Extending root shelf-life during marketing by cultivar selection

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5.1 Introduction

5.1.1 The constraints imposed on sweetpotato marketing by short shelf-life

Sweetpotato storage roots can be stored under controlled environments for several months. For example, in the USA, when roots are stored at temperatures of 13–15 ºC and high relative humidity, they can be kept for up to a year (Picha, 1986). The use of temperature-controlled storage of sweetpotatoes is usually not economically feasible in tropical developing countries. However, even in the absence of temperature control, storage for 3–4 months has been demonstrated, where roots are selected carefully and stored in traditional pits or clamps in which high humidity is naturally maintained (Hall and Devereau, 2000; van Oirschot *et al.*, 2000). The potential for long-term storage of sweetpotato and the behaviour of different cultivars under long-term storage conditions will be considered in Chapter 7.

During marketing under tropical conditions, sweetpotato roots have a much shorter shelf-life of only 2–3 weeks (Kapinga *et al.*, 1997; Rees *et al.*, 2001). The reason for this is that during marketing, for practical reasons, the conditions under which roots are kept are non-ideal. During transport, roots will be subjected to mechanical damage, temperatures may be

very high, and generally humidity is low so that roots dry out. Several surveys conducted in East Africa have highlighted the problems of such a short shelf-life. These included surveys conducted both by NRI and the

Tanzanian National Root and Tuber Crops Programme (e.g. Fowler and Stabrawa, 1993; Kapinga *et al.,* 1995). Precise economic losses have not been quantified, although it has been estimated that post-harvest losses of sweetpotato can range from 35% to 95% in developing countries. Such high figures require confirmation. Informal surveys, however, indicated that the marketing system is limited by the assumption that roots can remain in the market for a maximum of 3 days (R. Bancroft, personal communication).

5.1.2 The effect of mechanical damage on root shelf-life

Mechanical damage during post-harvest handling is detrimental to the shelf-life of fresh produce (Wills *et al.,* 1998), as the damaged areas form an avenue for moisture loss and an entrance for micro-organisms. Damage to sweetpotato is inevitable during handling and harvesting. This is certainly the case in East Africa where sweetpotatoes are often transported large distances over rough roads. In East Africa, sweetpotatoes are traditionally packed in large woven polypropylene sacks, each weighing between 100 kg and 140 kg. During transport, the roots are exposed to many minor impacts due to movement of the sacks on the vehicle, which result in skinning injury. The sacks are often dropped resulting in large impacts, causing the roots to break (Tomlins *et al.,* 2000). Susceptibility to damage has been shown to be variety-dependent in potatoes (*Solanum tubersosum*) (Blight and Hamilton, 1974) but, prior to these studies, little was known about sweetpotato cultivar differences in susceptibility to damage.

5.1.3 Shelf-life vs. long-term storability

Characteristics which give a root a long shelf-life during marketing are not necessarily the same as characteristics which make a root more suitable for long-term storage. For example, roots for long-term storage are not transported long distances, and are usually handled carefully, so that a cultivar which is susceptible to mechanical damage may be suitable for long-term storage, even though it would be unsuitable for marketing. Therefore, in order to avoid confusion, within this book we distinguish between ‘shelf-life’, which is used to describe keeping qualities under marketing conditions and ‘storability’, which is used to describe keeping qualities within long-term stores.

- Shelf-life = keeping qualities under marketing conditions
- Storability = keeping qualities within long-term stores

5.1.4 Objectives

Practically, an extension of shelf-life could be achieved by two strategies: improving handling techniques, or the introduction and promotion of cultivars with better keeping qualities. The first approach is often constrained by socio-economic factors outside the control of research and extension officers, whereas the introduction of improved cultivars causes minimal extra expense to farmers and traders. In this chapter, we describe a series of studies which were carried out to examine the potential for breeding for extended shelf-life. The specific objectives of these studies were:

- to determine the main forms of deterioration for sweetpotato roots during marketing
- to determine the extent to which sweetpotato cultivars vary in susceptibility to damage
- to determine the extent to which sweetpotato cultivars vary in their intrinsic perishability and the physiological factors that control root perishability
- to determine whether it is possible to breed for cultivars with longer shelf-life.

5.2 Methods

5.2.1 Assessing deterioration of roots in markets of Tanzania

A survey was carried out in 1996 and 1997 to assess the extent and type of damage to sweetpotatoes when they arrive at market, to assess the economic implications of damage, and to establish the most serious forms of damage affecting shelf-life.

Observations were made during months of peak and low supply in Dar es Salaam, Morogoro and Mwanza, and also on Ukerewe Island, a sweetpotato supply area. Further details are given below.

5.2.2 Storage trials to compare the shelf-life of a range of cultivars under simulated marketing conditions

Two things are desirable for breeding improved sweetpotato cultivars with extended shelf-life to be possible. Firstly, there should exist a sufficient range in shelf-life among existing germplasm, which is relatively stable across environments. Secondly, methods should be identified for selecting cultivars with better storability.

Trials were conducted on-station in Tanzania in 1997 and 1998 to assess a range of cultivars for their shelf-life under simulated marketing conditions. A range of other root characteristics were also examined, including dry matter content, sugar content, respiration rate, surface damage by rough weevil (*Blosyrus* spp.), latex production, cortex thickness and tissue hardness to obtain information on the physiological basis for cultivar differences. Further details are given below.

Survey Methods for Assessing Root Deterioration in Markets

For each urban centre, samples of wholesale sweetpotatoes were collected twice in each of the high and low seasons of sweetpotato supply (Table 5.1). For each sampling, three sacks of roots were bought as they arrived at the market, prior to any sorting by traders (for Mwanza, high season 1, only two sacks were bought). Each sack was treated as a separate replicate throughout the experiment. The roots in each sack were sorted into undamaged, superficial damage (scuffing) only, and more serious damage. The latter category was further classified as broken, cut, weevil (*Cylas* spp.) infested or rotting. Many roots suffered from more than one form of damage, but each was classified on the most obvious form. Where there was doubt as to which form of damage to use, classification was in the order: rotting, *Cylas* infested, broken and cut (determined by the seriousness of the damage in economic terms). The weight of roots in each class was recorded for each sack.

For each damage category, 15 roots were selected from each sack, and placed into separate sacks (clean polypropylene fertilizer bags) for storage. For categories with fewer than 15 roots, as many as possible were included. During storage, the sacks were kept open (rolled down to half height), in a well ventilated room. The extent of root deterioration was assessed weekly in terms of rotting and loss of fresh weight.

Rotting was scored on the extent observed on the external surface: 1 = 0%; 2 = 1–25%; 3 = 26–50%; 4 = 51–75%; 5 = 76–100%. After each assessment, those roots that scored 4 or 5 were discarded. In subsequent weeks, the previously discarded roots were still included with a score of 5 when the overall mean score was calculated.

Fresh weight loss was assessed by marking six random roots in each sack at the start of the trial and recording their weights weekly. Where roots were discarded due to rotting, only the remaining roots were considered when calculating the mean percentage weight loss.

Table 5.1 Markets and sampling seasons used for the survey of sweetpotato damage in the markets of Tanzania

Location	Season	Time of sampling	Markets sampled	Main supply area (distance and means of transport)	Main cultivar
Dar es Salaam	High 1	Late June 1996	Tandale	Gairo (350 km by road)	Kasimama
	High 2	Late August 1996		Bagamoyo (75 km by road) Kigambone (<50 km by sea)	Kasimama Kanada
	Low 1	January 1997		Zanzibar (100 km by sea)	Name unknown
	Low 2	April 1997		Zanzibar (100 km by sea)	Name unknown
Morogoro	High 1	June 1996	Central (2 sacks) Saba saba (1 sack)	Gairo (150 km by road)	Kasimama
	High 2	July 1996		Gairo (150 km by road)	Kasimama
	Low 1	November 1996		Ifakara (250 km by road)	Chanzuru
	Low 2	December 1996		Ifakara (250 km by road)	Chanzuru
Mwanza	High 1	April 1996	Kirumba	L. Victoria Islands (100 km by boat)	Sinia B
	High 2	May 1996		Various (by boat and road)	Mixed
	Low 1	February 1997		Various (by boat and road)	Mixed
	Low 2	March 1997		Various (by boat and road)	Mixed
Ukerewe Island		April 1996	Ukerewe Central, Ukerewe Soko Mshenzi	Local supplies Transported short distances by various means	Sinia B

Storage Trial Methods

Growth of roots

The trials were conducted at the Lake Zone Agricultural Research and Development Institute (LZARDI), Ukiriguru. Storage roots were obtained from two sets of cultivars grown in two field trials: Trial 1 (9/10 cultivars) and Trial 2 (22 cultivars) grown in consecutive years; 1997 and 1998. Cultivars (see Table 5.2) were selected from local landraces, new crosses and introduced germplasm to provide a wide range of root characteristics, but included only cultivars known to give reasonable yields. Two cultivars (SPN/0 and Mwanamonde) were common to both trials. For Trial 1, cultivar Sinia A was only included in the second year. For Trial 2, cultivar 440121(Naeshirazu) was replaced in the second year by cultivar 440144.

The trials for the first year were planted in the wet season on 28 December 1996, with planting of extra cuttings on 17 January due to poor establishment as a result of subsequent drought. Trials for the second year were also planted during the wet season, on 15 and 16 December 1997. Trials were harvested on 23 June 1997 and 15 May 1998, respectively. All field trials were planted as randomized complete block designs. Trial 1 had 4 replicates with plots of 6 m x 6 rows (3 plants/m), while Trial 2 had 2 replicates with plots of 6 m x 2 rows (3 plants/m). No fertilizers or chemicals were applied, and no irrigation was used.

Storage of roots

Following harvest, roots of marketable size (greater than 2.5 cm diameter) and low levels of visible damage were selected for post-harvest evaluation. For each cultivar, roots were divided into 3 replicates (not corresponding to field replicates) with 25 roots per replicate wherever possible.

To simulate normal marketing conditions, roots were stored in a well ventilated room in woven polythene sacks (one per replicate per cultivar), which were tied closed for 2 days, to simulate closed sacks during transport, then opened and rolled down to half height for the remainder of the storage period, to simulate the situation in the market and the home (see Figure 5.1).

Temperature and humidity within the room were recorded daily throughout. In 1997, recordings were taken at midday from a wet dry bulb thermometer on the wall of the room. In 1998, readings were recorded at 2–3 hourly intervals using two Vaisala temperature/humidity probes which were suspended approximately 30 cm above the top of the sacks in the centre of the room, and attached to a Grant squirrel data-logger.

Root assessment

Dry matter content

Immediately after harvest, three roots were selected for each cultivar and assessed for dry matter content by drying in an oven for 48 h at 80 ºC.

Weight loss

For measurement of weight loss, six roots were selected at random from each sack and numbered using a permanent marker. The weight of each of these roots was recorded at the start of the trial and at weekly intervals.

Rotting

The extent of externally visible rotting for each sack was assessed at the start of the trial and at weekly intervals by sorting all the roots into six categories (0 = 0% surface showing visible rotting; 1 = 1–10%; 2 = 11–25%; 3 = 26–50%; 4 = 51–75%; 5 = 76–100%), and calculating the average root rotting score. After each assessment, those roots that scored 4 or 5 were discarded. In subsequent weeks, the previously discarded roots were still included with a score of 5 when the overall mean score was calculated. To assess internal rotting, roots were cut into quarters and the exposed surfaces scored for rotting, using the same scoring system as for external rotting.[1]

Surface insect damage

External insect damage was caused by the rough weevil (*Blosyrus* spp.), which grazes on the root surface. Damage was recorded using a 1–5 scale depending on the percentage of surface damaged (1 = 0%; 2 = 0–25%; 3 = 25–50%; 4 = 50–75%; 5 = 75–100%). This form of damage only occurs before harvest, so that damage for each sack can be calculated as the average of all roots assessed in the course of the trial (2/week).

Root hardness, cortex thickness, latex production

Hardness was measured using a hand-held penetrometer as the force required for an 8 mm probe to penetrate the tissue after a small portion of periderm had been removed. The root was cut and cortex thickness was measured in millimetres at the widest part of the root. Latex production was assessed on a freshly cut transverse surface using a subjective 1–5 scale (1 = none; 2 = low; 3 = moderate; 4 = high; 5 = very high).

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[1]In most markets, roots with any significant levels of rotting would be unmarketable. Taking this into account another appropriate method of expressing rotting would be as a percentage of roots with more than a specified percentage (e.g. 10%) of rot. The data we collected can be recalculated in this way (see Rees *et al.*, in press).

Total soluble solids of root sap
Concentration of soluble solids in root sap was measured by refractive index using a hand-held refractometer. The root sap was extracted from a portion of grated tissue using a hand-held press.

HPLC analysis for sugar content
Freeze-dried samples were ground and extracted in water (1 g sample in 20 ml water) by shaking for 1 h at room temperature. The extract was filtered through muslin and filter paper, diluted with acetonitrile to 80% acetonitrile and further filtered through a 0.45 mm PTFE syringe filter. 10 ml samples were injected on to an amino-bonded high performance liquid chromatography (HPLC) column (Hypersil APS-2, 20 cm) maintained at 30 °C, using 80% acetonitrile running at 0.6 ml/min as the mobile phase. Sugars were detected using a refractive index detector (Hewlett Packard), and peak sizes were calculated using a Perkin Elmer LCI-100 Integrator.

Table 5.2 Cultivars included in storage trials conducted at LZARDI, Ukiriguru to compare cultivar shelf-life

Trial 1	Trial 2
1. SP/93/34	1. Kagole
2. SP/93/23	2. Polista
3. SP/93/2	3. Tula Omushako
4. Iboja	4. 440088 (NC 262)
5. Mwanamonde	5. Kombegi
6. Sinia B	6. 440037 (Imby 3102)
7. SPN/0	7. 440215 (Tainmg #65)
8. Budagala	8. 440025 (Xushu 18)
9. Budagala mpya	9. 440121 (Naeshirazu)[2]
10. Sinia A[1]	10. 440113 (Beniaka)
	11. Nyamwisekeleja
	12. Bagala
	13. Bilagala
	14. Ipembe
	15. Lutambi
	16. Shinamugi
	17. Tabu Waseki
	18. TIS 8250
	19. Luganza
	20. Itemve
	21. SPN/0
	22. Mwanamonde

[1]Included in second year of trials only.
[2]Replaced in second year of trials by 440144.

Figure 5.1 Sacks used to store roots during storage trial at LZARDI, Ukiriguru

Trial Methods for Assessing Germplasm Stability

In 1997 and 1998, trials were conducted at four sites around Tanzania, in addition to LZARDI, Ukiriguru. At each site, five key Tanzanian cultivars were included, together with additional local varieties. The sites and cultivars used are given in Table 5.3 (the trial at LZARDI is Trial 1 of the previous section). The five key cultivars are shown in bold. All field trials were planted as randomized complete block designs with 4 replicates and with plots of 6 m x 6 rows (3 plants/m).

The storage trial was carried out using essentially the same methods as described in the previous section.

5.2.3 Field trials to assess stability of germplasm across environments

For the introduction of cultivars with extended shelf-life, it is important to know not only whether cultivars with improved keeping qualities exist, but also how consistent their behaviour is across differing environments. The trial detailed (see below) was conducted to examine this issue.

5.2.4 Measurement of respiration rates

During the storage trials conducted at Ukiriguru in 1997, root respiration rates were measured by placing the roots in sealed jars and measuring the rate of increase in carbon dioxide levels). Further details are given below.

Table 5.3 Cultivars included in trials conducted at five sites in Tanzania to test the stability of cultivar shelf-life

LZARDI, Ukiriguru	Sugarcane Institute	HortiTengeru	MARTI-Uyole	Chollima-Dakawa[1]
1. SP/93/34	1. **SPN/0**	1. **SPN/0**	1. **SPN/0**	1. **SPN/0**
2. SP/93/23	2. **Sinia**	2. **Sinia**	2. **Sinia**	2. **Mwanamonde**
3. SP/93/2	3. **Mwanamonde**	3. **Mwanamonde**	3. **Mwanamonde**	3. Kasimama
4. **Iboja**	4. **Iboja**	4. **Iboja**	4. **Iboja**	4. Chanzuru
5. **Mwanamonde**	5. **Budagala**	5. **Budagala**	5. **Budagala**	5. **Budagala**
6. **Sinia**	6. Ukerewe	6. Tengeru R.	6. Mpufya	6. **Iboja**
7. **SPN/0**	7. Elias		7. Masyabala	
8. **Budagala**			8. Nyekundu	
9. Budagala mpya				

[1] Sinia failed to produce any roots at Chollima-Dakawa and, therefore, was omitted.

Respiration Measurements

Measurements were made after 5–7 days of storage. For Trial 1, 6 roots per cultivar (2/storage trial replicate) were assessed (replicates 1, 2 and 3 on days 5 and 6, days 5 and 7, days 6 and 7, respectively), while for Trial 2, 3 roots per cultivar (1/storage trial replicate) were assessed (replicates 1, 2 and 3 on days 5, 6 and 7, respectively). Only roots free of rot were selected. Each root was weighed and placed into a 3.2 litre sealed glass jar, with sealable inlet and outlet. After approximately 1 h, CO_2 was measured using a Combo Gas Analyser (David Bishop Instruments Ltd, Heathfield, UK).

Calculations

Respiration rate (R) [ml/kg/h] was calculated as:

$R = \% \, CO_2 * (V_{jar} - V_{root})/100*(W_{root} * t)$

where

$\% \, CO_2 = \% \, CO_2$ generated

V_{jar} = volume of jar (3.2 litre)

V_{root} = root volume (ml) calculated from root weight assuming a density of 1 kg/l

W = root weight (kg)

T = time (h)

Root weight loss due to respiration can be calculated assuming that carbohydrates were the only respiratory substrate and, therefore, that:

1 ml CO_2 generated/h = 1.24×10^{-3} g carbohydrate metabolized/h

(This calculation relies on the following: 1 mole CO_2 occupies 22.4 l, mol wt CO_2 = 44 g, generalized chemical structure of carbohydrate is $C_6H_{12}O_6$ (mol wt 180).)

5.2.5 Measurement of water loss through wounds using a porometer

During these studies, water loss through specific areas of the root periderm was measured using an instrument called a porometer adapted to fit on to the surface of a sweetpotato root (Figure 5.2). (A porometer is designed to measure the transpiration rate through the surface of leaves.) The leaf-chamber was adapted by replacing the rectangular aperture with a round aperture 1.5 cm in diameter. The lower clamp was removed and the head was padded with soft black foam to provide a seal and avoid damage to the sweetpotato surface during the measurement.

The Porometer

A porometer consists of a chamber that can be clamped around a leaf. Air is pumped through the chamber, where it is stirred by a small fan. By measuring the relative humidity of inflowing and outflowing air, the amount of water lost through the surface can be calculated. The calculation should also take into account parameters such as the temperature, flow rate of air through the chamber, area of periderm exposed in the porometer, atmospheric pressure, and saturated water vapour pressure at the ambient temperature.

Figure 5.2 **(a) Head of the porometer with round aperture and padding; (b) taking measurements of water loss from sweetpotato roots**

5.2.6 Assessing cultivars for susceptibility to damage

The objectives of these trials were to assess the variability among sweetpotato cultivars in susceptibility to damage and to investigate the role of shape and periderm thickness. Two standardized damage treatments were developed: one which assessed a root for its susceptibility to 'scuffing' (surface abrasion), and a second, which assessed a root for its susceptibility to impact damage.

Scuffing damage treatment

A scuffing damage treatment was applied by placing 10 sweetpotato roots in a metal barrel (0.55 m x 0.38 m) which was then rolled a distance of 10 m, thus simulating the agitation in sacks during handling and transport. This method was adapted from a scuffing treatment developed by the Scottish Agricultural Research Institute to assess potatoes (Andrew Muir, personal communication).

Impact damage treatment

Impact damage was applied by dropping a sack of roots four times from a height of 1 m (Tomlins *et al*., 2000).

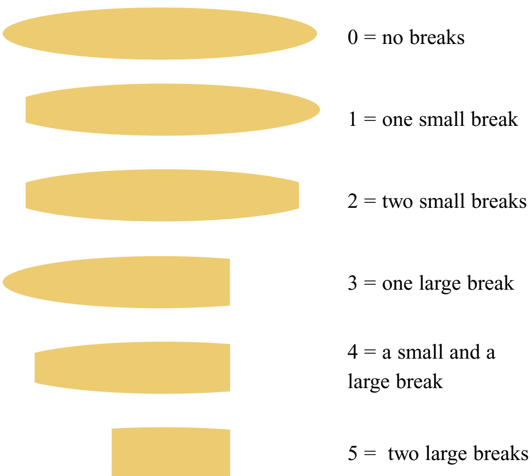

Figure 5.3 **Scoring system for assessment of breakage (from Tomlins *et al*., 2000)**

Damage assessment

Breakage was assessed using the scoring system presented in Figure 5.3. Deep wounds were defined as wounds at least 5 mm deep, and the number of deep wounds per root was recorded. Superficial damage was defined as abraded root surface 0.5–5 mm deep, containing cortex tissue as well as periderm, and was scored visually by estimating the percentage of the total abraded surface area. Skinning injury was defined as an abrasion of the periderm only and was scored by visually estimating the percentage of total abraded surface area.

Trial Design Used to Assess Cultivars for Susceptibility to Damage

Ten cultivars of sweetpotato were grown by the International Potato Center (CIP) in Nairobi, Kenya. The cultivars Yan Shu 1, Kemb 10, KSP 20, Zapallo, SPK 004, BP1-SP2, Caplina, Salyboro, Yarada and Julian were planted in a randomized complete block design in 3 replicates using 30 plants per cultivar. The roots were harvested in December 1998 using hand hoes. The roots were then transported to the National Agricultural Research Laboratory (NARL), Nairobi, washed and kept in crates until artificial damage treatments were carried out. Scuffing damage was conducted separately for 10 roots of each cultivar. Impact damage was applied on 21–23 roots per cultivar. Standardized damage treatments were repeated in two trials.

5.3 Results and discussion

5.3.1 The main forms of deterioration in sweetpotato storage roots under East African marketing conditions

After harvest, a sweetpotato root will deteriorate in quality, becoming less acceptable to users in terms of appearance, taste and texture. The shelf-life of a sweetpotato can be defined as the period of time after harvest, for which a root is saleable. There are several ways in which the quality of a root might deteriorate and these are shown in Table 5.4.

Observations of roots bought from Tanzanian markets and stored under simulated marketing conditions (see section 5.2.1), indicated that the main forms of deterioration of sweetpotatoes under normal marketing conditions in Tanzania are weight loss and rotting. The

Table 5.4 Forms of deterioration for sweetpotato storage roots

Weight loss	Roots can lose weight both by losing water, and also by metabolizing the starch reserves through the process of respiration. Under normal marketing conditions most weight loss (90%) is through water loss (Van Oirschot *et al.*, 2000; Rees *et al.*, in press). Water loss causes the root to become less attractive as it shrivels and, as described below, also appears to make the root more susceptible to rotting.
Rotting	Rotting of tissues occurs by both fungal and bacterial pathogens. When rotting starts a root quickly becomes unsaleable.
Sprouting	When a root sprouts, it will often become sweeter as starch is converted to sugar to provide energy for the growth of sprouts. The appearance of sprouts and loss of starch reduces the root value.
Loss of good taste	Many changes can occur in the root composition after harvest, which may affect the taste and texture of the cooked root.
Infestation by insects	The most important insect pest of the storage root is the sweetpotato weevil (*Cylas* spp.). Even if infestation is only slight, then the root can become completely unsaleable due to the production of bitter tasting phytoalexins as part of the defence mechanism of the root.

relative importance of these forms of deterioration depends on storage temperature, humidity, and growth conditions. Figure 5.4 shows the weight loss and rotting of roots purchased on two occasions from each of three markets. The rates of deterioration do vary, but the weight loss was higher than anticipated, 10–17% over 7 days, and 67% over 3 weeks in one case (Morogoro, low season 2). In all but one case, roots showed on average more than 50% surface rotting after 3 weeks.

In the same study, the levels of root damage in the markets, and the effect on rates of deterioration were examined. Figure 5.5 summarizes the damage observed. In almost all cases, insect infestation was due to the larvae of sweetpotato weevils (*Cylas* spp.), which burrow deep into the root, and are a serious problem worldwide (Chalfant *et al.,* 1990; Sutherland,

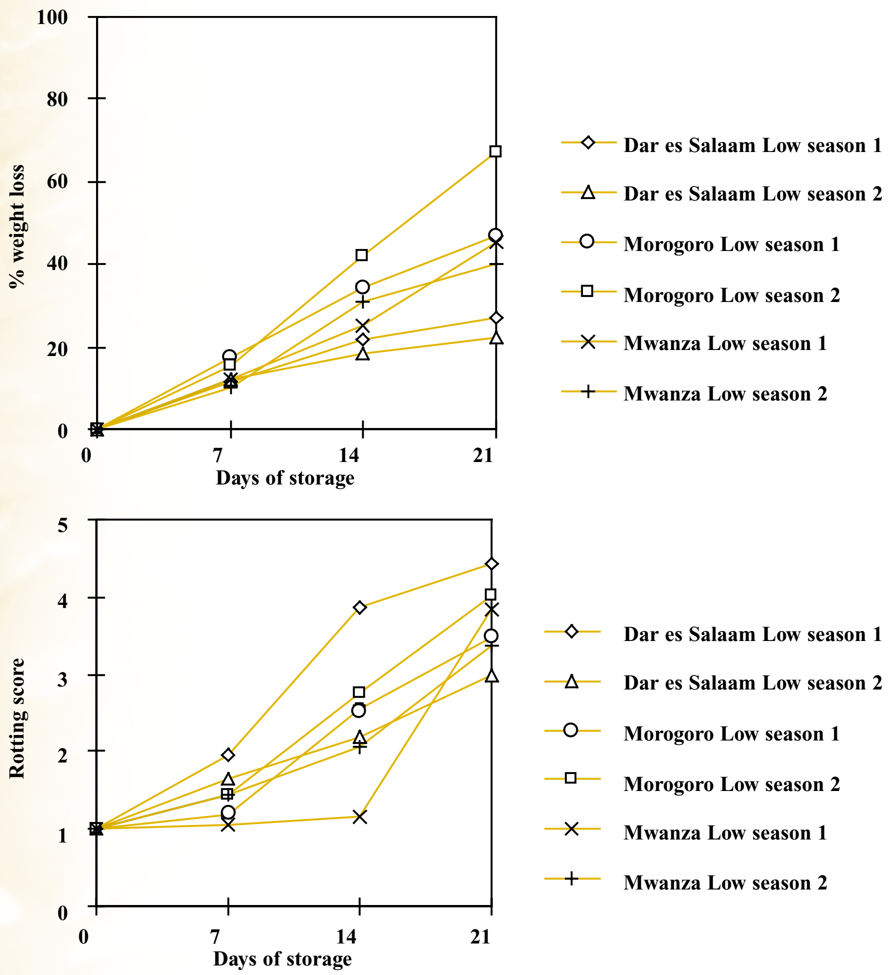

Figure 5.4 **Rates of weight loss and rotting for roots bought from markets and stored under simulated marketing conditions (see section 5.2.1 for details of rotting score)**

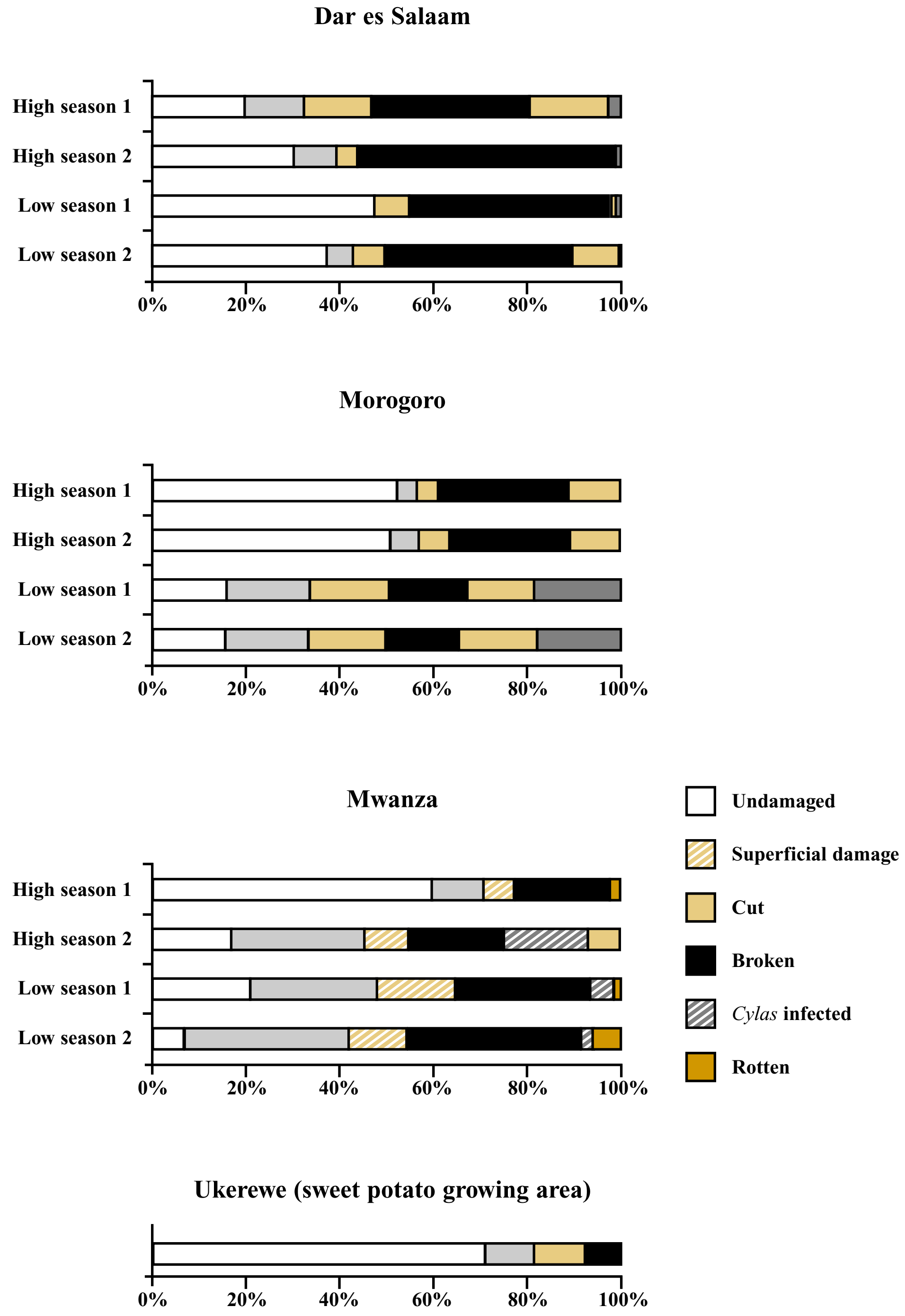

Figure 5.5 Levels and types of damage observed for sweetpotatoes in markets at four locations in Tanzania

1986). Levels of damage were variable, but were generally high with 44–67% seriously damaged roots (including all but superficial damage) and total damage of 49–93%. There was a clear seasonal effect in Morogoro with more damage, mainly rotting, in the low season, but such clear seasonality was not observed in Dar es Salaam or Mwanza. The roots sampled from the rural market on Ukerewe Island showed the least damage.

The effect of damage on rates of deterioration was considerable. Figure 5.6 shows rates of weight loss for undamaged roots and for roots with various forms of damage. The data indicate that for broken roots the rate of weight loss in the first week was three times that of undamaged roots.

Further details of this study can be found in Rees *et al.* (2001).

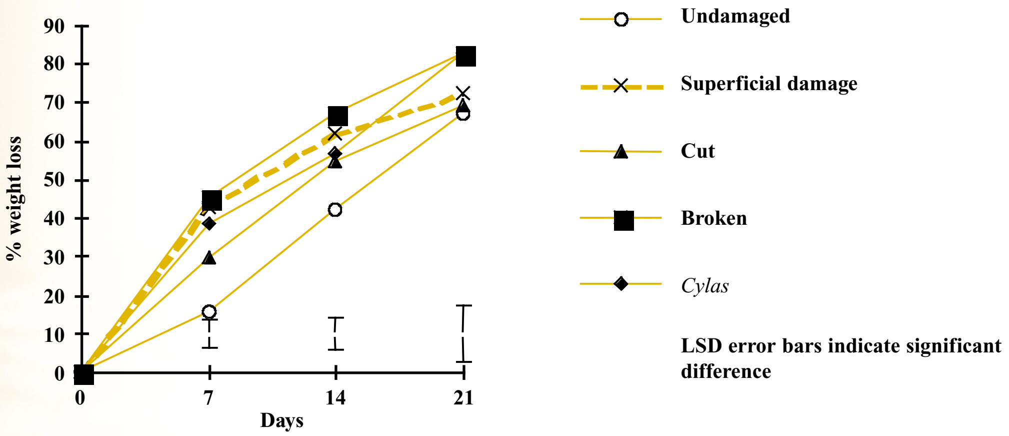

Figure 5.6 Rates of root weight loss in Morogoro during low season 2 and the effect of different forms of damage

5.3.2 Cultivar differences in keeping quality (weight loss and rotting) under simulated marketing conditions

The previous section underlines how short the shelf-life of sweetpotato is under marketing conditions. In order to determine the potential benefits of breeding for cultivars with longer shelf-life, trials were conducted in 1997 and 1998 to determine the keeping qualities of a wide range of sweetpotato cultivars (see section 5.2.2 for details of methods). As for the market studies described in the previous section, the main forms of deterioration observed were weight loss and rotting, while sprouting was not observed.

Figure 5.7a and b shows the extent of weight loss and rotting for a range of cultivars after 2 weeks of storage

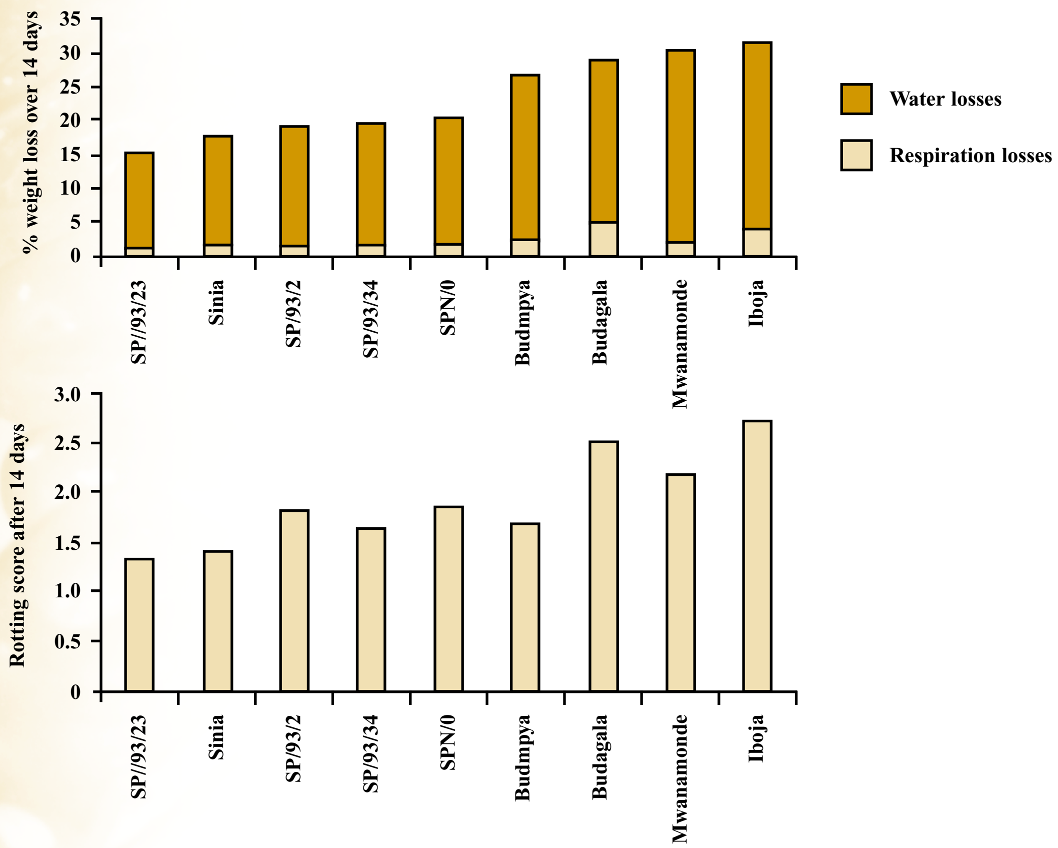

Figure 5.7a Rates of percentage weight loss (with estimated contribution from water loss and respiration) and rates of rotting for sweetpotato cultivars during storage under simulated marketing conditions – Trial 1, 1997, 9 cultivars

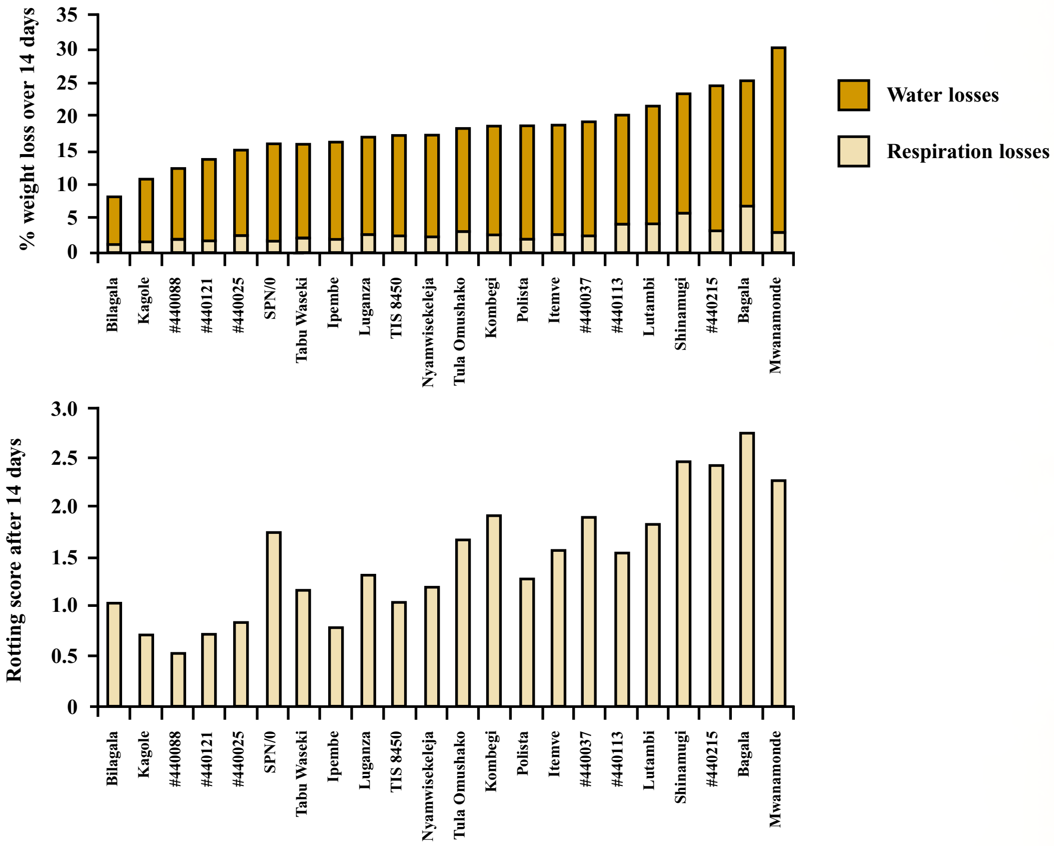

Figure 5.7b Rates of percentage weight loss (with estimated contribution from water loss and respiration) and rates of rotting for sweetpotato cultivars during storage under simulated marketing conditions – Trial 2, 1997, 22 cultivars

for the trials of 1997. A wide range in both parameters can be seen with more than a three-fold difference in weight loss among cultivars. Table 5.5 shows the weight loss data after 1 and 2 weeks for Trial 2. The data has been analysed by ANOVA, which confirms that there are cultivar differences significant to 0.1% after both 7 and 14 days. The least significant difference (LSD) can be used to get an indication of which cultivars differ significantly. For example, from this data it is reasonable to suppose that Kagole is significantly different from Kombegi, but not from Polista.

Table 5.5 Percentage weight loss during storage under simulated marketing conditions for roots from a range of sweetpotato cultivars

Cultivar	7 days	14 days	Cultivar	7 days	14 days
1. Kagole	5.98	11.27	14. Ipembe	9.67	16.59
2. Polista	8.42	18.88	15. Lutambi	10.16	21.88
3. Tula Omushako	8.50	18.44	16. Shinamugi	10.93	23.59
4. 440088 (NC 262)	6.94	12.49	17. Tabu Waseki	8.47	16.26
5. Kombegi	9.41	18.87	18. TIS 8250	9.00	17.42
6. 440037 (Imby 3102)	8.89	19.66	19. Luganza	8.96	17.21
7. 440215 (Tainmg #65)	11.83	24.88	20. Itemve	8.75	18.95
8. 440025 (Xushu 18)	7.68	15.11	21. SPN/0	7.80	16.09
9. 440121 (Naeshirazu)	6.90	13.94	22. Mwanamonde	12.93	30.62
10. 440113 (Beniaka)	10.35	20.54	Mean	9.01	18.36
11. Nyamwisekeleja	9.63	17.52	Cultivar effects	***	***
12. Bagala	12.39	25.41	LSD	3.21	5.11
13. Bilagala	4.53	8.38	CV%	21.6	16.9

*** Significant at 0.1% level of probability.

5.3.3 Water loss is the main driving force for deterioration under marketing conditions

The rates of root respiration measured during the first week of storage were used to estimate the contribution to weight loss of starch metabolism. For these trials we estimate that respiration is responsible for on average 14% (cultivars range from 8% to 27%) of root weight loss and, therefore, that weight loss is primarily due to water loss. This is indicated in Figure 5.7. Rates of respiration were greater for cultivars with higher weight loss, and this is probably an indication of the stress experienced by roots due to desiccation.

From Figure 5.7, it is possible to see that there is a tendency for the cultivars that lose weight rapidly to rot more. This is confirmed by a significant positive correlation between weight loss and rotting (r = 0.79, P< 0.001) for Trial 1. This trend was found for all four trials. We believe that under these conditions, water loss from roots weakens the tissues, and makes them more susceptible to rotting. The hypothesis that rotting is promoted by weight loss, rather than that weight loss is caused by rotting, is supported by the even stronger correlation of weight loss at 14 days with rotting at 21 days (r = 0.841, P<0.001). Again, the same trend was found for all trials.

Our overall hypothesis, therefore, is that one of the main factors affecting cultivar perishability under marketing conditions is the susceptibility of the root to lose water. The observation that cultivars differ widely in rates of water loss suggests that it may be feasible to breed cultivars with extended shelf-life.

Further details of this study can be found in Rees *et al.* (in press).

5.3.4 Stability of cultivars between years and between environments

For an improved cultivar to be successful, it should function well over all seasons and over a wide area and, therefore, over a range of environments. It is important to know how ‘stable’ is the low water loss characteristic. We found that the behaviour of the cultivars over the 2 years of trials was reasonably consistent. Figure 5.8 shows the weight loss for Trial 2 after 14 days plotted for 1998 vs. that for 1997. A correlation coefficient (r) of 0.619 was obtained, which is significant to 1%. For Trial 1, the correlation was even stronger (r = 0.912, significant to 0.1%).

Information on the consistency of cultivars between environments was tested in trials conducted at five sites throughout Tanzania (see section 5.2.3). The results obtained are less clear, but do indicate that certain cultivars are consistently better than others. Figure 5.9 shows the weight loss over 14 days for five cultivars assessed during seven different trials (including five sites and 2 years). The cultivars Iboja and SPN/0 are fairly stable; Iboja shows consistently high rates of weight loss, and SPN/0 shows relatively consistent low rates of weight loss (thus in six of the seven trials Iboja lost weight more rapidly than SPN/0). However, for the other cultivars the trends are less clear. Mwanamonde and Sinia in particular appear to have variable behaviour according to environment.

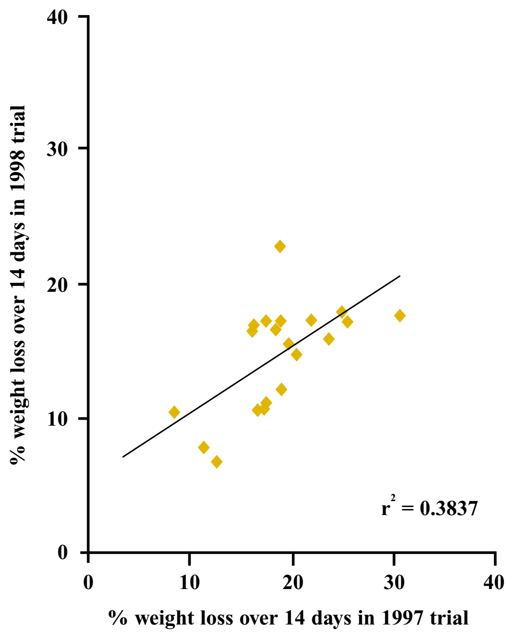

Figure 5.8 The relationship between weight loss over 14 days of storage under simulated marketing conditions in 1998 and 1997

5.3.5 Most water loss occurs through wounds

Water loss and wound healing efficiency

Having established that water loss from roots is a key factor in their keeping quality during marketing, it is important to learn more about this process. A porometer was used to determine the pattern of water loss from a sweetpotato root, and the results obtained are illustrated in Figure 5.10. This indicates that water loss through undamaged periderm is low, while damaged areas show much higher rates of water loss. Deep wounds (see Figure 5.11) showed the highest rates of water loss. The rate of water loss for all areas declined over the first week after harvest and is particularly marked for wounded areas. As described in Chapter 6, this is primarily due to healing of wounds. Nevertheless, deep wounds continued to have a rate of water loss considerably higher than less severe forms of damage, even 7 and 14 days after harvest. Presumably wound healing is not completely efficient in this case.

The importance of root damage for weight loss is confirmed by the results shown in Table 5.6. Here, roots were damaged using the standardized scuffing and impact treatments described in section 5.2.6. The

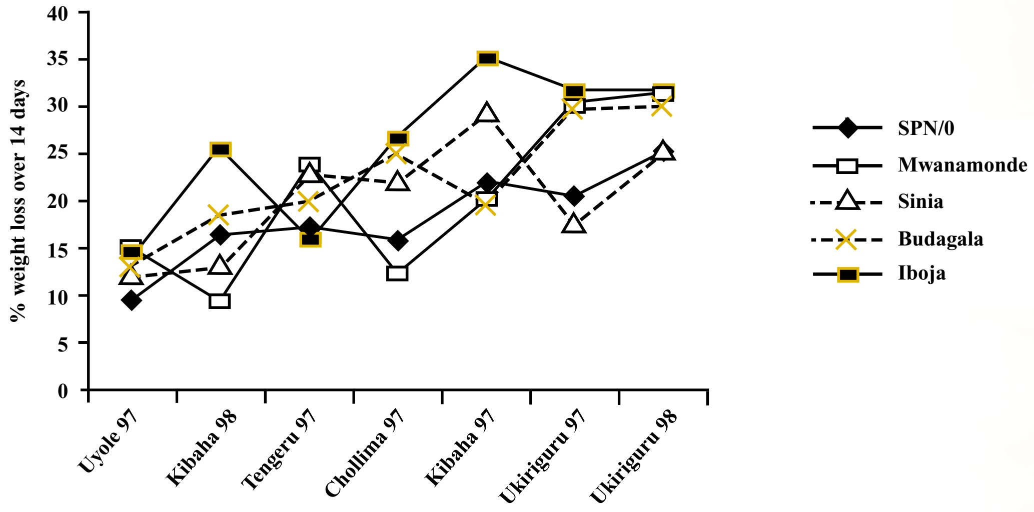

Figure 5.9 Weight loss over 14 days storage under simulated marketing conditions for five cultivars during seven trials. Trials have been ordered in terms of increasing rates of weight loss

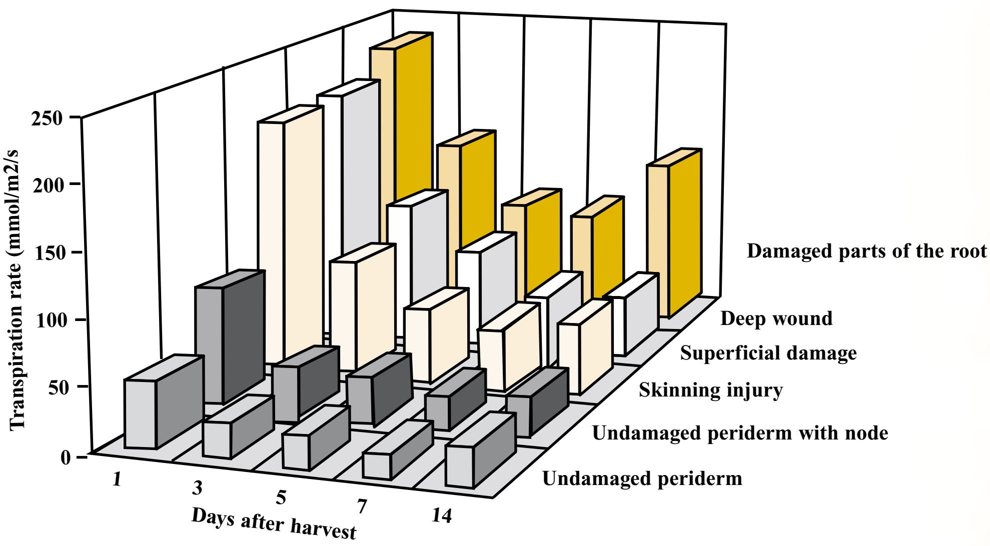

Figure 5.10 Transpiration rate through root surface with different kinds of damage measured at 1, 3, 5, 7 and 14 days after harvest (cultivar: KSP 20). (Note: Time scale is not linear)

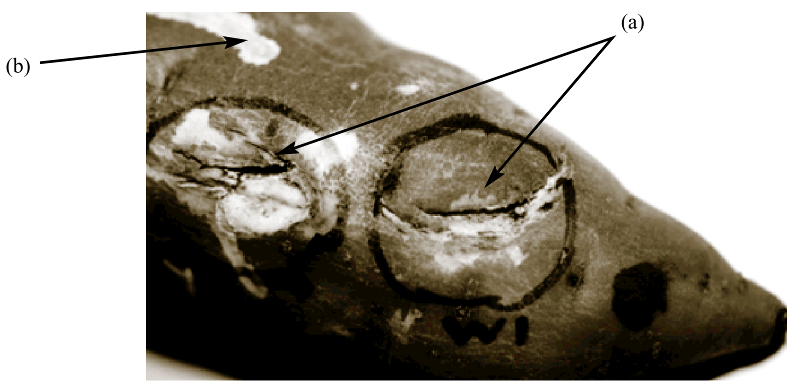

Figure 5.11 Deep wounds (a) and scuffing (b) on sweetpotato root surface (cultivar: KSP 20)

Table 5.6 Correlation coefficients between rate of weight loss and amount of damage for artificially damaged roots

Damage treatment	*N*	Damage type	Correlation coefficients – Days after damage treatments: 1	2	7	14
Scuffing	100[A]	Skinning injury	0.348**	0.449**	0.050	ND
	230[B]		0.535**	0.426**	0.087	ND
Impact	217[C]	Breaks	0.480**	0.414**	0.541**	ND
	72[D]		0.549**	0.588**	0.712**	0.669**
Impact	217[C]	Skinning injury	0.253**	0.155*	0.053	ND
	72[D]		0.087	0.252*	0.172	0.046

[A, B, C, D] refer to four different experimental trials.
** Significant at $P < 0.001$; * significant at $P < 0.05$.
ND = not determined.

level of damage for individual roots was related to the rate of weight loss of each root.

There was a significant positive correlation between the level of skinning injury and weight loss and between the extent of breakage and weight loss indicating that roots with high levels of skinning injury and/or breaks also had higher weight losses. The correlation between breaks and weight loss remained highly significant until 14 days after impact damage. Breakage thus has a long-term effect on weight loss. Skinning injury caused significant weight loss for the first 2 days only and thus has a rather short-term effect on weight loss. These results indicate that breakage is a more severe form of damage than skinning injury.

These results support the findings from the studies of root market damage (section 5.3.1) that damage reduces shelf-life and that breakage is the most serious form of damage.

5.3.6 Cultivar variation in susceptibility to damage

It was found that cultivars varied in the kind of damage to which they were susceptible (Table 5.7). Thus, Yan Shu 1, Kemb 10 and SPK 004 were highly susceptible to breaks, while Zapallo and Caplina had the lowest susceptibility to breaks. The ranking of susceptibility to skinning injury was consistent for both the 'scuffing' treatment and impact damage. Both Zapallo and BP1-SP-2 were highly susceptible to skinning injury, while SPK 004 and Kemb 10 showed least susceptibility. The cultivars KSP 20 and Salyboro ranked intermediate for all forms of damage.

Susceptibility to breakages and root shape

By classifying roots by shape, it was demonstrated, not surprisingly, that breakage was strongly associated with long-shaped roots, while round or oblong-shaped roots were less susceptible to breakage. Although sweetpotato root shape can be variable within any cultivar, for the cultivars SPK004, Kemb 10 and Yan Shu 1, more than 70% of the roots belonged to the long-shaped category. As shape, therefore, is a cultivar characteristic and affects susceptibility to breakage, it would be useful to select for rounded root shape.

Susceptibility to scuffing and periderm thickness

Microscopy was used to measure the thickness of the root periderm for several roots of each cultivar. The

Table 5.7 Overview of the mean ranks obtained for 10 sweetpotato cultivars for various forms of damage

Treatment	Damage	Cultivars: Yan Shu 1	Kemb 10	KSP 20	Zapallo	SPK 004	BP1-SP-2	Caplina	Saly-boro	Yarada	Julian
Scuffing barrel	Skinning injury	3.5	2.5	6.0	7.0	1.0	8.0	4.5	6.5	4.0	8.0
Impact damage	Breaks	9.0	7.0	5.0	1.0	7.5	3.0	2.0	5.5	6.0	4.0
	Deep wounds	3.0	7.0	6.5	4.5	8.5	6.0	4.0	4.0	1.0	2.0
	Skinning injury	4.5	2.5	6.5	7.5	1.0	8.5	4.0	5.5	4.0	6.0
	Superficial damage	3.5	5.5	5.0	9.0	1.0	8.0	5.0	4.0	4.0	4.0

A high rank corresponds to a high susceptibility to the particular form of damage, and is indicated by dark grey shading.

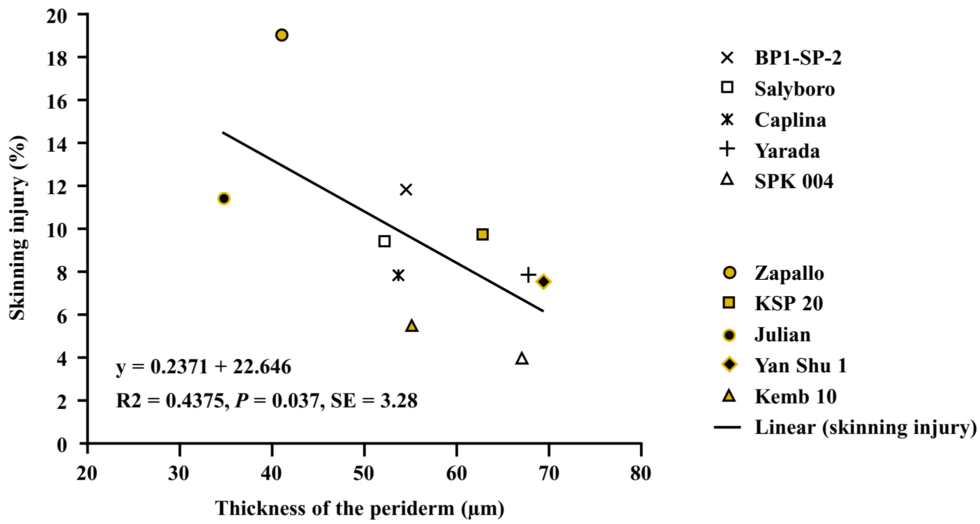

Figure 5.12 Relationship between periderm thickness and percentage skinning injury (percentage surface area of the root) after scuffing treatment; each point represents a cultivar

susceptibility to skinning injury was found to decrease with thickness of periderm (Figure 5.12) and this relationship was found to be significant (P = 0.037). The cultivars Yan Shu 1, Yarada and SPK 004 with the thickest periderms (65–70 mm) showed least susceptibility to skinning injury, while the cultivars Zapallo and Julian with a thin periderm (<40 mm) showed high susceptibility to skinning injury.

Further details of this study can be found in Van Oirschot (2000).

5.4 Conclusions and implications

- Under conditions typically experienced during marketing in East Africa, the main forms of deterioration in sweetpotato roots are water loss and rotting. Water loss appears to promote rotting and, therefore, if this can be reduced it should have an impact on the extent of rotting seen in the markets.
- There is a wide range in shelf-life among cultivars, which seems to be primarily due to differences in susceptibility to water loss.
- Susceptibility to water loss in cultivars is relatively consistent between seasons. The consistency between environments is less clear, but there are some cultivars that consistently do better than others.
- Greatest water loss from roots occurs through wounds. Damage, therefore, has a considerable effect in shortening root shelf-life.
- Two major factors controlling susceptibility to water loss are:
  - reaction of the root to wounding (this will be considered in the next chapter)
  - the susceptibility of roots to damage.
- Roots of rounded shape (i.e. not elongated) are less susceptible to breakages, and roots with thick periderms are less susceptible to surface damage (scuffing).

This chapter primarily considers the question of how cultivars could be selected with extended shelf-life for marketing. (This does not include suitability for long-term storage, which is covered in Chapter 7.) Although rotting is a serious restriction on shelf-life, we believe that water loss is more important. Although we would recommend that cultivar assessment includes measurement of water loss, rotting and also susceptibility to damage, where time/labour is restricted, a reasonably effective assessment of cultivar shelf-life can be obtained by measuring susceptibility to water loss alone. A simple test could be devised by placing roots of each cultivar on an open shelf, and measuring weight loss over 1 week.

Our data underline the effects of environment on cultivar behaviour. It is, therefore, very important that multi-site testing be carried out to cover the range of environments representative of the region for which breeding is being carried out.

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