0}C at +4wks

TABLE 12 STATISTICAL ANALYSIS OF BRUISING, TRIAL 2

The same model as above has been fitted with all five main factors, giving the following summaries.

Source	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Regression	11	28.99	2.636	2.64	0.002
Residual	36	63.69	1.769		
Total	47	92.68	1.972		

Parameter	estimate	s.e.	t(*)	t pr.
Constant	-3.007	0.488	-6.16	<.001
Treatment Dry vs..Wet	0.327	0.484	0.68	0.500
Timing HD vs. +3wk	0.965	0.339	2.85	0.004
Timing HD vs. +4wk	0.818	0.345	2.37	0.018
Variety Marfona vs. Piper	-0.687	0.261	-2.63	0.009

Timing and variety show significant differences, with the later sampling times and Marfona giving higher bruising responses. There is no difference between dry versus wet treatments.

Skin set

Interestingly, Marfona showed signs of the skin becoming less well set three weeks after haulm destruction than at haulm destruction, possibly due to the wetter soil conditions (Table 13).

TABLE 13 SKIN SET AND TUBER DRY MATTER, TRIAL 2

Percentage area skinned after treatment in SAC scuffing barrel

	Marfona				Maris Piper			
	At haulm destruction		3wk after HD		At haulm destruction		3wk after HD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Wet soil plots	0.29	0.16	0.71	0.09	15.29	2.29	0.25	0.05
Dry soil plots	0.48	0.27	0.64	0.27	2.29	1.19	0.24	0.04
% Tuber dry matter								
Wet soil plots	16.0		15.9		20.0		20.3	
Dry soil plots	15.8		15.5		19.6		20.0	

[Guide; area skinned should be less than 0.25 for packing quality]

Temperature
The rain covers had the effect of raising the mean air temperature (sensor 300mm above drill) of the "dry" plots by 1.5°C above that of the uncovered "wet" plots. No difference in the average soil temperature (at 200mm depth) was found but the minimum soil temperatures were 1°C higher in the covered plots compared to the uncovered plots.

One of the major concerns in using covers to keep the rain off is that we are not comparing like with like in terms of crop conditions. This is why the time the covers were on the growing crop was limited as much as possible to avoid causing too big a difference in solar radiation and a temperature rise.

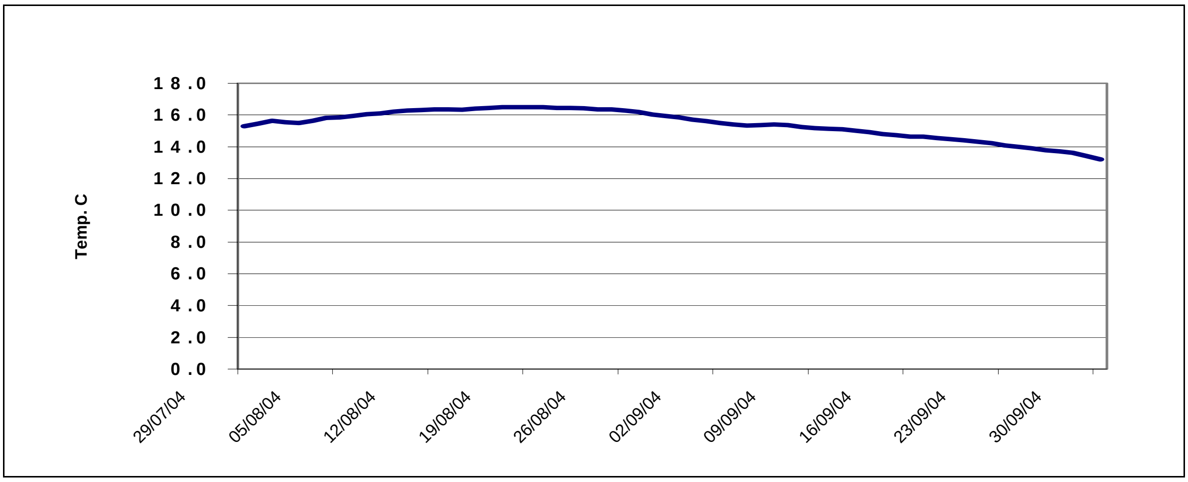

FIGURE 3 AVERAGE DAILY SOIL TEMPERATURE DURING TRIALS 1 & 2

3.3.3 Results of Trial 1, 2005

Rainfall and irrigation
Rainfall and irrigation data for the wet and dry plots for the two trials are provided in Table 14. The soil moisture around the tubers at the time of haulm destruction are given later with the specific trial.

TABLE 14 RAINFALL AND IRRIGATION DATA, 2005

(mm water)

	Trial 1			Trial 2		
	Wet Plots	Dry Plots		Wet Plots	Dry Plots	
13-May	6.4	6.4		6.4	6.4	
16-May	41.9	41.9		41.9	41.9	
03-Jun	40.8	40.8		40.8	40.8	
06-Jun	18	18		18	18	
09-Jun	0	0		0	0	
17-Jun	28.6	28.6		28.6	28.6	
24-Jun	1.8	1.8		1.8	1.8	
03-Jul	42.2	42.2		42.2	42.2	
10-Jul	14.7	14.7		14.7	14.7	
14-Jul	0	0		0	0	
22-Jul	23.6	23.6		23.6	23.6	
28-Jul	0.2	0.2		0.2	0.2	
02-Aug	49.8	49.8		49.8	49.8	
05-Aug	1.1	Rain		1.1	1.1	
09-Aug	0.8	Covers on		0.8	0.8	
10-Aug	20			0	0	
12-Aug	7.7			7.7	7.7	
15-Aug	24.6			4.6	4.6	
18-Aug	0			0	0	
Diff in Plots @HD			54.2			
19-Aug	2.4			2.4	2.4	
22-Aug	2.4	2.4		2.4	Rain	
24-Aug	2.1	2.1		2.1	Covers on	
29-Aug	5.4	5.4		5.4		
30-Aug	0	0		20		
01-Sep	0	0		20		
05-Sep	0	0		20		
06-Sep	2.4	2.4		2.4		
Diff in Plots @HD						72.3
08-Sep	1.3	1.3		1.3		
09-Sep	16	16		16		
12-Sep	0	0		0		
21-Sep	6.2	6.2		6.2	6.2	
28-Sep	5.6	5.6		5.6	5.6	
05-Oct				2.4	2.4	
10-Oct				0.6	0.6	
Totals	366	309.4		389	299.4	

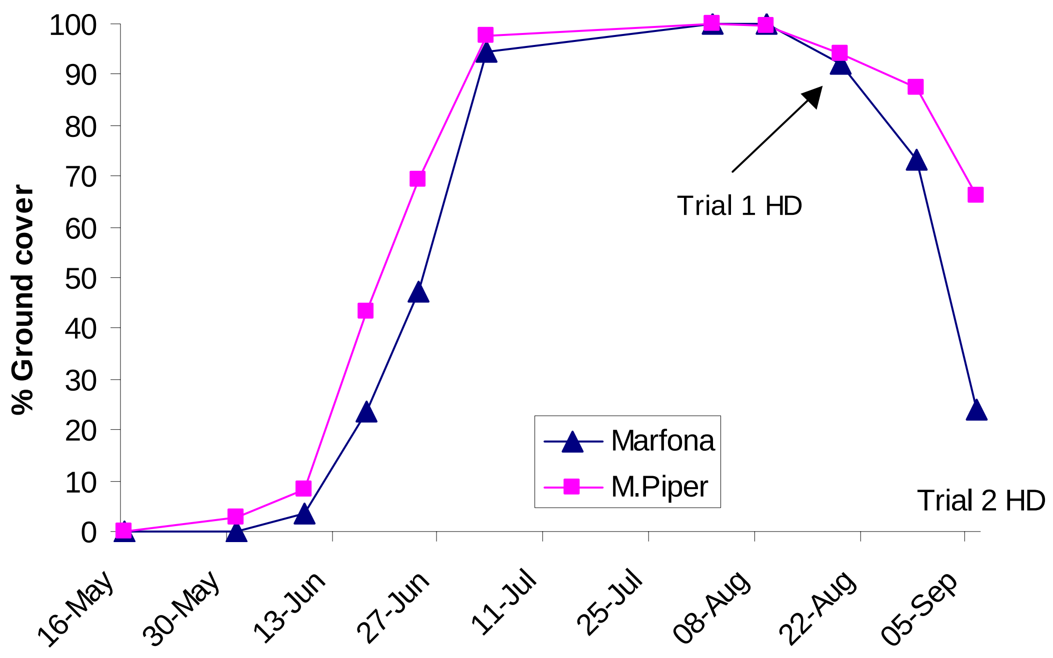

FIGURE 4 CROP GROUND COVER, 2005

As can be seen from the graph the first trial was conducted as both varieties were starting to lose ground cover.

Soil moisture content as determined by oven dried soil core samples is shown in Table 15. The soil type was a sandy loam. The field capacity of the soil was estimated to be $0.240m^3m^{-3}$

TABLE 15 SOIL MOISTURE AT HAULM DESTRUCTION, TRIAL 1 2005

		Water m^3m^{-3}		SE	SMD
Marfona	Dry soil plots	0.136		0.006	72.8
	Wet soil plots	0.187		0.003	37.0
	Diff.		0.051		
M. Piper	Dry soil plots	0.132		0.005	75.6
	Wet soil plots	0.190		0.007	35.0
	Diff.		0.059		
Avg.	Dry	0.134			74.2
	Wet	0.189			35.7
	Diff.		0.055		

<u>Effect of soil moisture on bruising</u>

As can be seen from Figure 5, Marfona and Maris Piper had very low levels of bruising at the time of haulm destruction irrespective of moisture regime. With Maris Piper, subsequent harvest dates at +3 wk, +4 wk, +5wk and +6wk all show increased levels of bruising sensitivity. Marfona, however, showed very little change in bruising sensitivity at subsequent harvest dates. When comparing the effects of the treatments of soil moisture there was a slight but consistent increase in bruising sensitivity from the drier soil plots than from the wetter soil plots with Maris Piper. No difference was found with Marfona.

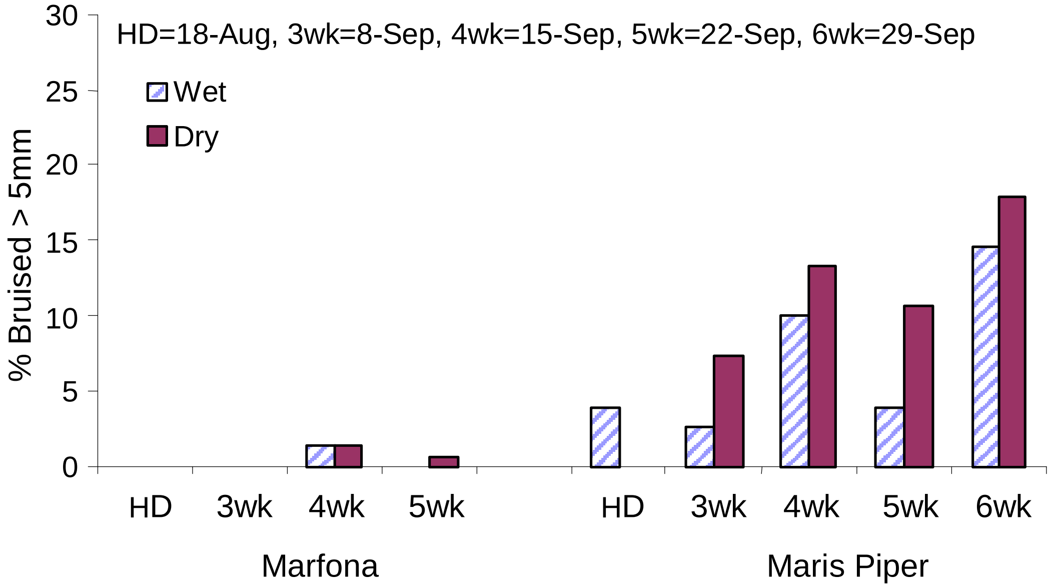

FIGURE 5 THE EFFECT OF SOIL MOISTURE AT HAULM DESTRUCTION ON BRUISING, TRIAL 1, 2005

Dry treatments were covered on 5th August and haulm destruction took place on 18th August.

Soil moisture wet plots = 0.189m^3m^{-3}, dry plots =0.134m^3m^{-3} (diff=0.055).

Soil temperatures were 15.6^{o}C at HD, 16.7 ^{o}C at +3wks, 13.1 ^{o}C at +4wks, 15.6 ^{o}C at +5 wk, and 12 ^{o}C at +6wk.

Statistical Analysis

TABLE 16 STATISTICAL ANALYSIS OF BRUISING, TRIAL 1

A model was fitted to the response (bruises more than 5mm) with three factors: treatment (dry or wet), timing of the harvest (at HD and 3, 4, 5 and 6 weeks later), variety (Marfona or M. Piper).

The first level listed is treated as the reference level for each factor. The analysis gave the following summary analysis of deviance, parameter estimates (on the logistic scale) and approximate significance probabilities.

Summary of analysis (Output from GenStat 8th edition)

Source	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Regression	6	180.5	30.081	30.08	<.001
Residual	101	148.7	1.472		
Total	107	329.2	3.076		

Parameter	estimate	s.e.	t(*)	t pr.	antilog of estimate
Constant	-6.616	0.605	-10.93	<.001	0.001339
Treatment Wet	-0.379	0.187	-2.02	0.043	0.6847
Variety Marfona vs. Piper	2.837	0.464	6.12	<.001	17.06
Timing HD vs. +3wk	0.945	0.489	1.93	0.054	2.572
Timing HD vs. +4wk	1.980	0.446	4.44	<.001	7.243
Timing HD vs. +5wk	1.398	0.465	3.01	0.003	4.048
Timing HD vs. +6wk	2.322	0.442	5.26	<.001	10.20

Parameters for factors are differences compared with the reference level:

Factor	Reference level
Treatment	Dry
Variety	Marfona
Timing	T1_HD

Treatment, variety and timing all show significant effects: with dry soil, all four sampling times after haulm destruction (Timing T1_3wk to a lesser extent) and Maris Piper all appear to give higher bruising responses.

Skin set

The results for skin set taken 3 weeks after haulm destruction is shown as percentage area skinned in Table 17. It is also expressed as a percentage of tubers in each category in

Figure 6. The results show that the wetter soil has the effect of reducing skin set with Marfona and to a lesser extent with Maris Piper.

TABLE 17 SKIN SET, TRIAL 1

% Area skinned after treatment in SAC scuffing barrel

	Marfona				Maris Piper			
	At haulm destruction		3wk after HD		At haulm destruction		3wk after HD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Wet soil plots	59.04	1.82	0.77	0.42	67.53	0.95	1.52	0.70
Dry soil plots	45.67	4.86	0.04	0.02	64.57	3.28	1.08	0.39

[Guide; area skinned should be less than 0.25 for packing quality]

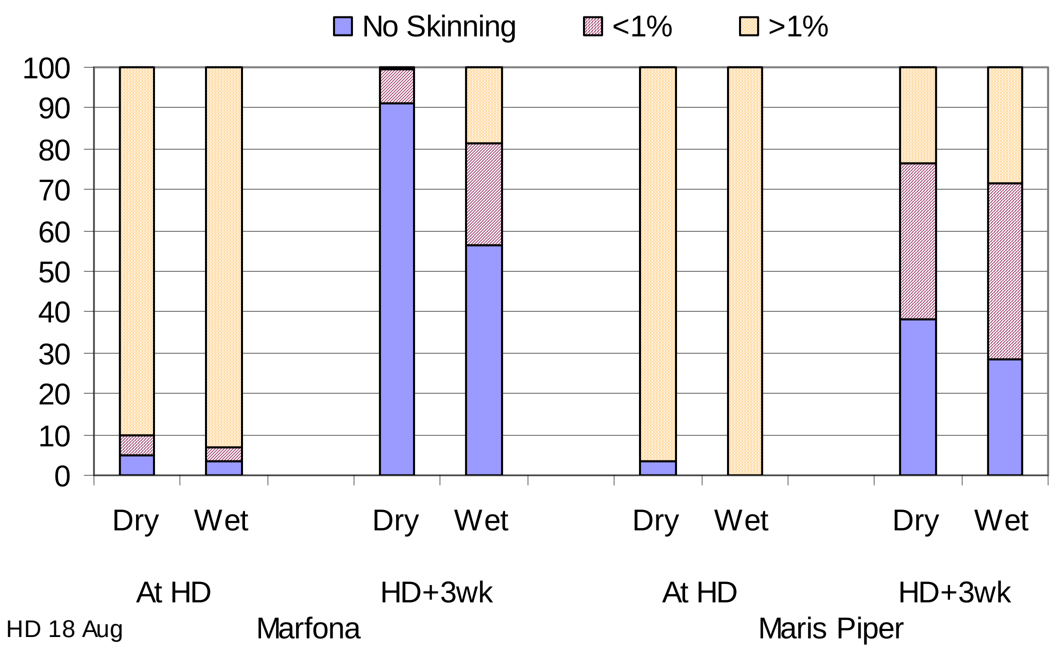

FIGURE 6 SKIN SET, PERCENTAGE TUBERS IN EACH CATEGORY, TRIAL 1

TABLE 18 TUBER DRY MATTERS, TRIAL 1

	Marfona				Maris Piper			
	At haulm destruction		3wk after HD		At haulm destruction		3wk after HD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Wet soil plots	15.4	0.2	15.7	0.1	19.4	0.5	19.5	0.6
Dry soil plots	16.3	0.3	16.7	0.4	20.0	0.3	20.4	0.5

3.3.4 Results of Trial 2, 2005

Soil moisture measurements

Table 19 shows the soil moisture content at haulm destruction in Trial 2, determined by oven dried soil core samples. The dry plots remained almost the same as in Trial 1 but the wet plots moisture increased to almost field capacity. The field capacity of the soil was estimated to be $0.240 m^3 m^{-3}$.

TABLE 19 SOIL MOISTURE CONTENT AT HAULM DESTRUCTION, TRIAL 2

		Water m^3m^{-3}	SE	SMD
Marfona	Dry soil plots	0.140	0.007	70
	Wet soil plots	0.234	0.006	4.2
	Diff.	0.094		
M. Piper	Dry soil plots	0.138	0.006	72
	Wet soil plots	0.236	0.009	2.8
	Diff.	0.098		
Avg.	Dry	0.139		70.7
	Wet	0.235		3.5
	Diff.	0.096		

Effect of soil moisture on bruising

The results of the bruising sensitivity test for Trial 2 are shown in Figure 7.

Marfona and Maris Piper had low levels of bruising at the time of haulm destruction irrespective of soil moisture regime although Maris Piper had more than Marfona. Subsequent dates after haulm destruction showed an increase in bruising sensitivity for both Marfona and Maris Piper.

At the first harvest date after haulm destruction (+3 weeks) both Marfona and Maris Piper show an increase in the bruising sensitivity with the wet plots having higher bruising than the dry plots. At subsequent harvest dates the trend is reversed with the dry plots exhibiting more bruising than the wet soil plots. This phenomenon was also seen in 2004 with Marfona in trial 2 + 3wk. In both cases the soil moisture content was above field capacity.

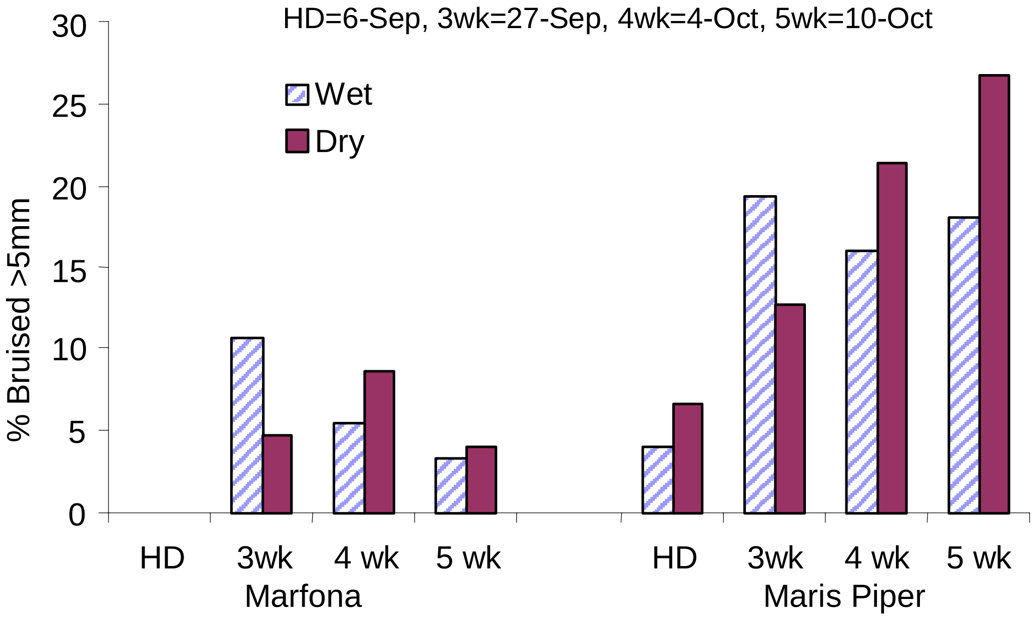

FIGURE 7 THE EFFECT OF SOIL MOISTURE AT HAULM DESTRUCTION ON BRUISING, TRIAL 2

Dry plots were covered on 22nd August and haulm destruction took place on 6th Sept.

Soil moisture (m^3m^{-3}) wet plots = 0.235, dry plots =0.139 (Diff=0.096).

Soil temperatures were 16.7^oC at HD, 13.1^oC at +3wks, 11.7 ^oC at +4wks and 12.4 ^oC at +5wk.

TABLE 20 STATISTICAL ANALYSIS OF BRUISING, TRIAL 2

The same model as above is used.
A model was fitted to the response (bruises more than 5mm) with three factors: Treatment (dry or wet), timing of the harvest (at HD and 3, 4, and 5 weeks later), and variety (Marfona or M. Piper).
The first level listed is treated as the reference level for each factor. The analysis gave the following summary analysis of deviance, parameter estimates (on the logistic scale) and approximate significance probabilities.

Summary of analysis (Output from GenStat 8th edition)

Source	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Regression	5	148.4	29.671	29.67	<.001
Residual	90	209.9	2.332		
Total	95	358.2	3.771		

Parameter	estimate	s.e.	t(*)	t pr.	antilog of estimate
Constant	-4.436	0.292	-15.21	<.001	0.01184
Treatment Wet	-0.117	0.140	-0.84	0.402	0.8893
Variety Piper	1.373	0.161	8.55	<.001	3.946
Timing HD vs. +3wk	1.624	0.285	5.69	<.001	5.076
Timing HD vs. +4wk	1.721	0.284	6.07	<.001	5.590
Timing HD vs. +5wk	1.737	0.283	6.13	<.001	5.678

Parameters for factors are differences compared with the reference level:

Factor	Reference level
Treatment	Dry
Variety	Marfona
Timing	HD

Timing and variety show significant differences, with the later sampling times and Maris Piper giving higher bruising responses. There was no difference between dry versus wet treatments. This is due to the reversal of the response (wet>dry) at the +3wk sample date.

To examine the effect of the +3weeks data on the analysis, the + 3week data was removed and the data re-analysed. When this was done, the test for significance of treatment (wet versus dry plots) changed to a t pr.=0.010, indicating that the dry plots were more susceptible to bruising if the +3 week data is taken out.

<u>Skin set</u>

The results for skin set taken at haulm destruction and 3 weeks after haulm destruction is shown as percentage area skinned in Table 21. It is also expressed as the percentage of tubers in each category in
Figure 8. The results show that the wetter soil has the effect of reducing skin set with both Marfona and Maris Piper.

TABLE 21 SKIN SET, TRIAL 2

% Area skinned after treatment in SAC scuffing barrel

	Marfona				Maris Piper			
	At haulm destruction		3wk after HD		At haulm destruction		3wk after HD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Wet soil plots	9.30	2.06	0.92	0.88	14.69	6.55	5.45	2.49
Dry soil plots	3.07	0.32	0.06	0.05	9.48	4.07	0.53	0.17

[Guide; area skinned should be less than 0.25 for packing quality]

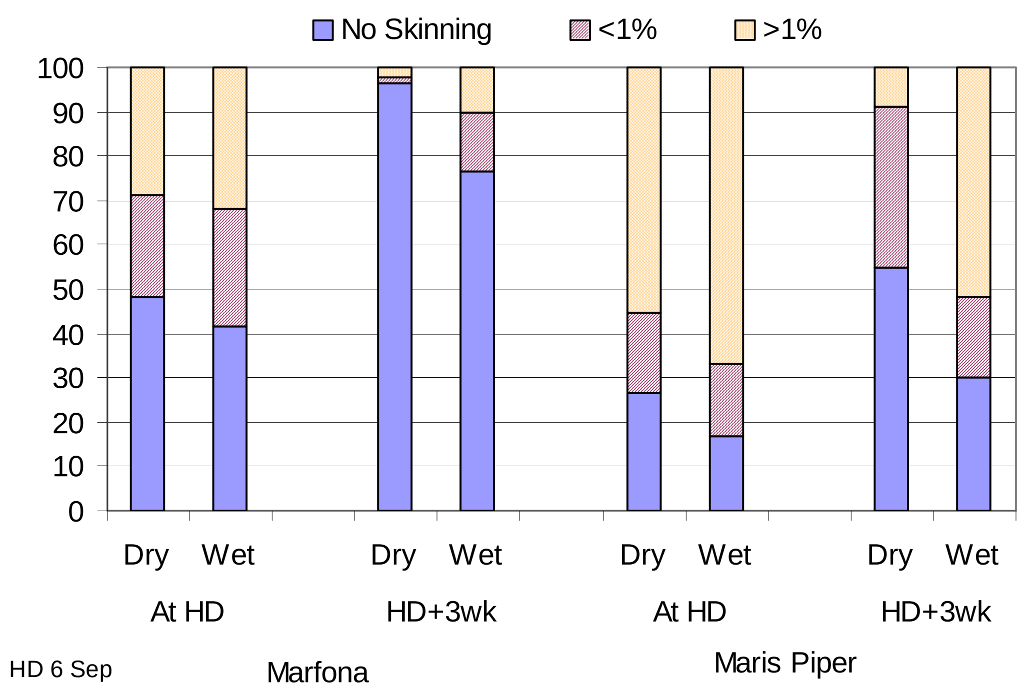

FIGURE 8 SKIN SET, PERCENTAGE TUBERS IN EACH CATEGORY, TRIAL 2

TABLE 22 TUBER DRY MATTERS, TRIAL 2

	Marfona				Maris Piper			
	At haulm destruction		3wk after HD		At haulm destruction		3wk after HD	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Wet soil plots	17.2	0.3	17.4	0.2	21.7	0.4	21.1	0.4
Dry soil plots	17.9	0.2	17.7	0.1	21.6	0.2	22.3	0.5

Yields

Yield data is shown in Table 23. Trial 1 yield data taken on 15 Aug. Trial 2 data taken on 5 Sep.

TABLE 23 CROP YIELDS

Yields (> 35 mm)	Trial 1		Trial 2	
	t/ha	SE	t/ha	SE
Marfona	46.73	1.48	58.94	2.25
M. Piper	45.61	1.42	50.95	2.25

Temperature

Soil temperature at 200mm below ridge. (Trial 1 HD=5 Aug, Trial 2 HD=6 Sep)

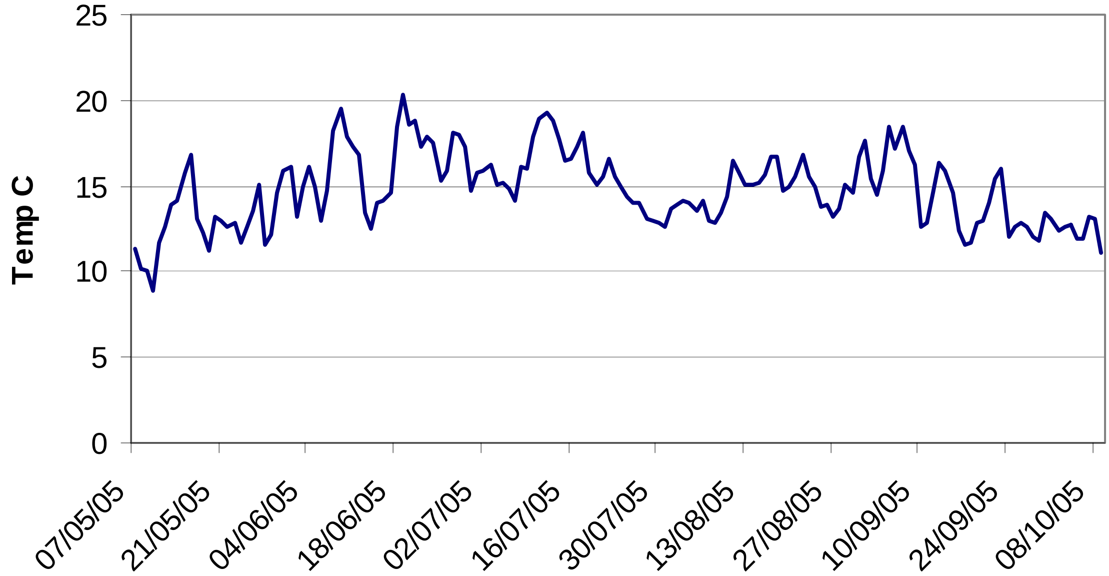

FIGURE 9 AVERAGE DAILY SOIL TEMPERATURE DURING TRIALS 1 & 2

3.3.5 Results, 2006

Rainfall and irrigation

Rainfall and irrigation data for the wet and dry plots for the trial are provided in Table 24. The soil moisture around the tubers at the time of haulm destruction as determined by oven drying core samples is given later (Table 25).

TABLE 24 RAINFALL AND IRRIGATION DATA 2006

(mm water)

Date	Wet Soil Plots	Dry Soil Plots	
28-Apr	0	0	
05-May	0.5	0.5	
08-May	4.8	4.8	
19-May	20.3	20.3	
29-May	30.2	30.2	
02-Jun	1.8	1.8	
08-Jun	0.0	0.0	
15-Jun	4.6	4.6	
23-Jun	24.8	24.8	
30-Jun	22.1	22.1	
07-Jul	58.0	58.0	
13-Jul	16.0	16.0	
20-Jul	10.4	10.4	
27-Jul	18.7	18.7	
04-Aug	43.2	43.2	
07-Aug	0.0		
18-Aug	9.9		
21-Aug	23.5	Rain Covers On	
25-Aug	1.9		
25-Aug	Defoliation		
28-Aug	3.5		Difference.
			between plots
31-Aug	3.7		42.5
07-Sep	24.6	24.6	
15-Sep	39.3	39.3	
20-Sep	0.0	0.0	
25-Sep	13.3	13.3	
03-Oct	17.1	17.1	
04-Oct	3.3	3.3	
Total	395.5	353.0	

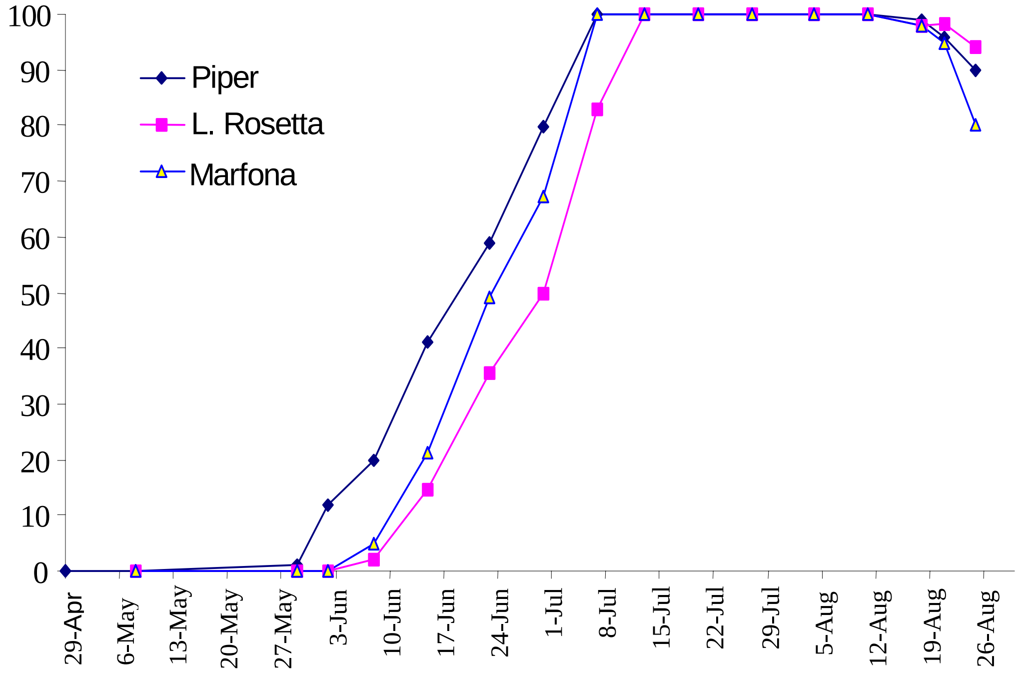

FIGURE 10 CROP GROUND COVER, 2006

Soil moisture content as determined by oven dried soil core samples is shown in Table 25. The soil type was a sandy silt loam. The field capacity of the soil was estimated to be 0.220$m^3 m^{-3}$

TABLE 25 SOIL MOISTURE AT HAULM DESTRUCTION, 2006

	Wet soil plots		Dry soil plots		Difference
	m^3 m^{-3}	SE	m^3 m^{-3}	SE	m^3 m^{-3}
Marfona	0.217	0.0069	0.143	0.0023	0.074
M.Piper	0.204	0.0058	0.141	0.0049	0.063
L.Rosetta	0.210	0.0048	0.138	0.0051	0.072
Avg.	0.210		0.141		0.070
SMD	7		55		48

<u>Effect of soil moisture on bruising</u>

As can be seen from
Figure 11, all three varieties had low sensitivity to bruising at haulm destruction. At three weeks after haulm destruction, Lady Rosetta and Maris Piper showed larger differences between treatments than Marfona. Marfona did however have higher bruising levels than Maris Piper at this stage. Lady Rosetta clearly demonstrates its reputation for bruising, with an average number of tubers bruised from the dry soil plots of 43 % and wet soil plots of 36 % at the 5week stage, this from an impact equivalent to a drop of only 200mm. As the soil became wetter at the 5wk period Piper began to exhibit more bruising in the wet soil plots (also seen in previous years). At the 5-week stage, Maris Piper did not exhibit as great a difference between treatments as it has in past years, however Lady Rosetta and Marfona clearly did.

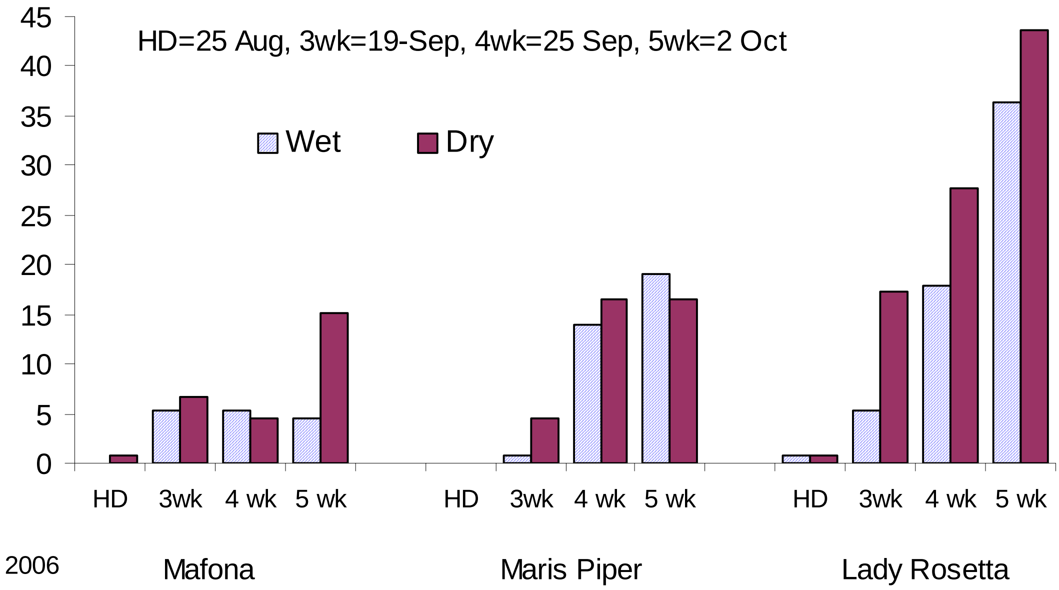

FIGURE 11 THE EFFECT OF SOIL MOISTURE AT HAULM DESTRUCTION ON BRUISING

Dry treatments were covered on 7th August and haulm destruction took place on 25th August.
Soil moisture wet plots = $0.210 m^3 m^{-3}$, dry plots $= 0.141 m^3 m^{-3}$ (diff=0.070)
Soil temperatures were 13.7^oC at HD, $13.9\ ^oC$ at +3wks, $14.0\ ^oC$ at +4wks, $13.0\ ^oC$ at +5 wk.

Statistical Analysis

TABLE 26 STATISTICAL ANALYSIS OF BRUISING

A model was fitted to the response (bruises greater than 5mm in dia.) with three factors: treatment (dry or wet), timing of the harvest (at haulm destruction [HD] and 3, 4, and 5 weeks later), variety (Marfona M. Piper or Lady Rosetta).
The first level listed is treated as the reference level for each factor. The analysis gave the following summary analysis of deviance, parameter estimates (on the logistic scale) and approximate significance probabilities.

Summary of analysis (Output from Genstat 8th edition)

Source	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Regression	6	453.9	75.650	75.65	<.001
Residual	137	243.4	1.777		
Total	143	697.3	4.876		

Paramater	estimate	s.e.	t(*)	t pr.	antilog of estimate
Constant	-6.415	0.592	-10.83	<.001	0.001637
Treatment wet	-0.441	0.115	-3.84	<.001	0.6432
Variety Piper	0.594	0.168	3.54	<.001	1.811
Variety Rosetta	1.539	0.154	10.01	<.001	4.660
Timing HD vs. +3wk	3.091	0.593	5.21	<.001	22.00
Timing HD vs. +4wk	3.988	0.585	6.81	<.001	53.92
Timing HD vs. +5wk	4.585	0.583	7.86	<.001	97.97

Parameters for factors are differences compared with the reference level:

Factor	Reference level
Treatment	Dry
Variety	Marfona
Timing	HD

Treatment, variety and timing all show significant differences.
Tubers from dry soil plots resulted in significantly more bruising than tubers from wet soil plots.
Maris Piper and Lady Rosetta showed significantly greater bruising than Marfona.
The three sampling times after haulm destruction all resulted in significantly more bruising than at haulm destruction.

Skin set

The results for skin set taken 3 weeks after haulm destruction is shown as the percentage area skinned in Table 27. The results show that the wetter soil has the effect of reducing skin set with all three varieties.

TABLE 27 SKIN SET

% Area skinned after treatment in SAC scuffing barrel at 3 weeks after haulm destruction

	Wet soil plots		Dry soil plots	
	Mean	SE	Mean	SE
Marfona	0.74	0.47	0	0
M.Piper	3.01	0.66	0.18	0.07
L.Rosetta	0.13	0.06	0.03	0.02

[Guide; area skinned should be less than 0.25 for packing quality]

TABLE 28 TUBER DRY MATTERS

	Dry soil plots		Wet soil plots	
	Mean	SE	Mean	SE
Marfona	16.5	0.53	16.3	0.24
M.Piper	19.7	0.15	19.1	0.07
L.Rosetta	22.7	0.38	21.3	0.19

As can be seen from Table 28 there is a small increase in tuber dry matter from the dry soil plots.

Yields

Crop yield at haulm destruction is shown in Table 29.

TABLE 29 CROP YIELDS

	Yield (>35mm)	
	t /ha	SE
Marfona	57.8	1.2
Maris Piper	49.7	1.5
Lady Rosetta	40.7	1.0

Temperature

Soil temperature taken at 200mm below ridge (HD=25 Aug).

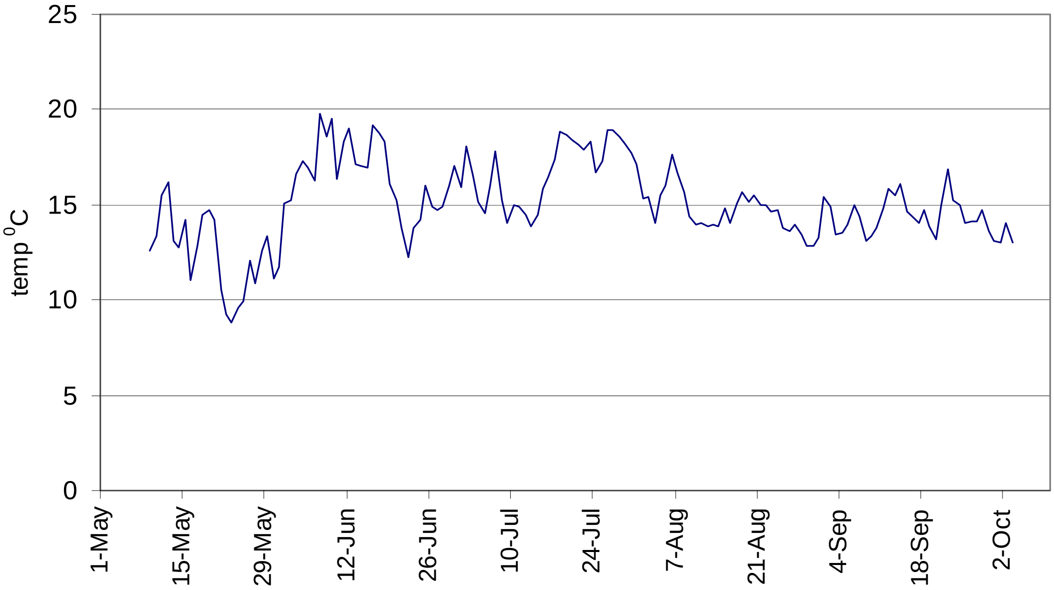

FIGURE 12 AVERAGE DAILY SOIL TEMPERATURE DURING TRIAL

3.3.6 Comparison of tuber impact devices and time of impact, 2006

Tests were undertaken to evaluate the difference between impactors (*Protect* and SAC). There was also a suspicion (from previous work with skin set) that the tuber sensitivity to an impact may change depending on the length of time after harvest the impact is delayed for. The results of the preliminary tests are shown in Table 30. The results show that the *Protect* impactor results in more tubers bruising than using the SAC impactor. This is to be expected as the *Protect* impactor imparts 0.7 joules of energy whereas the SAC impactor imparts only 0.4 joules and a large area of head. Both impactors resulted in a lower amount of bruising to tubers if impacting was delayed for 24 hours after harvest compared to impacted at harvest. Results are shown in Table 30.

TABLE 30 COMPARISONS OF IMPACTORS AND TIMING OF IMPACT AFTER HARVEST

Variety, Maris Piper.

Comparison no.	Impactor used	Impacted (% tubers bruised)		
		Within 20 min of harvest	24hrs after harvest	
1	SAC	12.8	1.6	5 reps
	Protect	52	n.r.	5 reps
2	SAC	2	1	4 reps
	Protect	27	12	4 reps
3	*Protect*	42	7	4 reps

Due to the results in Table 30, further tests were carried out with a shorter time interval of 4 hours after harvest instead of 24 hours and compared to within 20 minutes from harvest.

The results in Figure 13 show a significant reduction in the level of bruising when impacting the tubers was delayed for 4 hours after harvest compared to within 20 minutes of harvest. The numbers of tubers exhibiting bruising in 10 out of 12 test is markedly reduced. This demonstrates how quickly sensitivity to bruising can change. The discovery of this phenomenon could lead to a solution to harvesting sensitive crops, if found to be consistent. The reason for this rapid change needs investigating as it may lead to a method allowing manipulation of bruising sensitivity.

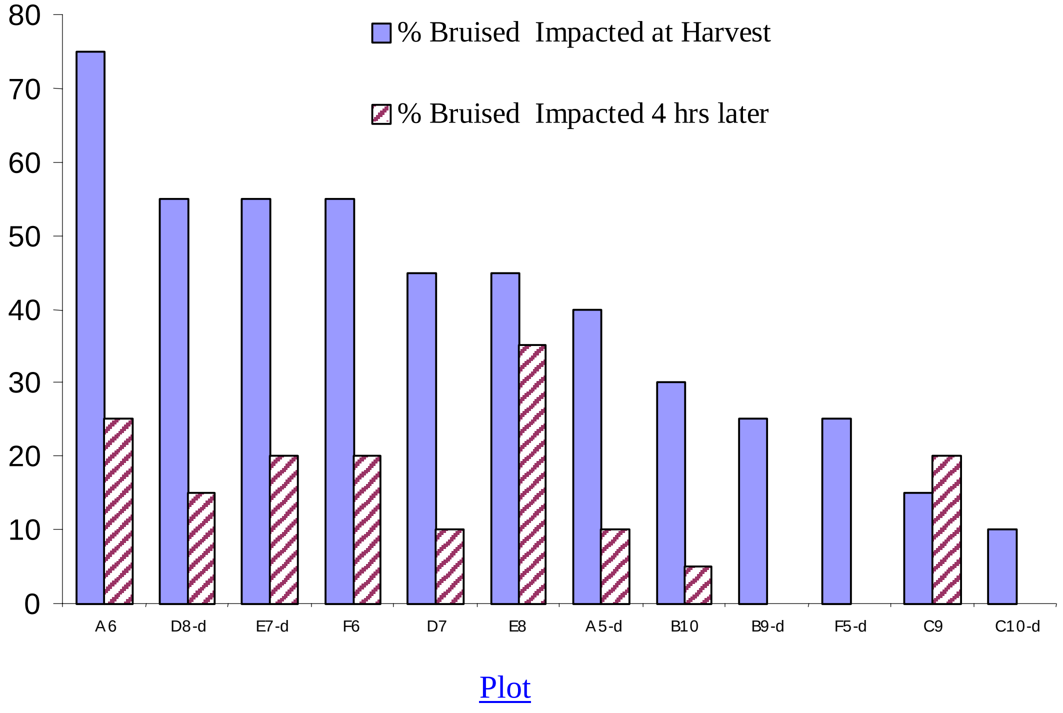

FIGURE 13   TIMING OF IMPACT AFTER HARVEST AND BRUISE SENSITIVITY

Ranked left to right, highest to lowest bruising at harvest
Lady Rosetta, SAC impactor 12/13 Oct

3.3.7 Respiration and bruising, 2006

Experiments were carried out to examine whether there was a relationship between respiration levels (CO_2) and bruising sensitivity at harvest. The results are shown in Figure 14 and a scatter plot in Figure 15 including the difference of the two respiration levels.

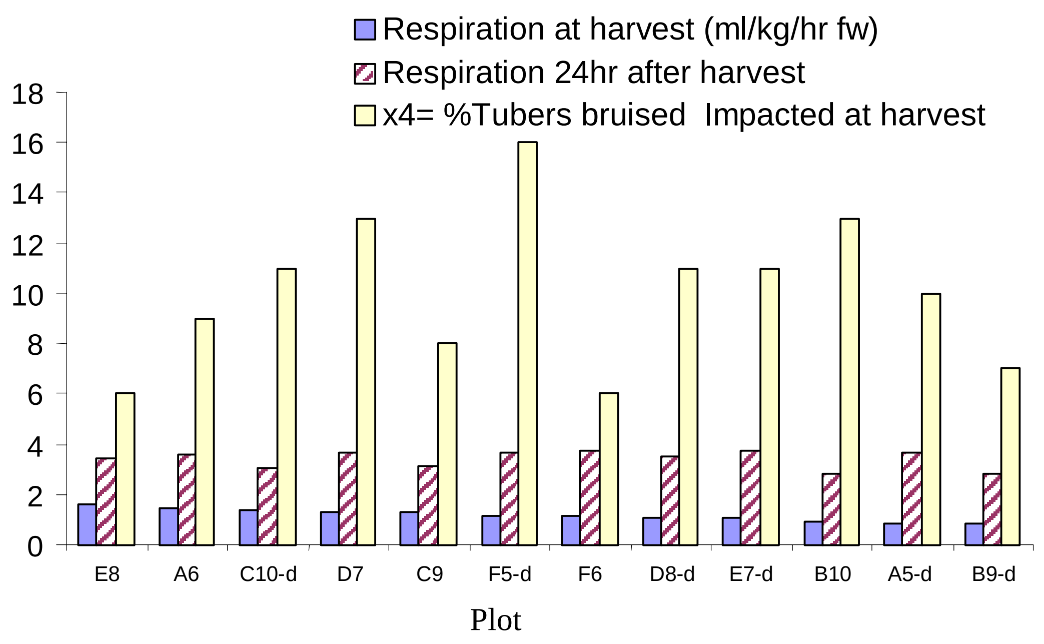

FIGURE 14 TUBER RESPIRATION AT HARVEST AND 24 HRS LATER

Single sample from plots
Graph is ranked left to right, highest to lowest respiration level at harvest.
Note, to get % bruising multiply value by 4. (Scaled to aid viewing respiration values).

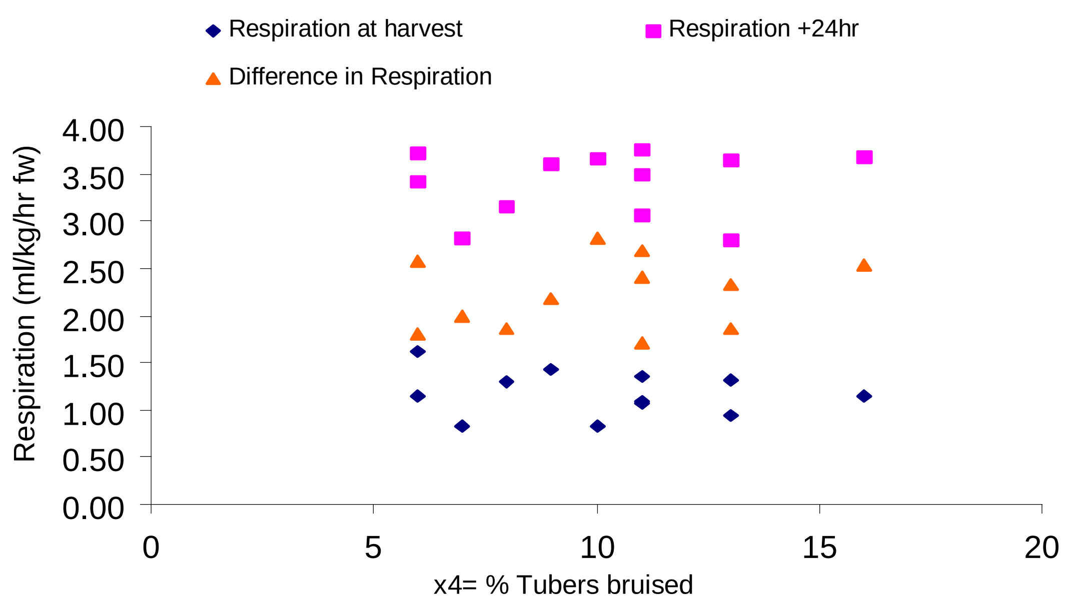

FIGURE 15 TUBER RESPIRATION AND SENSITIVITY TO BRUISING

Additional tests were carried out using the shorter time interval of 4 hours after harvest. Results are shown in Figure 16.

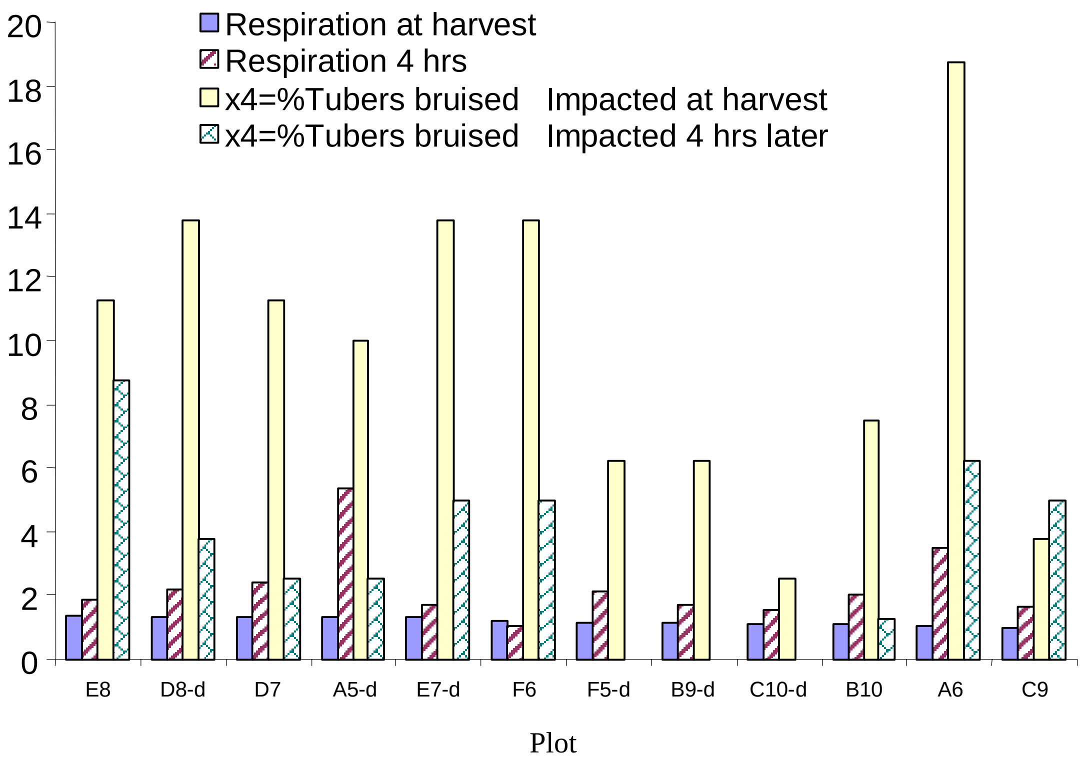

FIGURE 16 TUBER RESPIRATION AT HARVEST AND 4 HOURS AFTER HARVEST

Single sample from plots
Ranked left to right, highest to lowest respiration at harvest
Experiment conducted on 12/13 Oct. Variety Lady Rosetta harvested and impacted (SAC pendulum) within 20 min of harvest and second sample 4 hrs after harvest.

It is interesting that the respiration levels 24 hours after harvest were at least double those at harvest (Figure 14) and a noticeable rise was found after only 4 hours (Figure 16). There appears to be no indication of a correlation with bruising sensitivity and respiration (CO_2) rate.

The rationale for this small experiment was to look at respiration as a measure of tuber metabolic activity which may be influencing tuber sensitivity to bruising. The measurement of CO_2 production as an indicator of respiration was the simplest first step to try. The measurement of CO_2 as a single indicator of respiration is not valid however. Several metabolic activities can produce and consume CO_2 within the tuber therefore the association between metabolic activity and bruising should not be ruled out from this initial test.

3.4 Discussion

In 2005, Marfona was more mature than we would have liked (started senescing and canopy opening up) at defoliation due to a delay in supply of the rain covers. The degree of SMD in the dry treatments is more than most growers with irrigation would be happy with. However, this can occur frequently in commercial practice and certainly occurred in 2003. The results show that there is strong evidence that moisture availability at haulm destruction can have an effect on bruising sensitivity, at harvest. The effect was most pronounced with Maris Piper at the 3rd and 4th week after haulm destruction. Marfona did not exhibit the same dramatic changes as seen in Maris Piper, which suggests that while moisture can affect bruising sensitivity it is variety dependent, and other factors may be involved. Both trials had identical treatments but did not respond similarly. The trend of increased bruising sensitivity post haulm destruction is evident in both trials, although the effect was greater in the first trial rather than in the second. This is most likely to be the result of haulm destruction on an active plant rather than any other factor such as temperature, which is often suggested as the cause (temperature from start to finish, trial 1, 16.3-14.8 ^{0}C; trial 2, 15.4-13.3 ^{0}C). Skin set showed a trend of being less well set in the wet soil treatment at both haulm destruction dates and after 3 weeks compared to the dry soil.

Trial 2 data should be interpreted with caution. Due to heavy rain the soil had more water than we could effectively remove in the short time the covers were on prior to haulm destruction. At the time of haulm destruction we did manage to obtain some moisture differences, but in contrast to trial 1 where moisture loss was from the root profile, in trial 2 it was from the surface with the subsoil still wet.

Marfona haulm was very open and nearly dead at the time of haulm destruction and Maris Piper was well senesced. From observations, the moisture profile in the drill was not as evenly distributed as it was in the first trial as surface evaporation accounted for most of the moisture loss rather than plant uptake. This may account for the increased variability in bruising sensitivity with the samples. Maris Piper did not show any major signs of a difference between treatments but Marfona did show increase sensitivity in the dry soil treatment over the wet soil treatment at HD+4 wk. Skin set showed a similar trend as in trial 1 with the wet soil having poor skin set. Marfona was showing signs of unsetting of the skin with the crop lying in wet soil.

In 2005, Marfona was planted later than Maris Piper so that we could achieve similar timings of the onset of haulm senescence. This was achieved, with Marfona having just started to senesce with 92 % ground cover and Maris Piper at 94% ground cover at the time of haulm destruction in trial 1.

The early crop trial (trial1) had an SMD difference of 39mm imposed (35mm for wet soil plots and 74mm for the dry soil plots). Lower bruising sensitivity was found in both varieties compared to the first year. This was especially noticeable for Marfona, which this year hardly bruised (max 1.3%) compared to the first year (max 14%). Maris Piper exhibited a similar response to the first year but with less sensitivity to bruising, peaking at 18% compared to 34%. No response was found with Marfona with regard to soil moisture but Maris Piper followed a similar trend to last year with increased bruising in the dry soil plots.

The mature crop trial (trial 2) had an SMD difference of 67mm (3.5mm for the wet plots and 71mm for the dry plots) at haulm destruction. At the time of defoliation, ground cover was only 24% for Marfona and 66% for Maris Piper. Both Marfona and Maris Piper showed an increase in bruising in the test carried out at haulm destruction compared to that at +3 week or later.

Interestingly, at the +3 week test after haulm destruction both Marfona and Maris Piper had greater bruising in tubers from the wet soil plots compared to the dry plots. This was reversed in the following weeks with dry plots more sensitive to bruising than the wet soil plots.

Skin set again showed a trend towards being less well set in the wet soil treatment at both haulm destruction dates and after 3 weeks compared to the dry soil.

In 2006 at haulm destruction the main trial showed an SMD difference of 48mm between plots, 7mm for wet soil plots and 55mm for the dry soil plots.

At the time of defoliation ground cover was still high (90% for Maris Piper, 80% for Marfona) but the crop was senescing.

All three varieties showed very little bruising at haulm destruction, with an increase at 3 weeks after defoliation for all varieties and treatments (very small in Maris Piper from wet soil plots). Bruising then increased in Maris Piper and Lady Rosetta at the 4-week stage. Lady Rosetta continued to increase at the 5week test but Maris Piper stabilised and the wet plots showed greater bruising than dry plots. This tendency to increased bruise levels in saturated soil has been seen in previous years. Marfona showed very little difference between treatments except at the 5week stage when the dry soil plots had 3 times more bruising than the wet soil plots. Maris Piper did show treatment differences with the dry soil plots having greater bruising than the wet soil plots up until the 5week stage when bruising in the wet soil plots was marginally greater than in the dry plots. Lady Rosetta had more bruising in the dry plots in every sample except at defoliation when they were similar.

Statistical analysis on all the data shows that Marfona is not more prone to bruising in dry soils compared to wet soils at defoliation. However, Maris Piper is highly sensitive to increased bruising in dry soils at defoliation.

The timing of an impact after harvest in relation to sensitivity to bruising was evaluated in 2006. An initial test compared tubers impacted at 24 hours after harvest with tubers impact within 20 minutes of harvest. Results showed major reduction when impact was delayed for 24 hours (Table 30). This was followed up using a shorter interval of 4 hours in a subsequent series of tests. The results also showed a significant reduction in the level of bruising when impacting the tubers was delayed for 4 hours after harvest compared to within 20 minutes of harvest (Figure 13). The number of tubers exhibiting bruising in 10 out of 12 test was markedly reduced. This demonstrates how quickly sensitivity to bruising can change. The discovery of this phenomenon could lead to a solution to harvesting sensitive crops, if found to be consistent. The reason for this rapid change needs investigating as it may lead to a method allowing manipulation of bruising sensitivity.

3.5 Conclusions

Tuber sensitivity to bruising does not stay at a constant level at harvest time and can change in the same crop by several orders of magnitude depending on environmental factors and time of harvest after defoliation. It has also been found that sensitivity to bruising can change very rapidly as shown by a greatly reduced incidence of bruising when impacted 4 hours after harvest compared to being impacted at harvest. Tubers harvested before or soon after defoliation have a much lower bruising level than the same crop harvested three to five weeks after defoliation.

- Soil moisture content at haulm destruction and bruising sensitivity.
  The overall results from the three years shows that in some varieties there is a definite risk of more bruising from soils that are dry at haulm destruction. The magnitude of the effect varies with variety and was most noticeable with Maris Piper and Lady Rosetta. The response of Marfona was inconsistent and unpredictable so no conclusion could be reached. However the presumption that dry soils are *always* more prone to bruising compared to wet soils does not appear to be true either as several comparisons showed no difference. Each year there was always an occasional data-set where the trend described above was nearly reversed with the wet treatment exhibiting greater bruising than the dry treatment (Figure 2 2004 trial 2 Marfona 3+wk, Figure 7 2005 trial 2 Marfona and Maris Piper +3wk, Figure 11 2006 Maris Piper +5 wk). The reason for this has not been positively identified but appears to occur when the soil becomes saturated above field capacity after defoliation. While soil moisture content at haulm destruction appears to influence sensitivity to bruising at harvest, the effect is not consistent. This leads us to consider whether soil moisture is influencing tuber sensitivity directly (such as an effect on turgor) or whether it is altering some other factors that we are not measuring. This maybe why, on some occasions, tubers from the wet soil plots are more prone to bruising.

  The experiment has shown that we now have a consistent method of manipulating tuber sensitivity to bruising (M.Piper & Rosetta) which we did not have before. This will allow the production of samples to test the key factors involved in sensitivity changes in tuber bruising with reduced amount of variation.

- The effect of haulm destruction on bruising sensitivity. There was a consistent trend of very low to non-existent bruising at defoliation (green top) and a very large increase in bruising at harvest three to five weeks after defoliation. The trend was consistent in all varieties and statistically significant in all trials. The reason for this has not been identified. Understanding why this happens could help reduce bruising at harvest. This phenomenon could also be used as a means of the production of differentially sensitive tubers for tests.

- Skin Set. A consistent trend emerged with skin set. The drier soil resulted in a more rapid tuber skin set than tubers from the wet soils. The tubers from the wet soil plots had poorer skin set, for a longer period of time after defoliation than from the drier soil. A compromise may need to be reached if crops are to be lifted soon after defoliation, as extra water will slow down skin set but could reduce bruising.

- Timing of impacts. Tests on the effect of the time between harvesting and when the tubers were impacted showed that there was far less bruising if impacted 24 hours after harvest compared to impacted within 20 minutes of harvest. An intermediate time of 4 hours also showed a large difference in the amount of bruising occurring. This has major implication when testing crops for sensitivity to bruising as a predictor to harvester damage. Further work needs to be carried out to detect why this occurs, as it has implications for possible practical solutions in crops that are difficult to harvesting due to bruising sensitivity.

  - Respiration. Studies on respiration (CO_2) levels at harvest showed that respiration rates increased considerably a short time after harvest. However, in the preliminary studies we did not find a correlation with CO_2 produced and bruising sensitivity.

Recommendations

- The effect of soil moisture at defoliation on bruising appears to be variety dependent. Some varieties will be affected and others will not.

- Try to avoid allowing soils to reach too high a soil moisture deficit [SMD] at defoliation, as there is a greater risk of bruising at harvest especially with Maris Piper and Lady Rosetta.

- Crops lifted soon after defoliation exhibit lower bruising levels than crops harvested three-five weeks after defoliation.

3.6 References

- Nelson D., EAPR Physiology meeting SCRI Dundee 2003
- BPC Project report No.2004/4. Factors associated with internal damage and bruising in potato tubers J Fellows, *Warwick HRI*
- Dobson, A.J. (1990). *An Introduction to Generalized Linear Models*, Chapman & Hall, London.
- McCullagh, P. & Nelder, J.A. (1989). *Generalized Linear Models (second edition)*, Chapman & Hall, London.
- BPC Project report, Bruising sensitivity at harvest R252, 1st year report 2004
- BPC Project report, Bruising sensitivity at harvest R252, 2nd year report 2005

4. Summary of technology transfer and project deliverables

2004

- Attendance at Potato in Practice 2004 SCRI Dundee, discussed bruising problems with growers. Press Reports in Scottish Farmer, Farmers Weekly.
- Presentation to "SAC Potato study group", which includes representatives from BPC, DEFRA, SEERAD, potato processors, supermarket agronomists, packers, seed merchants, farmers, and machinery manufacturers. 7 Dec 2004 Bush Estate
- Presentation to SAC potato specialists 6 Dec 2004 at SAC Edinburgh.
- Liaison with
    - Di Pitts, Romney Marsh Potato Company Ltd
    - Matthew Smallwood, Taypack Potatoes Ltd
    - Ben Tyreman, RS Cockerill (York)
    - David Nelson, Branston Potatoes
    - Peter Harkett, McCains
    - Allan Stevenson, Farmer, Essex

2005

- BPC KT Bruising forum meeting Peterborough, 8 Feb 2005, presentation of results.
- BPC Joint projects meeting with CUF, Durham, and SAC. Univ. Durham 20 April.
- BPC Harvester workshops (33) around country.
- Potato Newsletter article, June 2005.
- Potatoes in Practice 11 Aug 2005 SCRI Dundee.
- Presentation to "SAC Potato study group", which includes representatives from BPC, DEFRA, SEERAD, potato processors, supermarket agronomists, packers, seed merchants, farmers, and machinery manufacturers. 24 Nov 2005 Bush Estate.
- Presentation at BP2005, Nov. 30 / Dec1, Future for Fresh "Confronting the future for harvesting"and stand duty for BPC at the event.

2006

- Sappio Link Meeting, Greenvale Floods Ferry 26 Jan 2006, presentation of results.
- BPC KT Bruising forum meeting Peterborough, 22 Feb 2006, presentation of results.
- BPC Harvester workshops (8) around country.
- Presentation to "SAC Potato study group", which includes representatives from BPC, DEFRA, SEERAD, potato processors, supermarket agronomists, packers, seed merchants, farmers, and machinery manufacturers. 24 Nov 2005 Bush Estate.

5. Appendix

FIGURE 17 RAIN SHELTERS

FIGURE 18 PENDULUM IMPACTOR.