HDC REPORT FV146
FINAL REPORT (1993-1994)

REDUCTION OF BROWNING IN PARSNIPS

A McGARRY
HRI WELLESBOURNE

Relevance to growers and practical application

Application

Parsnips brown after harvest. The basis of cultivar differences in browning susceptibility has been examined by comparing a range of mechanical and biochemical properties. Tissue browning or bruising in horticultural products is caused by the enzyme polyphenol oxidase (PPO) converting phenols firstly into orange-brown intermediates and then the brown/black pigment, melanin. In both cultivars examined, PPO activity and phenol concentration was highest in the skin (outer 1.5 mm). Phenols were activated by mechanical damage. PPO activity is higher in the flesh of the browning-susceptible cv Cobham Improved Marrow than the more resistant cv White Spear. Careful handling at harvest and lifting crops during the cooler part of the day may reduce wastage due to browning by minimising damage, lowering PPO activity and preventing substrate activation. A rapid test for assessing browning potential has been developed and involves incubating slices of root tissue on agar plates containing buffered catechol/proline. This allows the effects of genotype and growing conditions to be evaluated in the field or packhouse.

Summary

Skin colour/finish is of primary importance to parsnip growers. Any processes adversely affecting the appearance of a crop is a serious limitation to sales. Parsnips brown rapidly after harvest, changing from paper white to dull yellow/brown. There is no market for discoloured products and trimming such roots is generally not economically viable. Work in Canada has suggested that susceptibility to browning is affected by both cultivar and growing conditions, with stony or abrasive soils inducing

more extensive browning than peat soils (Kaldy, Dormaar, Molnar and Ragan, 1976; Toivonen, 1992).

Browning occurs as a result of polyphenol oxidase (PPO) oxidizing phenols into coloured intermediates which polymerize or react with various cell constituents, such as proteins, to form the brown/black pigment, melanin. Work on other horticultural products (notably potatoes) has suggested that enzyme and substrates are located in separate cellular compartments and that membrane damage is sufficient to bring these molecules together and enable discoloration to occur (Reeve, 1968; Ilker, Spurr and Timm, 1977; Mueller and Mondy, 1977).

A comparison of cultivars reported to differ in browning susceptibility revealed no difference in the rate or extent of browning following injury (Toivonen, 1992). However, the browning susceptible cv Cobham Improved Marrow did leak solutes more readily after roots had been abraded with a brush. This suggests that in this cultivar, membrane integrity can be compromised by mild mechanical damage. Further, Toivonen (1992) suggested that differences in browning susceptibility were attributable to differences in tissue strength and not PPO activity or phenol levels.

The objective of the present investigation was to establish the mechanism of browning susceptibility in parsnips by examining both physical and biochemical properties in the cultivars, Cobham Improved Marrow and White Spear.

It was demonstrated that cut flesh of cv Cobham Improved Marrow browned more readily than the flesh of cv White Spear. This could be explained by the fact that Cobham Improved Marrow flesh had higher PPO activity and lower porosity (more cellular material per unit area) than White Spear flesh. In addition, PPO activity and phenol concentration was highest in the skin. As a result even minor damage at

harvest (such as shearing off lateral roots) can induce localized browning. More severe damage appears to activate phenols with the result that there are more substrates available for PPO.

The browning-susceptible cv Cobham Improved Marrow was tougher (more resistant to fracture) than White Spear. However, this test (along with the tensile test) induces cell wall breakage and so measures the force or energy required to fracture cell walls. It is possible that browning in parsnips does not require cell wall fracture. A loss of membrane integrity may be sufficient to induce browning in parsnips. For future work, an impact test (such as falling bolt or pendulum tests) may be a more appropriate means of assessing resistance to browning.

It is likely that cultivar differences in browning are due to differences in PPO activity/phenol concentration and membrane integrity. Factors affecting these properties may influence susceptibility to browning, for instance, handling temperature may affect both PPO activity and membrane integrity. Handling and storing roots at low temperatures (less than 8°C) will probably keep post-harvest discoloration to a minimum. Even short periods at ambient temperatures may be sufficient to cause considerable browning. In addition, as roots expand they become tougher and more porous but PPO activity and phenol levels are not affected. Delaying harvest until after this toughening may reduce the incidence of browning since more mature roots (over 50 g) are tougher and have more extensive air spaces (as a result, tissue from mature roots can deform more readily under an impact without fracturing). Baby parsnips (having weaker tissue and lower porosity) may be particularly prone to browning.

A test has been developed which allows root browning potential to be evaluated (extent of discoloration following a standard injury). This test involves incubating slices

of root tissue in contact with an agar plate containing buffered catechol/proline. This test will allow the influence of growing and environmental conditions on browning to be assessed in the field or packhouse.

This work has shown that PPO activity and phenol levels are unaffected by plant age but parsnip tissue gets tougher and more porous as it expands (and may be more able to withstand impacts). Minimising handling damage, growing roots on fine, well-drained soils and lifting during the coolest part of the day may reduce wastage as a result of browning, lower staff costs, improve quality and profitability.

Experimental Section

Introduction

Skin finish/colour is a major quality attribute in parsnips (Toivonen, 1992). Processes leading to discoloration are a serious limitation to sales. Whilst some effort has been devoted towards evaluating the potential of various fungicides against black and orange/brown canker (fungal disorders which cause sunken lesions to appear around the crown of affected roots; Cerkauskas and McGarvey, 1988), little attention has been focused on the problem of postharvest discoloration/browning. This disorder is characterised by a yellowing of tissue exposed to the atmosphere, especially if damage has been inflicted during harvesting. Wastage as a result of browning may exceed 20% (McGarry, unpublished observations). There is one report that the degree of discoloration after handling is affected by cultivar and soil type, with abrasive or heavy/stony soils inducing more damage and postharvest browning than peat soils (Kaldy *et al*, 1976).

Browning or discoloration in most horticultural products involves the oxidation

of phenolic compounds in the presence of atmospheric oxygen by PPO (Mayer, 1987). It is suggested that in undamaged cells, the phenols and enzyme are located in different cellular compartments and so are unable to react (Mueller and Mondy, 1977). However, following membrane damage, phenols can be oxidized via a range of coloured intermediates to melanin (Matheis, 1987). Cell wall damage does not appear to be necessary to induce browning (Reeve, 1968; Ilker *et al*, 1977).

Some Canadian workers have used a colormeter to measure the whiteness of parsnip tissue after homogenization (Chubey and Dorrell, 1972). These workers found that potential browning was greatest in the sub-surface tissue (1.5 - 3.0 mm from the surface), that chlorogenic acid was the preferred substrate (although present at very low levels throughout the root and, as a result, it is unlikely to play a major part in tissue browning) and that the concentration of phenols was lowest in the skin and highest in the core although the latter showed virtually no browning after injury. Toivonen (1992) extended this work by comparing discoloration in cultivars reported to have different susceptibilities to browning and measuring the leakage of cell contents following a standard injury (abrading roots with a stiff brush). Toivonen (1992) found that cultivar had no affect on browning potential but that the browning-susceptible cv Cobham Improved Marrow showed greater solute leakage after injury than the more resistant cv White Spear. Further, he found that post-harvest dips of antioxidants such as vitamin C and calcium chloride reduced browning in only one cultivar out of four tested. On the basis of these observations, Toivonen (1992) suggested that cv Cobham Improved Marrow tissue was weaker (less resistant to damage) than tissue of cv White Spear.

Recent work at HRI Wellesbourne has developed a number of mechanical tests

to measure the strength and toughness of plant materials (FV46a 'Cellular basis of tissue strength in carrot storage roots'). These tests were used to measure the mechanical properties of cvs Cobham Improved Marrow and White Spear. In addition, a method for measuring parsnips PPO activity was developed and the reaction has been partially characterized.

Materials and Methods

Plant materials

Seeds of the cultivars Cobham Improved Marrow (Tozer Seeds) and White Spear (Breeders Seeds) were sown in Levington's compost in 30 cm diameter pots. Plants were watered daily. Seedlings were thinned to 12 per pot at the four true leaf stage. Random samples (15 for each cultivar) were taken through the experiment.

Physical properties

Porosity

The air space fraction (porosity) was estimated using the method of Jensen, Luxmore, van Grundy and Stolzy (1969). A core of tissue was removed from the outer flesh (less than 10 mm from the skin) and weighed (W_R). A pycnometer bottle was filled with water and weighed (W_W). The tissue was placed in the bottle filled with water and weighed (W_{W+R}). Finally, the tissue was disrupted with a homogenizer, placed in the pycnometer bottle and weighed (W_H). The porosity of the tissue was then calculated with the formula,

$\%\ porosity = 100\ (W_H - W_{R+W})/(W_W + W_R - W_{R+W})$.

Fracture toughness

Blocks of tissue measuring 5 x 3 x 5 mm were removed from the outer flesh. Specimens were positioned with the flesh adjacent to the skin uppermost on the testing stage of an Instron universal testing instrument fitted with a 100 N static load cell. Longitudinal fracture toughness was estimated by driving a 30° wedge into a free-standing block of tissue at a rate of 1 mm min^{-1}. Initially the wedge cuts its way through the tissue but later, as the wedge penetrates further, the sides of the specimen are bent outwards storing strain energy in the process. When sufficient strain has accumulated, energy is fed into the tip of the crack which starts to propagate ahead of, but parallel with, the wedge tip. It is possible to estimate fracture toughness (the energy required to create new fracture plane) from this part of the test.

Tensile strength

Strips of tissue (25 x 2 x 2 mm) were isolated from the skin or outer flesh (less than 3 mm from the skin) and superglued onto card templates (to give an effective specimen length of 17.5 mm). Each specimen was edge-notched to a depth of 1 mm at the mid-point and extended at a rate of 1 mm min^{-1}. Tensile strength is defined as the force at failure/effective specimen cross-sectional area (2 mm^2 in this case). Specimens not failing at the notch were discarded.

Tissue colour/biochemistry

Tissue colour

Samples of 15 roots of each cultivar were harvested 191 d after sowing, rinsed briefly and sealed in polythene bags until required. A transverse cut was made across each root, *ca.* 50 mm from the crown. The colour of the cut flesh was measured in each

root using a tristimulus Hunter reflectance colormeter. The meter gives three readings for each specimen,

'L': Lightness (0 = black, 100 = white),

'a': red (positive values) to green (negative values), and

'b': yellow (positive values) to blue (negative values).

Six random readings were taken for each root at intervals up to 6 h. Between colour measurements, the roots were sealed in polythene bags.

Biochemistry

Polyphenol oxidase activity

The method used to assay PPO activity was modified after Burton, Love and Smith (1993). 8 g of tissue was removed from either the skin (outer 1.5 mm) or flesh (1.5 - 3.0 mm from the surface), ground under liquid nitrogen and homogenized in 32 ml of 100 mM sodium phosphate buffer (pH 8). Extracts were centrifuged at 35 000 g for 20 min at 4°C. PPO activity was assayed spectrophotometrically using 10 mM catechol/proline in 100 mM sodium phosphate buffer (pH 7) at 20°C by measuring the initial slope of increase in absorbance at 525 nm.

Incubating slices of root tissue on agar plates containing buffered catechol-proline for 20 min enabled browning potential to be evaluated and the site of maximum discoloration within the root to be identified.

Substrate specificity

PPO activity was assayed spectrophotometrically at 20°C using 10 mM catechol/proline, L-3,4 dihydroxyphenylalanine (DOPA) or chlorogenic acid in 100 mM sodium phosphate buffer (pH 7).

Effect of pH

The effect of pH on PPO activity was evaluated over the range pH 5.0 - 10.0. The effect of pH on non-enzymic oxidation was measured using buffered catechol/proline (*i.e.* without enzyme extract).

Measurement of soluble phenols

Skin or flesh tissue was freeze-dried, ground to a fine powder using a rotary mill and stored in a desiccator until required. Soluble phenols were extracted by shaking freeze-dried samples in 80% (v/v) ethanol at 75°C for 30 min. After filtering, phenol levels were determined by the Folin-Ciocalteu's method using gallic acid as the standard (Singleton and Rossi, 1965; Burton *et al*, 1993).

Substrate activation

Samples of skin or flesh tissue were sliced in a food processor for 0.5 min and incubated at 20°C for up to 48 h. Soluble phenols were measured as described above.

Results

Scanning electron microscopic studies have shown that parsnip flesh contains numerous and extensive air spaces (over 1 mm in diameter). These air spaces are most abundant immediately below the skin (Fig. 1). As root growth continues, mean tissue porosity increases from 12.7% at 101 d to 21.5% at 144 d (s.e.d. = 0.047). By 185 d, porosity is significantly higher in roots of cv White Spear than cv Cobham Improved Marrow (23.3 and 19.4% respectively, s.e.d. = 1.28).

There was no significant difference in toughness between cultivars until 185 d

(Table 1). Thereafter, toughness was highest in Cobham Improved Marrow tissue. Both cultivars showed tissue toughening between 122 and 144 d.

The tensile strength of the skin tissue was unaffected by cultivar or plant age (Table 2). Flesh tissue became weaker after 144 d. Initially there was no difference between the strength of skin and flesh tissue. By 144 d, however, the skin was significantly stronger than the flesh (Table 2; s.e.d. for comparing cultivar means at 144 d were 0.051 and 0.052 for White Spear and Cobham Improved Marrow respectively). Flesh tensile strength and porosity were negatively correlated at all harvests (r^2 = -0.63 to -0.97).

Initially flesh whiteness was highest in White Spear roots (mean 'L' values at 0 h were 82.9 and 81.6 for White Spear and Cobham Improved Marrow respectively, s.e.d. = 0.49; Fig. 3). Thereafter, whiteness declined most rapidly in Cobham Improved Marrow tissue. By 60 min after cutting, Cobham Improved Marrow roots had the highest 'a' values (*i.e.* the roots of this cultivar were more red than roots of White Spear). In both cultivars, 'a' values increased between 120 and 240 min and decreased between 240 and 360 min (s.e.d. = 0.25). This may indicate the formation and subsequent conversion of a red intermediate (probably a conjugated quinone) 2 to 6 h after cutting. 'b' values increased up to 360 min. By 60 min, 'b' values were significantly higher in Cobham Improved Marrow roots (s.e.d. for comparing cultivar means = 0.39).

Skin PPO activity was unaffected by plant age (Table 3). The skin tissue of White Spear roots had the highest PPO activity across all harvests. Flesh PPO was highest in Cobham Improved Marrow. Parsnip PPO was able to utilize catechol/proline or DOPA but not chlorogenic acid as substrate. Activity was over 5 times greater with

catechol/proline than DOPA (Fig.4). PPO activity increased with rising pH (Fig. 5). However, at pH values above 7.5, a significant proportion of this apparent activity was due to the non-enzymic oxidation of catechol/proline. For this reason, PPO activity was measured at pH 7. Incubating slices of root tissue with buffered catechol/proline immobilised in agar showed that in both cultivars discoloration was limited to the flesh, the core remaining white. In cv Cobham Improved Marrow the discoloration was more widespread but patches of flesh tissue remained unreacted. Roots of cv White Spear showed less browning.

The skin contained more soluble phenols than the flesh (Table 4). Phenol concentration reached a peak at 144 d then declined. The level of phenols was higher in the cv White Spear than Cobham Improved Marrow. Following mechanical damage there was a decline in the concentration of soluble phenols between 0 and 2 h, followed by an increase after 8 h (Fig. 6; s.e.d. for comparing phenol levels at different times = 0.13).

Conclusions

Freshly-cut cv White Spear roots were whiter than roots of cv Cobham Improved Marrow (Fig. 3). Thereafter, the latter browned more readily. This is in disagreement with Toivonen (1992) who found that the browning potential of these two cultivars was the same. However, it is possible that cutting and homogenization induces a different set of biochemical events in parsnip tissues as they do in potato tubers (McGarry, Hole, Drew and Parsons, submitted). Roots of cv Cobham Improved Marrow had the highest redness ('a') values between 2 and 6 h after cutting. It is probable that this cultivar accumulates more red intermediates (conjugated quinones) than cv White

Spear during this period.

On the basis of greater solute leakage in cv Cobham Improved Marrow tissue, Toivonen (1992) suggested that this cultivar was structurally weaker (less resistant to damage) than cv White Spear. The fracture tests used in the current study found that cv Cobham Improved Marrow was tougher than cv White Spear. However, these tests induce tissue fracture by cell wall breakage and so may not be best suited to studies on tissue browning in parsnips. Cell wall damage does not appear to be necessary to induce bruising in potatoes, a loss of membrane integrity appears to be adequate (Reeve, 1968; Ilker *et al*, 1977). As a result, membrane integrity may be the most important factor in determining resistance to browning. It is probable that leakage through membranes is greater in cv Cobham Improved Marrow than cv White Spear. This difference in integrity is probably due to a differences in the degree of fatty acid saturation (Spychalla and Desborough, 1990). Lower whiteness ('L') values in cv Cobham Improved Marrow may be partly explained by differences in tissue porosity. Cobham Improved Marrow tissue was less porous and so had more cellular (reactive) material per unit area.

This work has demonstrated that parsnip PPO preferentially uses proline/catechol as substrate, is unable to oxidize chlorogenic acid and has a pH optimum of 7.0. This disagrees with Chubey and Dorrell (1972) who reported that chlorogenic acid was the preferred substrate and that parsnip PPO had pH optimum of 4.4 and 5.2 (they measured PPO activity at the higher pH). This discrepancy may be due to the fact that Chubey and Dorrell (1972) used a different cultivar (Hollow Crown) and, more importantly, a different method of enzyme extraction/assay (for instance, they used a sub-optimal pH and citrate-phosphate buffer. The latter may

interfere with PPO activity; K.S. Burton, personal communication). In agreement with Chubey and Dorrell (1972), activity was higher in the skin (outer 1.5 mm) than the flesh (1.5 - 3.0 mm from the surface). PPO activity was higher in the flesh of cv Cobham Improved Marrow than cv White Spear. This may account for the greater browning in cut cv Cobham Improved Marrow tissue. Reacting slices of tissue with buffered catechol/proline in agar showed that the extent of browning was greater in cv Cobham Improved Marrow than cv White Spear. In part this difference was due to the higher levels of soluble phenols in the flesh of cv Cobham Improved Marrow.

Undamaged skin tissue contained *ca.* 1.8 μg gallic acid equivalents mg^{-1} dry weight. This value is in broad agreement with the values quoted by Craft and Audia (1962) using a different extraction procedure (these authors found concentrations of *ca.* 3.0 μg mg^{-1} dry weight in parsnip skin). Phenols were most abundant in the skin but there was no consistent difference between cultivars. It is possible, however, that parsnip PPO is unable to use all the phenols measured using the Folin-Ciocalteu test and that cv Cobham Improved Marrow contains more utilizable phenols than cv White Spear.

After mechanical damage, phenols are activated, beginning 8 h after cutting/ It is not clear whether this is due to the synthesis of new phenolic compounds or whether phenolic precursors are activated following damage.

Parsnips skin tissue contains the highest concentration of phenols and has the highest PPO activity. Mechanical damage increases the availability of potential substrates. Cultivar differences in flesh browning can be explained by differences in PPO activity and possibly membrane integrity. Cobham Improved Marrow tissue is tougher than cv White Spear tissue.

Future work needs to establish substrate specificity and to quantify the relative abundance of the different phenols. In addition, the role of environmental and agronomic factors (such as, soil type and irrigation scheduling) on PPO activity, substrate activation and solute leakage needs to be established.

Glossary

Strength	The force needed to break an object
Toughness	Resistance to fracture
Membrane	Thin sheets of fat-protein that divide cells into discrete compartments
Enzyme activity	The rate at which an enzyme converts substrate into product
Porosity	Air space volume fraction
pH	A quantitative expression of acidity-alkalinity (less than 7 is acid, more than 7 is alkaline. pH 7 is neutral)

References

Burton, K.S., Love, M.E. and Smith, J.F. (1993). Biochemical changes associated with mushroom quality in *Agaricus* spp. *Enzyme Microbial Technology* **15**: 1-6.

Cerkauskas, R.F. and McGarvey, B.D. (1988). Fungicidal control of phoma canker in parsnip. *Canadian Journal of Plant Pathology* **10**: 252-258.

Chubey, B.B. and Dorrell, D.G. (1972). Enzymatic browning of stored parsnip roots.

Journal of the American Society of Horticultural Science **97**: 107-109.

Craft, C.C. and Audia, W.V. (1962). Phenolic substances associated with wound-barrier formation in vegetables. *Botanical Gazette* **123**: 211-219.

Ilker, R., Spurr, A.R. and Timm, H.,1977. Ethylene pretreatment and blackspot of potato tubers, *Solanum tuberosum*: Histochemistry and histology of wound healing. *Zeitschrift Pflanzenphysiologie Bd.* **83s**: 55-68.

Jensen, C.R., Luxmore, R.J., van Grundy, S.D. and Stolzy, L.H. (1969). Root air space measurements by a pycnometer method. *Agronomy Journal* **61**: 474-475.

Kaldy, M.S., Dormaar, J.F., Molnar, S.A. and Ragan, P. (1976). Browning of parsnips as related to varieties, soil conditions and length of storage. *55th Annual Report of the Canadian Horticultural Council* pp 100-102.

Matheis, G., 1987. Polyphenol oxidase and enzymatic browning of potatoes (*Solanum tuberosum*). I. Properties of potato polyphenol oxidase. *Chemie Mikrobiologie Technologie Lebensmittel* **11**: 5-12.

McGarry, A., Hole, C.C., Drew, R.L.K. and Parsons, N. Bruising damage in potatoes;a review. Submitted to *Postharvest Biology and Technology*.

Mayer, A.M. (1987). Polyphenol oxidases in plants-recent progress. *Phytochemistry*

26 11-20.

Mueller, T.O. and Mondy, N.I., 1977. Effect of sprout inhibition on the lipid composition of potatoes. *Journal of Food Science* 42: 618-621.

Reeve, R.M., 1968. Preliminary histological observation on internal blackspot in potatoes. *American Potato Journa*l 45: 157-161.

Singleton, V.L. and Rossi, J.A. (1965). Colorimetry of total phenolics with phopshomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture 16*: 144-158.

Spychalla, J.P and Desborough, S.L. (1990). Fatty acids, membrane permeability and sugars of stored potato tubers. *Plant Physiology* **64**: 1207-121.

Toivonen, P.M.A. (1992). The reduction of browning in parsnips. J*ournal of Horticultural Science* **67**: 547-551.

Appendix (figures and tables)

FIGURE 1

Scanning electron micrograph showing air spaces in beneath the skin of a cv White Spear root

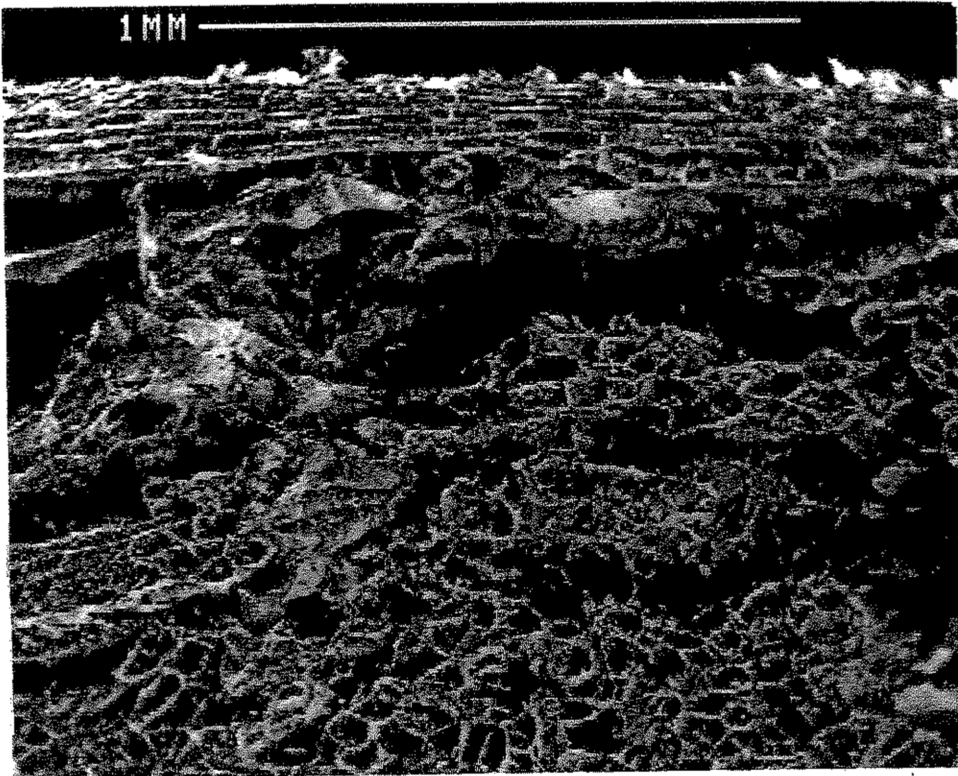

FIGURE 2

Effect of plant age and cultivar on porosity of flesh tissue (● Cobham Improved Marrow, ○ White Spear). Standard deviations shown.

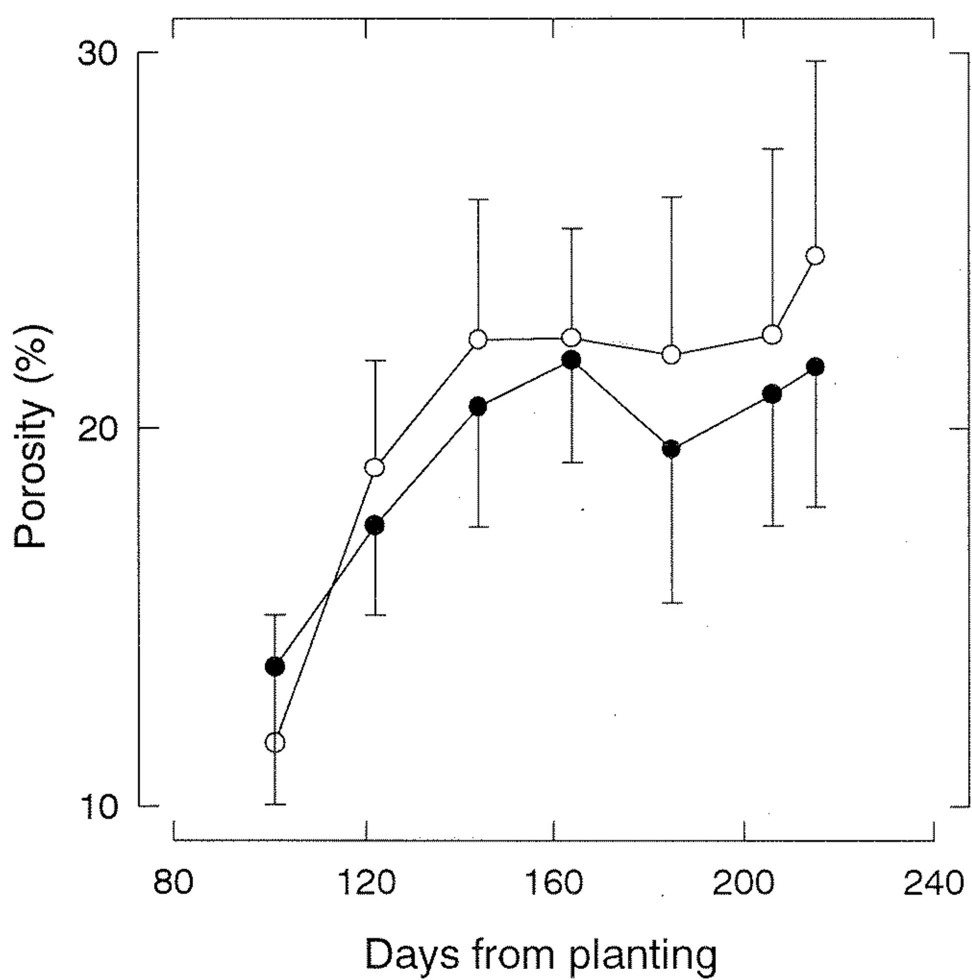

FIGURE 3

Changes in tissue colour in cut parsnip roots (● Cobham Improved Marrow, ○ White Spear). Standard deviations shown. 'L' = lightness, 'a' = red-green balance, 'b' = yellow-blue balance

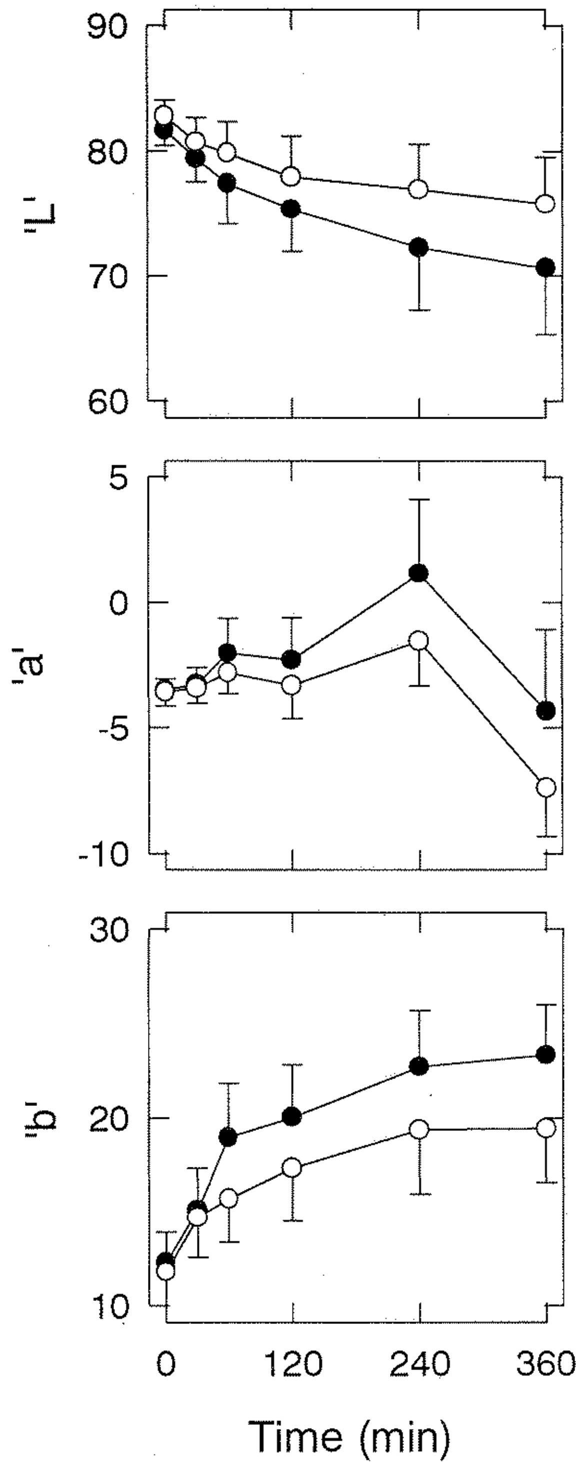

FIGURE 4

Relative PPO activity (μmols min^{-1}) using catechol/proline (●) and DOPA (○) as substrate at pH 7

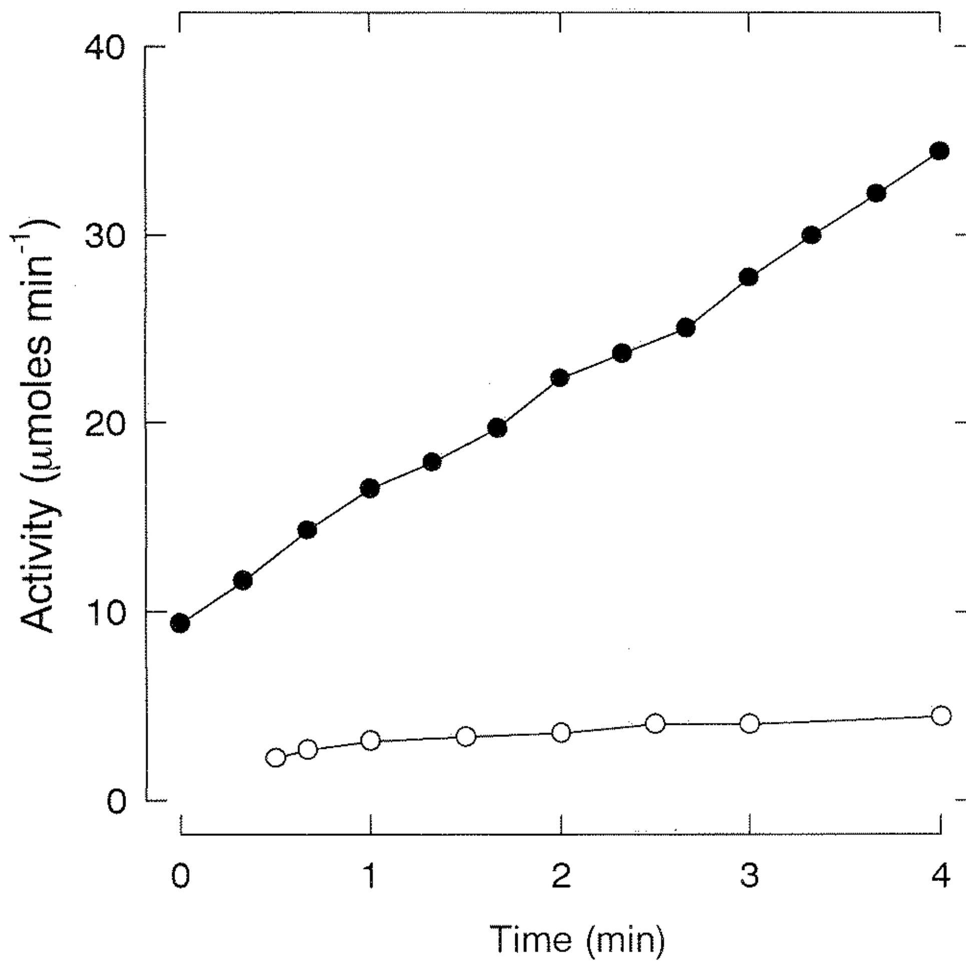

FIGURE 5

Effect of pH on enzymic (●) and non-enzymic (○) oxidation (μmols min^{-1}) of proline/catechol

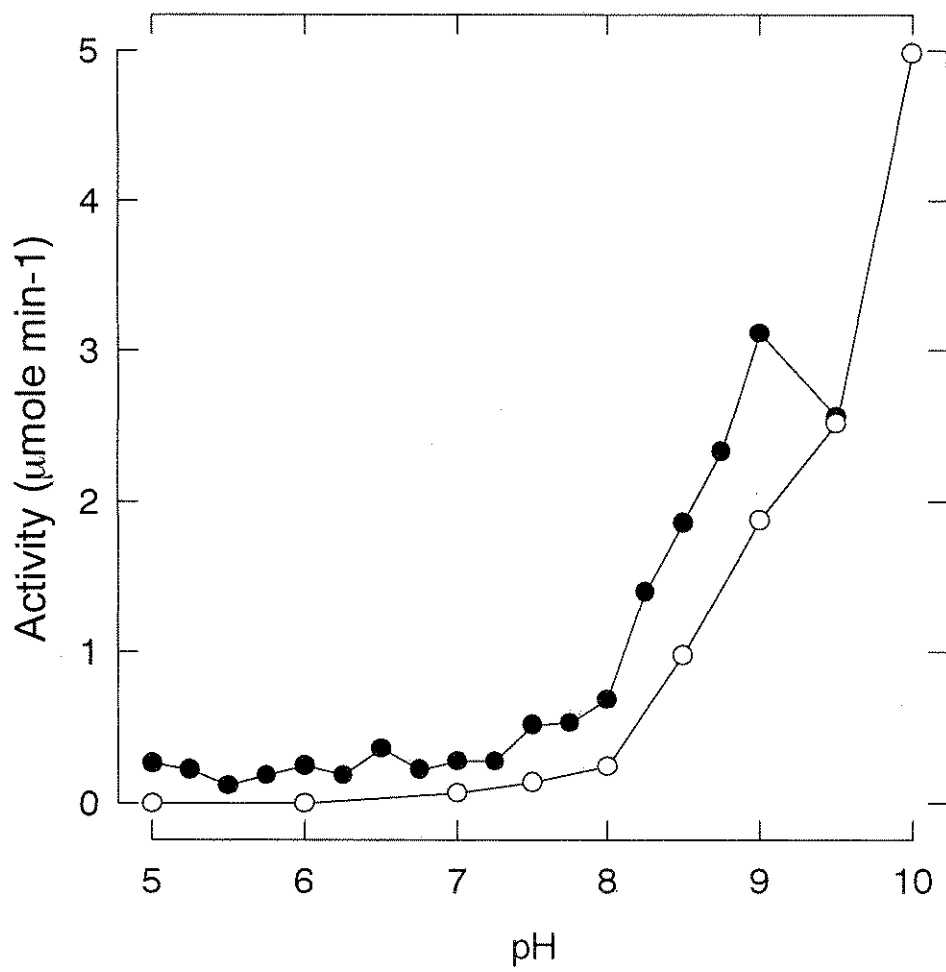

FIGURE 6

Phenol activation in sliced (a) skin and (b) flesh parsnip tissue (● Cobham Improved Marrow, ○ White Spear). Standard deviations shown.

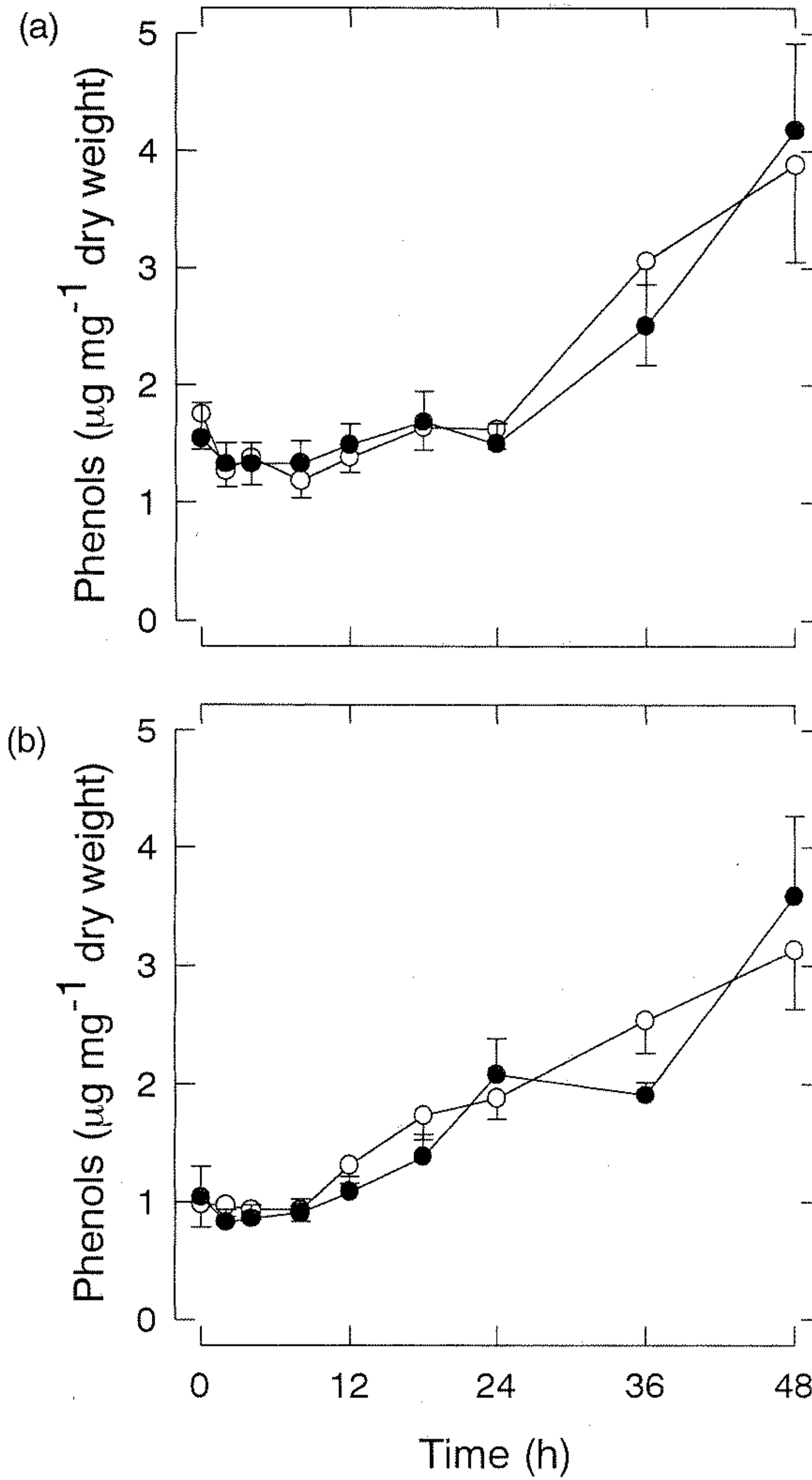

TABLE 1
Effect of plant age and cultivar on parsnip flesh fracture toughness (J m^{-2})

Plant age (d)	White Spear	Cobham Improved Marrow	Mean
101	230	244	237
122	256	200	228
144	572	571	571
164	435	515	495
185	429	561	486
206	397	575	486
215	491	533	512
Mean	402	457	429

s.e.d. for comparing,
cultivar means = 22.1 (105 degrees of freedom)
harvest means = 41.3 (30 d.f.)
cultivar.harvest means = 58.5 (15 d.f.)

TABLE 2
Effect of plant age and cultivar on the tensile strength (in MPa) of parsnip tissue

Plant age (d)	White Spear	Cobham Improved Marrow	Mean
(a) Skin			
122	0.553	0.573	0.563
144	0.659	0.719	0.689
164	0.672	0.664	0.668
185	0.549	0.676	0.612
206	0.672	0.660	0.637
215	0.615	0.555	0.585
Mean	0.611	0.641	0.626
(b) Flesh			
122	0.547	0.573	0.560
144	0.607	0.599	0.603
164	0.414	0.422	0.418
185	0.467	0.525	0.496
206	0.315	0.405	0.360
215	0.379	0.385	0.382
Mean	0.455	0.484	0.470

	Skin	Flesh	d.f.
s.e.d. for comparing,			
cultivar means	0.028	0.028	105
harvest means	0.052	0.052	30
cultivar.harvest means	0.074	0.074	15

TABLE 3

Effect of plant age and cultivar on polyphenol oxidase activity (μmols min^{-1} g^{-1} fresh weight)

Plant age (d)	White Spear	Cobham Improved Marrow	Mean
(a) Skin			
164	0.185	0.173	0.179
185	0.187	0.170	0.178
206	0.213	0.192	0.202
215	0.187	0.175	0.181
Mean	0.193	0.177	0.185
(b) Flesh			
164	0.167	0.170	0.169
185	0.112	0.135	0.123
206	0.154	0.156	0.155
215	0.146	0.156	0.151
Mean	0.145	0.155	0.150

	Skin	Flesh	d.f.
s.e.d. for comparing,			
cultivar means	0.005	0.004	105
harvest means	0.010	0.007	30
cultivar.harvest means	0.014	0.010	15

TABLE 4
Effect of plant age and cultivar on the concentration of soluble phenols ($\mu g\ mg^{-1}$ dry weight)

Plant age (d)	White Spear	Cobham Improved Marrow	Mean
(a) Skin			
122	1.35	1.71	1.53
144	3.39	2.85	3.12
164	1.67	1.56	1.61
185	1.49	1.50	1.49
206	1.30	1.26	1.28
215	1.46	1.68	1.57
Mean	1.78	1.76	1.77
(b) Flesh			
122	1.14	0.65	0.89
144	2.13	1.52	1.82
185	1.11	1.08	1.09
206	0.97	1.04	1.00
215	1.22	1.22	1.22
Mean	1.28	1.08	1.18

	Skin	Flesh	d.f.
s.e.d. for comparing,			
cultivar means	0.053	0.031	105
harvest means	0.100	0.059	30
cultivar.harvest means	0.141	0.083	15

CONTRACT

1. **TITLE OF PROJECT:**

   Reduction of browning in parsnips

2. **BACKGROUND AND COMMERCIAL OBJECTIVE:**

Since parsnips are sold whole skin quality and finish are extremely important. Discussions with UK parsnip producers have indicated that browning (localised discolouration of the superficial tissues) may affect 30-50% of a crop reducing gross returns to the grower.

Previous work (in Canada) has suggested that susceptibility to bruising is affected by cultivar and soil type (with sandy, rather than organic/loamy, soils predisposing roots to damage). At the cellular level bruising must be a consequence of localised cell wall rupture, exposing cell contents to the atmosphere and leading to the oxidation of phenolics and tissue browning. Whilst phenolics appear to be distributed uniformly throughout parsnip tissue, the enzymes responsible for their oxidation are concentrated in the superficial tissues. Resistance to bruising is likely, therefore, to be determined by a combination of cell wall strength, cell packing and tissue turgor in these superficial tissues. Work at Wellesbourne has already demonstrated that small reductions in carrot storage root turgor can result in increased damage resistance.

The objective of the proposed work would be to develop a laboratory method for routinely inducing bruising, to establish the relationship between root water relations and spontaneous/induced bruising in an attempt to evaluate the feasibility of agronomically manipulating parsnip root turgor as a means of reducing bruising

damage.

3 POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY:

Parsnip bruising is a man-made problem, resulting from the browning of superficial injuries inflicted during or after harvest. Whilst precise figures on the incidence of bruising are not available, discussions with growers have indicated that losses may reach 30-50% during particular stages of the season. In addition to the direct loss incurred by damaged roots there remains the task of manually removing affected roots from the line in the packhouse.

A manipulation of root moisture content could render the product more amenable to conventional handling procedures, reduce wastage and improve packhouse efficiency.

4 SCIENTIFIC/TECHNICAL TARGET OF THE WORK:

Preliminary work at HRI Wellesbourne has shown that in carrot storage roots tissue strength (resistance to damage) is largely determined by root water relations, cell wall thickness/strength and cell packing. Since bruising involves localised cell wall rupture, the same factors are likely to influence the mechanical properties of parsnips. The proposed work would attempt to evaluate the influence of water relations on the incidence of bruising in a range of cultivars and assess the feasibility of reducing bruising by lowering root turgor prior to harvest.

5 CLOSELY RELATED WORK COMPLETED OR IN PROGRESS:

Parsnip agronomy and physiology have been largely ignored in the UK but studies conducted in Canada suggest that both cultivar and soil type influence the incidence of bruising. Although all the parsnip varieties tested appeared to have the same potential for browning (*i.e.* there was no difference in either phenolic concentration or enzyme activity), differences in tissue deterioration after injury were detected. Attempts to reduce bruising have involved the application of postharvest dips (containing combinations of calcium chloride, ascorbic acid and citric acid), but this approach has met with only very limited success. Further, given the cost involved and the public's reluctance to accept any additional chemical treatments to food materials, such a treatment is unlikely to prove politically or economically feasible. A more cost-effective and acceptable method would be to assess the influence of turgor on parsnip tissue strength with a view to minimising bruising by small reductions in root moisture content prior to harvest. This work would be supported and underpinned by more fundamental studies on the nature of storage root strength (under the Agro Food Quality LINK project C219 "Cellular basis of tissue strength in carrot storage roots").

6 DESCRIPTION OF THE WORK:

A range of parsnip cultivars showing differing bruise susceptibility will be grown at Wellesbourne under polythene (to protect the crop from rainfall) and at a range of soil water potentials. In addition, roots subjected to different agronomic treatments will be supplied by one or more commercial growers. Initially these cultivars will be compared in terms of root water relations (determined by psychrometry) and anatomy (in particular, cell packing and the ratio of cell wall to tissue volume will be measured using scanning electron microscopic techniques) with a view to establishing

the mechanism of bruise susceptibility/resistance. Subsequent work will evaluate the influence of withholding irrigation (to reduce cell and tissue turgor) prior to harvest on the incidence of spontaneous bruising. Further a test will be devised to induce bruising (for instance, repeatedly compressing whole parsnips using a serrated plate fitted to an Instron Universal testing instrument) and used to evaluate the influence of root turgor on resistance to bruising (bruising will be assessed by measuring the absorbance of tissue extracts using a spectrophotometer). At the end of these studies the feasibility of achieving an agronomic reduction of bruising will be assessed.

7 **DURATION/START DATE:**

One year in the first instance beginning March 1993.

8 **STAFF RESPONSIBILITIES:**

Project leader would be Dr A. McGarry (Annual Crops Department).

9 **LOCATION:**

HRI,Wellesbourne.

10 **COSTS:**

FIGURE 1

Scanning electron micrograph showing air spaces in beneath the skin of a cv White Spear root