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MEASUREMENTS OF THE ADHESION STRENGTHS OF POTATO SKIN RELATED TO HAULM TREATMENTS

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A b s t r a c t. This paper presents some of the first results of a project at the Scottish Agricultural College in Edinburgh which is investigating skin strength in potatoes.

These first results highlight how little we know and how much more there is to learn about skin adhesion strength in potatoes, especially about the mechanism of skin set, however, a number of general conclusions can be made. It is perhaps only when there are large differences in a characteristic such as skin thickness. The second is that we are now looking more closely at changes in the zone of separation, such as water content, changes in biochemistry of substances, such as pectins. These are probably more important.

Overall, between haulm destruction and harvesting we estimate a force of 15-20 N is equivalent to the thumb test when skin is set.

K e y w o r d s: adhesion strength, potato skin

INTRODUCTION

This paper presents some of the first results of a project at the Scottish Agricultural College in Edinburgh which is investigating skin strength in potatoes.

In Scotland over 60 % of the crop is grown for seed and of course crop health is of highest priority. We often advise farmers to harvest crops early to minimise disease problems associated with the harvesting, however early harvesting can impose the risk that crops may have skins which are too weak or poorly set.

The scuffing damage or skinning - loss of skin which can occur during the harvesting and grading of such crops - can often be very severe. These areas of damage provide important sites for infection by disease, points of water loss and the possibly initiation of physiological changes in the tuber as well. Skin strength and the factors that affect it, I believe, are very poorly understood and it is the aim of this work to begin to find some the answers. Our aims are therefore essentially twofold:

1. To measure skin strength and to measure susceptibility to scuffing. Traditionally, the strength of skin is tested by applying pressure with the thumb, the so called 'thumb test', but clearly this technique whilst able to give an approximate guide to skin strength is inaccurate and not quantitative.

2. To identify the factors that affect skin set. How the structure of the skin is related to strength and then how the effects of crop husbandry affect skin strength.

The skins of potatoes have characteristic structure which is shown in Fig. 1. The periderm or skin is seen here under low magnification and has a distinct layer of cells about 5-15 cell layers (70-150 μ thick). Cells

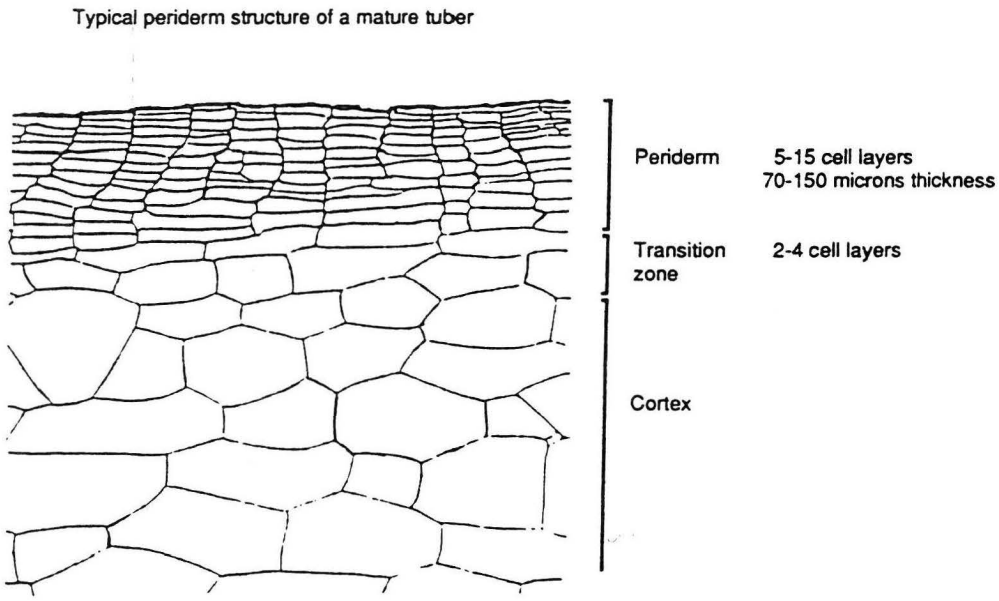

Fig. 1. Cell structure of near surface tissues of potato.

may be arranged within the skin in a regular stacking pattern as seen here with often distinct ends to stacks, - or sometimes in an irregular pattern. The size of individual cells can vary. Between the periderm and the cortex there is what is becomed termed the transition zone, an area where the cells show intermediate characteristics of both the periderm and cortex in respect of their morphology. There is very little information on how these characteristics effect skin strength.

When a tuber is scuffed and complete areas of the skin are removed it is along a zone of separation which coincides with the transition zone, in that the skin separates along the line of weakness between cells. This is quite characteristic of scuffing damage between haulm destruction and harvest. Skin adhesion could be measured by a new technique which is described by Ostby *et al.* elsewhere. This very briefly involved measuring the tangential force required to remove an isolated area, 1 cm^2 of skin. A constant normal force was applied to hold the skin firm. The machine developed to do this is known as 'the scuff meter' (Fig. 2).

The scuff meter consist of two transducers mounted on an orthogonal frame which allows the application and measurement of forces mutually perpendicular and referred to as normal and tangential to the surface of the tuber. The transducers are of parallelogram configuration with sputtered strain

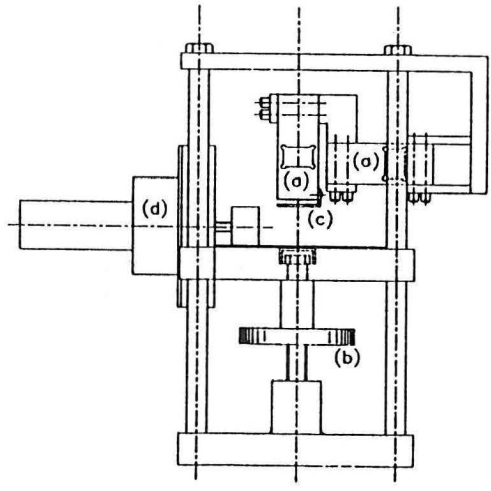

Fig. 2. The scuff meter.

gauges incorporated. The ranges of the transducers are 100 N each.

The normal force is applied by elevating the platform on which the cut tuber is place. A carborundum surface is used to attach the skin to the anvil of the scuffer. Once the normal force is applied, the linear motor drive pushes the tuber off its skin. The tangential force applied is measured and peak forces are digitally monitored and stored in the computer.

Figure 3 shows typical output of a scuffing test with the force building up to a point where the skin separates, after which the adhesion force then declines. The peak of the graph is taken as the measure of the skin adhesion strength, the point at which skin separates from the sub-surface. This technique is essentially our mechanical thumb. The thumb, however, is a sophisticated sensor. This is actually an important point because it must be noted that in these experiments the scuff meter was used on isolated skin only. It was used to measure the lateral adhesion strength and not any other force such as the tensile or the shear strength within the skin, whereas the thumb does all of these simultaneously. However, that is not to say that the scuff meter cannot be used in the same way. Instead of isolating a full piece of skin if we only isolate on three sides, for example, we can measure tensile strength and the adhesion strength simultaneously.

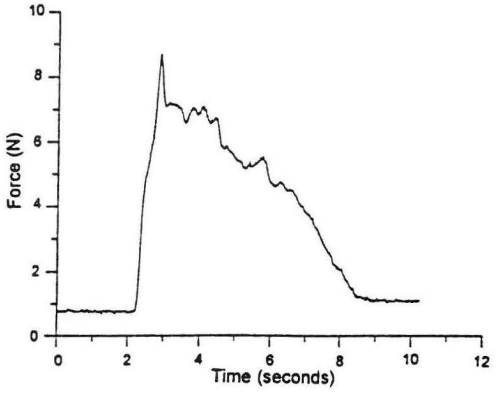

Fig. 3. Typical output of a scuffing test

EXPERIMENTAL RESULTS

Now we present the results of two experiments in which we have used the scuff meter to examine skin strength or susceptibility to scuffing. The first is the relationship of skin set or adhesion strength with skin structure in 6 common British varieties of potato. The second is the effect of three methods of haulm destruction on skin strength and skin structure.

The first experiment examines the skin strength of 6 varieties over a period of 50 days between haulm destruction and harvest. Prior to haulm destruction by pulverisation all varieties were grown under a common regime. There was no natural senescence in the crop at the time of haulm destruction. Measurement of both skin strength and skin structure were made at regular intervals over the 50 day period.

Figure 4 shows the changes in skin adhesion strength in the 6 varieties over the 50 day period. It was characteristic of all varieties for the skin strength to increase steadily after haulm destruction, although the rates of change varied between varieties. Initial skin strength varied between varieties, the variety Desiree having greater skin strength and the variety Record having one of the weakest. By the 20th day however, Record had a significantly stronger skin than other varieties. The other 5 varieties had similar adhesion strength by the end of the experiment. No relationship appeared between rates of increase and maturity of the varieties.

Table 1 shows skin adhesion strength measurements of both thumb test and scuff meter in relation to some of the measured skin structural characteristics. Results are given for just the 22 day sample. Only some of the measurements that were made are given here. Skin thickness, number of cell, cellular size, suberin content, cellular arrangement within the skin, in other words the gross morphology of the samples is also measured. Generally, although there were differences in skin characteristics, between

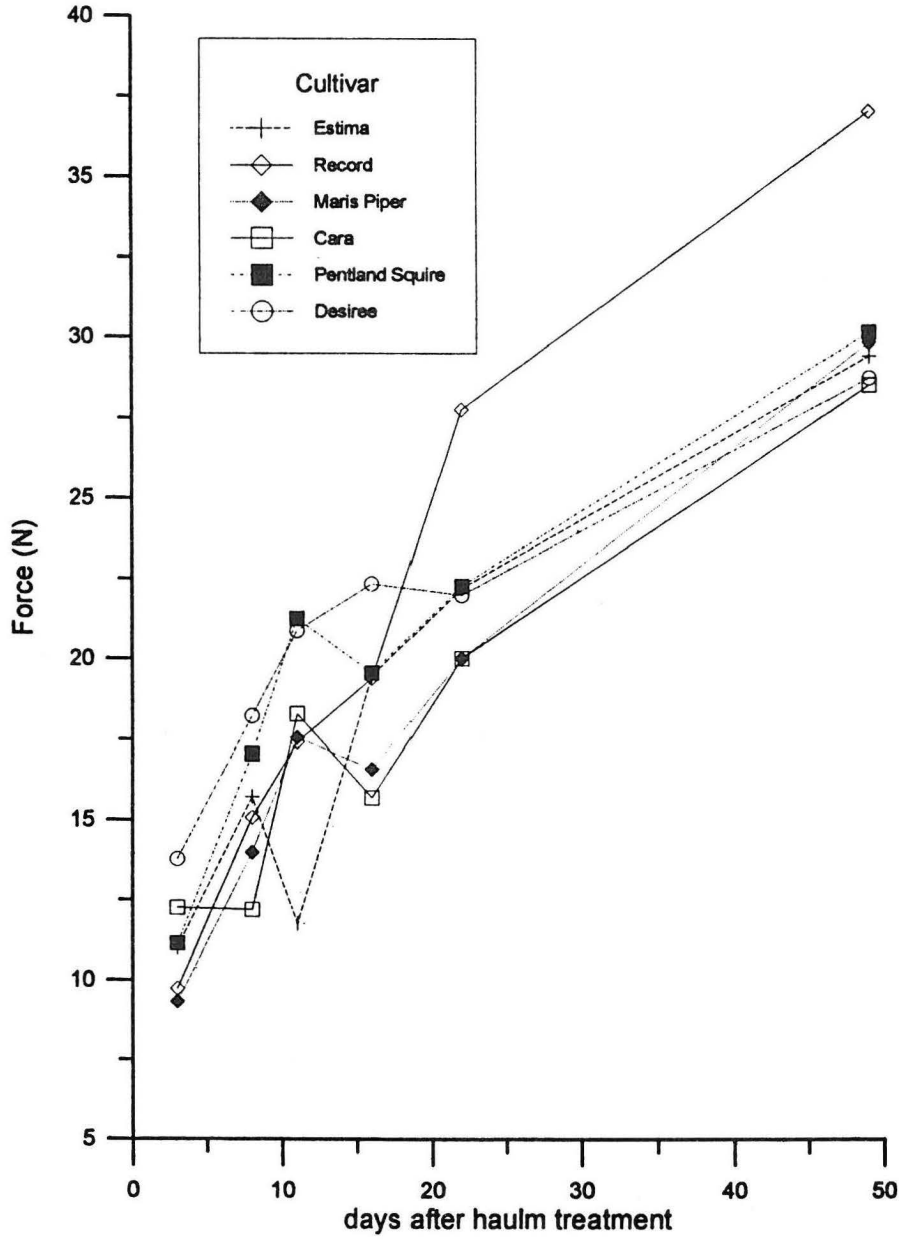

Fig. 4. Changes in skin adhesion strength for six varieties.

samples at all sampling dates there was a poor relationship between skin characteristics and skin adhesion strength, that is, no one characteristic was related to a stronger skin. An exception to this general statement is that the strong skin of Record was always associated with its thickness of skin but thick skins in other varieties were not necessarily related. Cara tended to have thinner skin on all dates and also weaker skin but differences were not significant overall. It is also worth mentioning that the errors associated

Table 1. Relationship between potato skin structure and skin strength measurements 22 days after haulm destruction

Variety	Skin thickness (μ)	Nos cell layers in skin	Suberin score	Skin strength (N)	Thumb-test (% tubers set)
Cara	67.5	6.1	3	19.1	62.5
Desiree	96.0	6.6	5	21.8	75.0
Estima	103.6	7.7	5	20.9	75.0
Maris Piper	86.6	7.3	5	19.3	75.0
Pentland Squire	70.6	5.6	5	21.8	67.5
Record	124.7	8.5	5	26.7	82.5
SED	4.7	1.1	-	2.2	-

with the measurement of characteristics were surprisingly less than expected. That is, characteristics were quite uniform within a crop. Actually skin thickness tended to decline over the period, this was thought to be due to reduced phellogen activity not replacing sloughed off skin.

An interesting point arises from the comparison of skin strength assessment by scuff meter and thumb test. Thumb test results indicate a larger difference between varieties than the scuff meter. It separates Cara and Pentland Squire from Desiree, Estima and Maris Piper whereas the scuff meter results are very similar for all 5 varieties. We believe this could be a real effect perhaps explained by the fact that the thumb test measure tuber skin strength, i.e., adhesion + tensile whereas the scuff meter is measuring essentially only adhesion strength. Adhesion strength is the most important factor in influencing skin retention but there must be a component due to skin strength. If these are tensile or shear they represent strengths within the skin and not between the skin and the underlying tuber as is the adhesive force. As characteristics such as skin thickness may be expected to have greater influence than perhaps indicated here, then the poor skin set score associated with Cara and Pentland Squire may be associated with thinner skins. Skin thickness is likely to be associated with better skin adhesion as indicated by Record but until we know more about what changes lead to the mechanism of skin set it is difficult to reach any firm conclusions.

The second experiment in which we used the scuff meter to measure skin strength looked at 3 methods of haulm destruction: first was flailing, second was haulm pulling, third was chemical desiccation using Diquat. These methods were applied at two stages of crop maturity, the first being when there was still active growth in early August and the second at the onset of senescence in mid-September. Variety was Estima, skin strength and structure was measured as before over a 20 day period. Figure 5 gives the results showing changes in skin strength. Consistent increases in adhesion strength with one or two fluctuations after haulm destruction are shown. Skins were weaker at the early date as would be expected but note that skin strength after pulling at the last treatment date was greater over the 20 days and at the end gave a significantly stronger skin. Skins tended to be weakest following flailing.

Assessment of the incidence of scuffing damage was made after machine harvesting at 20 days and confirmed the results. Only 25 % of tubers showing signs of scuffing damage after pulling compared to 33.6 % after Diquat and 37.6 % after flailing.

At the later treatment dates when skins were stronger there were fewer differences between flailing and haulm pulling, although the final skin strength was significantly higher after pulling. Cold, wet weather after applying

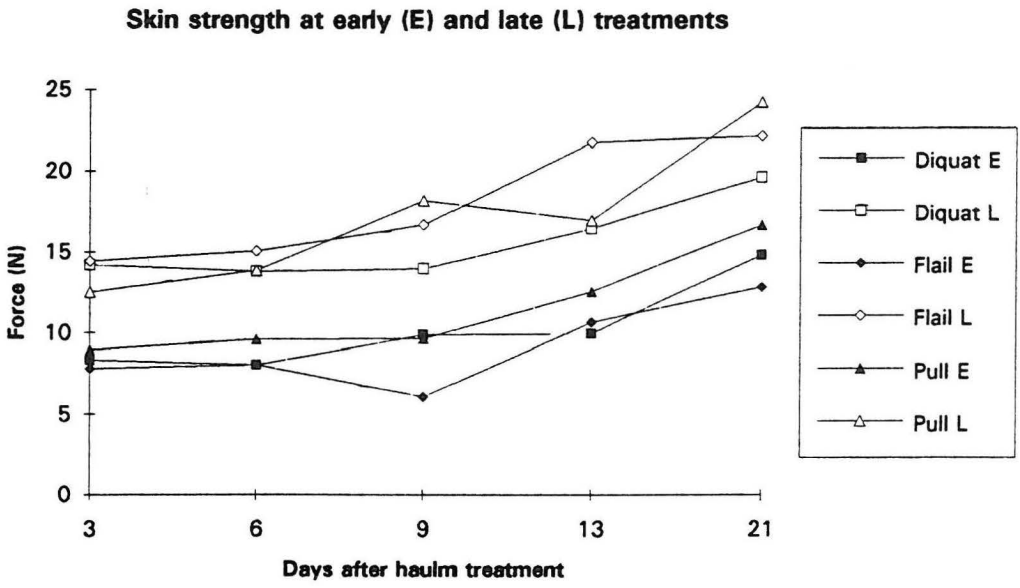

Fig. 5. The effect of the method of haulm treatments on skin strength.

Diquat at the later date resulted in a slow kill of the foliage and it is thought this reflects in the poor skin set shown here. Assessment of the skin structure characteristics showed that there was no effect of method of haulm destruction on skin structure.

CONCLUSIONS

These first results highlight how little we know and how much more there is to learn about skin adhesion strength in potatoes, especially about the mechanism of skin set, however, a number of general conclusions can be made. It is perhaps only when there are large differences in a characteristic such as skin thickness, in Record for example that an effect is observed. The second is that we are now looking more closely at changes in the zone of separation, such as water content, changes in biochemistry of substances, such as pectins. These are probably more important.

Overall, between haulm destruction and harvesting we estimate a force of 15-20 N is equivalent to the thumb test when skin is set.

As adhesion strength increases the other skin strengths, such as tensile and shear may become more important as they then may become the weakest force components. When this occurs the type of damage is different, a more superficial scuffing rather than large pieces of skin being removed. We are looking at the relative importance of these forces with time.

In future we also intend to look at soil temperature, moisture and fertiliser (NPK) levels. It is most important, we believe, to be able to give constructive advice to farmers through the use of implements like the scuff meter whereby we can derive fundamental data and give educated answers to fundamental questions. In terms of the scuff meter and scuffing, the kind of advice it is hoped to be able to give is how to manage the crop better, to give better stronger skins and hence reduce damage and losses.