CROP POST HARVEST PROGRAMME

The extension of storage life and improvement of quality in fresh sweetpotato through selection of appropriate cultivars and handling conditions.

R 6507 (ZB0021)

FINAL TECHNICAL REPORT

Jan 1996 – Dec 2000

Natural Resources Institute, University of Greenwich, UK.

Ministry of Agriculture, United Republic of Tanzania

Silsoe College, Cranfield University, UK

Project Leader:
Dr D. Rees.
Natural Resources Institute,
University of Greenwich

CONTRIBUTORS AND COLLABORATING INSTITUTES

Natural Resources Institute
University of Greenwich, Chatham Maritime, Kent ME4 4TB, UK

Dr D. Rees
Dr Q. van Oirschot
K. Tomlins

Silsoe College
Cranfield University, Silsoe, Bedford MK45 4DT, UK

Dr. J. Aked

LZARDI-Ukiriguru (formally ARI-Ukiriguru)
P.O. Box 1433, Mwanza, Tanzania

E. Rwiza
R. Amour
***Dr. R. Kapinga**

Sugarcane Research Institute (Kibaha)
P.O. Box 30031, Kibaha Pwani, Tanzania

M. Muhanna
K. Mtunda
M. Kilima
H. Kiozya

HortiTengeru
P.O. Box 1253, Arusha, Tanzania

T. Ndondi
M. Chottah

ARTI Uyole
P.O. Box 400, Mbeya, Tanzania

C.M. Mayona
D. Mende

Dakawa A.R.C.
P.O. Box 1892, Morogoro, Tanzania

D.N.V. Chilosa
A. Goa
A. Lipande
M. Kiteleki

Sokoine University of Agriculture
P.O.Box 3006, Morogoro, Tanzania

L.B. Mbilinyi

***Present address**
c/o CIP, Sub-Saharan Africa Region
P.O.Box 25171, Nairobi, Kenya

ACKNOWLEDGEMENTS

This publication is an output from a research project funded by the United Kingdom Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID. R6507 Crop Post-harvest Research Programme.

We would like to thank the Tanzanian and Ugandan Ministries of Agriculture for permission to conduct and publish this research, and the Kenyan Agricultural Research Institute (KARI) for allowing us to use laboratory facilities at NARL, Nairobi.

A very special thanks goes to the International Potato Center, especially to the staff based in Nairobi for their support for the work of this project. They provided extensive technical assistance as well as providing material for much of the experimental work. We are delighted that they have become collaborators in a follow-on project.

Finally we would like to make a dedication to the memory of Mr,. M. Nyango of LZARDI-Ukiriguru who contributed to much of the work of this project prior to his death in 2000.

ADMINISTRATIVE DATA

<table>
<tr><td>Period under report: Jan 1996 – Dec 2000</td><td>Project Leader/Institution: D.Rees/NRI</td></tr>
<tr><td>NRIL Contract Number: ZB0021</td><td>Collaborating institution(s)

❑ Root and Tuber Crops Programme, Ukiriguru Agricultural Research Institute, Tanzanian Ministry of Agriculture

❑ Silsoe College, Cranfield University</td></tr>
<tr><td>DFID Contract Number: R6507</td><td>Target Institution(s)

❑ National Root and Tuber Crops Programme, Tanzania.
❑ Tanzania Food and Nutrition Centre.
❑ National Agricultural Research Organisation, Uganda.
❑ International Potato Center
❑ (In the longer term: NGOs and community groups for their ability to promote more widely germplasm with desirable characteristics.)</td></tr>
<tr><td>Project Title:
The extension of storage life and improvement of quality in fresh sweetpotato through selection of appropriate cultivars and handling conditions.</td><td>Start Date: 1 Jan 1996
End Date: 31 Dec 2000</td></tr>
<tr><td>Research Programme:
Crop Post-harvest Programme</td><td>Budget (i.e. Total Cost):
£ 380 832</td></tr>
<tr><td>Production System:
Forest Agriculture Interface/Hillsides</td><td></td></tr>
</table>

CONTENTS

EXECUTIVE SUMMARY

The purpose of this project was to improve sweetpotato storage techniques or strategies for fresh and processed products. Extension of shelf-life could be brought about by improving handling techniques, and/or using cultivars with better keeping qualities.

The project was carried out as a collaboration between the Natural Resources Institute (NRI), Cranfield University and the Tanzanian Ministry of Agriculture, with contributions from Sokoine University of Agriculture (Tanzania) and the National Agricultural Research Organisation (Uganda). Considerable technical assistance was provided by the International Potato Center (CIP). Experimental work was conducted in the UK, Tanzania, Uganda and Kenya.

It was demonstrated that under marketing conditions in East Africa root deterioration is driven by water loss through fresh and incompletely healed wounds. Changes in sensory characteristics are not significant over the timescale considered. There is sufficient genetic variability among existing sweetpotato germplasm for breeding to be a feasible approach. Cultivars with long shelf-life are those which are able to wound-heal under conditions where humidities are lower than ideal, and among the germplasm considered cultivars with low dry matter content are more efficient. Follow-on work is being funded to look for cultivars with high dry matter and efficient wound-healing. Susceptibility to damage during handling is also important. As expected root shape has a big effect on susceptibility to breaking and periderm thickness affects susceptibility to scuffing (but not rate of water loss through undamaged periderm).

Longer-term storage is possible in purpose built structures where roots are stored at higher humidities, as long as sufficient ventilation is provided. In this case root deterioration is primarily through rotting. Cultivars differ in rates of rotting, but are not as consistent as in the case of water loss. The main rotting pathogen in Morogoro Region of Tanzania is *Rhizopus oryzae*. Resistant cultivars appear to produce toxins when infected. Cultivars suitable for long-term storage are not the same as those with long shelf-life during marketing.

Where storage of fresh roots is not feasible, sweetpotato can be stored as sun-dried chips, in which case storage life is limited by insect infestation. In Kumi District, Uganda the most damaging infesting insect was found to be *Araecerus fasciculatus.* Salting or parboiling of chips were both found to be effective control methods. Variation in susceptibility to *A. fasciculatus* was found among cultivars, and further work on this aspect is recommended.

Wherever new cultivars are being selected it is important that they have acceptable eating qualities. But very little information existed on the preferences of urban consumers. Survey work conducted in Lake Zone found that for both traders and consumers important criteria were starch/floury (high dry matter content), good taste and good appearance. As many of the criteria are very difficult to assess analytically, a study was conducted to assess the potential for using an on-station trained taste panel to assess cultivars. The panel was found to be consistent and to be able to distinguish between cultivars. Sensory profiles of the preferred cultivars in three locations surveyed in Lake Zone were found to be very similar, suggesting that this approach is possible.

Dissemination of results has occurred primarily through conference presentations. The production of a publication for dissemination to national programmes throughout the world is being funded in a follow-on project.

BACKGROUND

The background to this project and some of the pre-existing scientific literature is summarised below. More detailed reviews of the scientific literature are given in Oirschot 2000 (considering physiological and sensory aspect of sweetpotato deterioration), Muhanna 2001 (considering pathological aspects of sweetpotato deterioration) and Agona 1998 (considering storage of sun-dried chips)

i. The importance of sweetpotato as a food security crop and for income generation.

Sweetpotato (*Ipomoea batatas*) is the world's seventh most important staple crop, grown in over 100 countries of the world, covering an estimated total area of 9.2 million Ha, with an annual global production around 125 million tonnes. Almost 95% of the total production is in developing countries (CIP 1996). Past and current production trends suggest that sweetpotato output in developing countries is increasing, for example in Africa it is estimated that it is presently growing at about five percent per year (CIP 1996).

Being relatively resistant to pests and diseases and comparatively water-use efficient, sweetpotato grows well in regions of marginal agricultural production. The crop has the additional advantage that due to rapid soil coverage and good rooting characteristics, it helps to reduce soil erosion. Thus, sweetpotato is a particularly valuable crop for poorer farmers. This is reflected in the distribution of the crop. With an annual per capita production in Africa averaging nearly 9 Kg, per capita consumption often exceeds 100 Kg within poorer communities (CIP 1996).

This project was focused primarily towards East Africa where, as in most parts of the developing world, sweetpotato is grown not only for home consumption, but increasingly to supplement household income by marketing. With the increasing urbanisation of the East African population, marketing of food to urban centres is of growing importance.

ii. The need to improve the keeping qualities of sweetpotato roots.

Several surveys conducted over the past few years in East Africa have indicated that the perishability of the sweetpotato storage root following harvest constitutes a major constraint to its potential as a food security crop. Although large-scale physical losses are not generally observed, this appears to be because the pattern of consumption and marketing has been adapted to the short shelf-life of the commodity, whereas a longer shelf-life would increase opportunities for consumption and marketing. Recommendations have therefore been made, in a number of reports, that efforts should be made to increase shelf-life through the improvement of handling practices or cultivar selection (Fowler and Stabrawa 1993; Kapinga *et al*. 1995). These findings were supported by a survey conducted by NRI in Mwanza, Dar es Salaam and Morogoro regions (R. Bancroft *pers. comm.*). This project was therefore concerned with the extension of shelf-life and improvement of quality of the sweetpotato crop in East Africa.

Improvements in quality and shelf-life could be brought about in a number of ways; by identifying improved methods of handling, harvesting and production and through selection of higher quality and less perishable cultivars. In the case of cultivar selection, which was a major focus of this project, cultivars could be selected from existing germplasm, or improved cultivars could be developed as part of a longer-term breeding programme. To make selection more efficient a programme of research was set out to identify those characteristics associated with good post-harvest behaviour with the aim of developing selection techniques to be used in breeding programmes, such as those undertaken by the International Potato Centre (CIP). Although in the long-term it is envisaged that the main benefits would be obtained through the breeding of improved varieties, the diversity of the existing East African Germplasm (see section x. below) provides great potential for short-term improvements through selection and promotion of the cultivars most appropriate for each set of conditions and use.

iii. Forms of root deterioration.

The post-harvest physiological processes that may affect storability include the following,
a) Respiration;
b) Evaporation of water from the product;
c) Sprouting;
d) Changes in chemical composition;
e) Diseases;
f) Damage by extreme temperatures.

The relative importance of these processes differs with the storage environment. Under tropical conditions high temperatures are likely to result in high rates of respiration. Increased rates of metabolic breakdown could result in increased levels of weight loss. The evaporation of water is directly related to atmospheric water vapour pressure deficit. Although the relative humidity in the tropics is frequently high, for uncovered roots during marketing it can be sufficiently low to allow rapid water loss through the skin surface.

Within this project we are mainly considering the keeping qualities of roots during marketing, rather than during long-term storage in specialised storage structures. During marketing the relative humidity to which roots are exposed can be low, whereas during long-term storage much higher humidities are likely. The main forms of deterioration will differ accordingly.

iv. Definition of quality.

In order to be able to put any meaningful value on the rate of deterioration, it is essential to understand the criteria of quality used by consumers, both for fresh roots, and also when the roots are to be processed, e.g. dried. Prior to the initiation of this project some information had already been collated on farmers' varietal preferences within Tanzania (e.g. Kapinga *et al.* 1995, Kileo and Rugimbana 1995), and an extensive survey ha also been conducted in Uganda (Hall 1995); however, information on the preferences of urban consumers appeared to be scarce.

v. Root deterioration through post-harvest physiological changes.

The storage root is primarily a starch storage organ, with some sugars (mainly sucrose, glucose and fructose) and low levels of protein. The main post-harvest physiological changes are associated with water loss, and carbohydrate (starch and sugar) metabolism. The extent of water loss is expected to depend on the properties of the periderm and the ability of the root to heal wounds. This is considered below (see section vii).

As the storage root is a living organ, low levels of metabolism are necessary to maintain the integrity of the cells. However high rates of metabolism can be detrimental to quality, by changing the carbohydrate composition, or in the extreme case, by metabolising so much starch that air spaces form, and the texture of the root becomes spongy. Most work on the carbohydrate metabolism and respiration has been carried out on North American or Japanese cultivars under the temperature regimes used in refrigerated stores (typically 13-15°C) (e.g.Woolfe 1992 and references therein, Takahata *et al*. 1992). These have generally shown that sugar levels increase during storage (Woolfe 1992). However, the metabolic rate is temperature dependent, and the cultivars can vary significantly in their metabolic characteristics (e.g. Ahn *et al*.1980), so that there is a need to determine how the major East African cultivars behave under tropical conditions. A better understanding of the control of the metabolic rate would help us to select cultivars and conditions for slow metabolism.

During longer term storage, sprouting of the root can cause loss. Although sprouting is not considered to be a major problem in East Africa under the present handling conditions, it could become so if longer term storage were feasible. Sprouting can be controlled by sprout suppressants, but this is not economically feasible under most situations in East Africa. Initial observations at NRI have indicated that East African cultivars differ very markedly in their tendency to sprout during storage (D.Rees, unpublished results).

Under certain conditons, notably at low oxygen levels, a switch to anaerobic repiration, which involves the production of alcohol, and is detrimental to quality can occur. For example, the sweetpotato crop is particularly sensitive to low oxygen conditions that occur during water logging. During storage in pits and clamps, oxygen levels can fall, and anaerobic repiration can occur. A understanding of the control of the switch to anaerobic respiration may enable the selection of varieties to minimise this problem.

vi. Root loss through post-harvest rots.

Roots are susceptible to rotting especially after damage due to mechanical injury or insect infestation. Trials conducted in Tanzania have shown clear indications of varietal differences in susceptibility to rots, but the basis of this difference has not been investigated (Chilosa *et al.* 1995). More detailed studies have been carried out on North American germplasm (e.g. Clark *et al.* 1989 and references therein; Clark 1992) where resistance to rotting has also been shown to exist within certain varieties.

The root possesses several mechanisms of resistance to invading pathogens, including the formation of physical barriers, as in the formation of wound periderm and hypersensitive cell death, and the production of chemicals toxic to invading pathogens such as phytoalexins, proteinase inhibitors and phenols. The relative importance of these mechanisms, which are considered in more detail below, appears to vary depending on variety and pathogen. A greater understanding of the role of these different mechanisms among the African germplasm could lead to the development of indirect selection techniques to facilitate selection from existing germplasm, and in future breeding programmes.

vii. Mechanisms of resistance to rotting and water loss.

Wound healing and the practice of curing

Mechanical wounding during harvest, or subsequent handling can considerably shorten the storage life of sweetpotato roots, as the wounds provide entry points for bacterial and fungal rots, and also increase water loss. Storage can be prolonged if roots are placed for a period of time, under conditions which promote the healing of wounds.

The process of wound healing initially involves the drying of surface cell layers which subsequently die to form a dessicated layer. This is followed by the formation, by cell division, of an underlying wound periderm with a composition very similar to normal periderm (Walter and Schadel 1982, 1983). Work carried out on the control of wound healing in sweetpotato at the molecular level has indicated that ethylene, which is known to stimulate many other plant responses, such as fruit ripening, is involved in the control of the wound response (e.g. Imaseki *et al.* 1968, St.-Amand and Randle 1991). The literature is much more extensive for potato, and it is possible, although the physiological origin of the potato tuber and the sweetpotato root are quite distinct, that much of the information could be extrapolated.

In the practice of curing, sweetpotatoes are exposed to conditions to promote wound healing. This is used routinely in the storage of sweetpotatoes in temperate regions. For example, in the US where sweetpotatoes are stored at 13-15°C, this is preceded by 5-7 days at a warm temperature of about 30-33°C and a high humidity of 85-95%. There are a number of reports in which different curing conditions for sweetpotato are compared (e.g. Gull and Duarte 1974, Lawrence 1985, Gooding and Campbell 1964, Delate *et al.* 1985). A high relative humidity is recommended since low relative humidity causes surface cells to die by desiccation and thus inhibits wound periderm formation. The optimum temperature is determined by the temperature dependence of the enzymes involved. Thompson (1972) postulates that roots grown under tropical conditions may need higher temperatures to cure than those grown under temperate conditions.

Deliberate curing of sweetpotato roots does not appear to be a normal practice in East Africa. It is probable that in many cases, for example when roots are stored in sacks, that the temperature and humidity are sufficiently high to promote wound healing naturally. However, during surveys it was noted that traders preferred to maintain roots under dryer conditions to prevent rotting (R. Bancroft *pers. comm*,). A common practice was to "sun-cure" roots by drying in the sun for a day immediately following harvest, in order to harden the skin. A careful comparison of these two techniques, in order to determine if there is an advantage for promoting "high-humidity" curing has not been undertaken under East African conditions.

There is evidence, mostly with respect to North American varieties that the efficiency of wound healing may vary between varieties (Gull and Duarte 1974, Clark 1992, Clark *et al.* 1989). Initial studies of 4 Kenyan varieties undertaken at NRI have also indicated differences. If this is the case, it could be a very useful characteristic to select for.

<u>Hypersensitive cell death.</u>

In other crops, notably potato, it has been observed that infection can lead to a hypersensitive response, in which the formation of oxygen radicals leads to localised plant cell death, thus creating a barrier which effectively halts the growth of the pathogen (e.g. Doke and Chai 1985). No investigations appear to have been carried out to determine whether this is a significant defence mechanism in sweetpotato.

<u>Phytoalexin production.</u>

Phytoalexins are low molecular weight compounds synthesised by plant tissue, which are toxic to invading micro-organisms. Their production can be induced by mechanical damage alone, but is stimulated more strongly in the presence of pathogens. In sweetpotato several sesquiterpenes, mainly furanoterpenes have been identified, the most abundant of which has been named Ipomeamarone, and has been studied extensively by groups in the USA (Catalano *et al.* 1977, Martin *et al.* 1978, Clark *et al.* 1981) and Japan (Inoue *et al.* 1984).

<u>Phenolics and polyphenolics.</u>

In addition to acting as precursors in the formation of structural molecules such as lignin and suberin, phenolic compounds can also contribute to resistance by directly inhibiting pathogenic growth and associated cell wall degrading enzymes. Oxidation products of phenols released by the action of the enzymes polyphenol oxidase and peroxidase may also be important for inhibiting pathogen enzyme activity. Studies of the role of phenolics in resistance of sweetpotato are limited. However Arinze and Smith (1982) did a detailed study of the distribution of phenolics after infection of sweetpotato roots by a range of fungal rots, and also demonstrated direct inhibition of fungal enzymes by extracts of sweetpotato, which they attributed to phenolics.

<u>Proteinase inhibitors.</u>

Proteinase inhibitors which inhibit the enzymes of invading insects and pathogens occur at moderately high levels in sweetpotato, with a range of activity between cultivars. In the case of potatoes, proteinase inhibitors are expressed constitutively (i.e. irrespective of pathogen or insect attack), and are therefore always present in the tubers, but are only synthesised in leaves as a reponse to damage. By extrapolation, it is likely that proteinase inhibitors are also expressed constitutively in sweetpotato roots, but no specific evidence has been found in the literature. Their role in defence against pathogens has not been considered in detail for sweetpotato.

viii. Processing of roots and storage in dried form.

In many situations, even if sweetpotato cultivars with improved keeping qualities were identified, it would not be practical to store roots in fresh form. This is particularly so in regions with a unimodal rainfall, and therefore very long dry seasons. In this case the only practical alternative is to store roots in the form of sun-dried chips.

This form of food storage is particularly important in Uganda. In many regions of Uganda sweetpotato is becoming increasingly important due to the failure of the cassava crop as a result of African Cassava Mosaic Virus Disease Complex (ACMVDC). Unlike cassava, sweetpotato cannot be left in the field through the dry season due to infestation by sweetpotato weevil (*Cylas* spp). In these regions losses due to insect infestation limit storage to 2-3 months. In many areas, the inability to store sweetpotato through the dry season leads to severe food shortages. Since the problem has arisen relatively recently, mechanisms to solve it have not been developed. This situation already exists in many regions of Uganda (e.g. Kumi, Soroti), and is likely to spread with ACMVDC.

Sun-drying of sweetpotato has been practised for a longer time in the dryer regions of Tanzania (Lake Zone), and consequently methods for controlling insects appropriate to this region have been devised. However, as in these regions cassava is a more important food security crop than sweetpotato the effectiveness of these methods is not as critical and have therefore perhaps not been fully tested.

Dried sweetpotato chips, succumb to insect pest infestation after about 2-3 months of storage, (Agona, 1995). Pest infestation is manifested by perforations of dried chips, development of off-flavours, mouldy chips, mite infestation, reduced flour content, frass and cast skins of dead insects. To reduce damage levels, farmers always conduct routine inspections and re-drying in the sun. The results are often discouraging since damage levels continue to escalate with prolonged storage duration. Farmers respond to the problem by requesting insecticides. The use of insecticides to prevent and/or control infestation has many problems. Farmers are resource poor, lack technical expertise in chemical handling and application, very few insecticides are available and those which are available have low shelf-life and are prone to user abuse. The need for effective pest management strategies are therefore urgently required.

Various pest management methods, especially for dried cassava chips have been demonstrated. The methods include storage of dry chips in sealed containers (Ingram and Humphries, 1972), varietal manipulation (Pillai, 1977), mixing of chips with common salt prior to drying (Kumar and Karnavar, 1986), and parboiling of roots prior to slicing and drying (Nwana and Azodeh, 1984; Pillai and Rajamma, 1987; Nwana, 1993). Other disinfestation methods e.g. use of focused solar energy (Nakayama *et al*., 1982; Silim and Agona, 1993) have been successfully demonstrated on other insect pests.

ix. The potential for the improvement of post-harvest characteristics through breeding.

Sweetpotato is considered to be the most under-exploited of the developing world's major crops (Walker and Crissman 1996). This has probably arisen as a result of its status as a poor man's crop, and the fact that it is produced almost entirely in developing countries. Research on this crop is therefore likely to produce particularly high returns for effort.

Breeding initiatives for sweetpotato are at a relatively early stage compared to other staple crops. The main international breeding effort for developing countries is led by the International Potato Center (CIP) based in Lima. CIP has breeding sites throughout the world, including in sub-Saharan Africa, and actively provides clones for testing in East Africa. In addition several of the national programmes in East Africa (including Tanzania, Kenya and Uganda) are now carrying out their own crossing and have recently reached the stage of releasing their own cultivars.

While the main objectives of breeding programmes have traditionally been an increase in yield and improvement of other production characteristics, the importance of post-harvest characteristics is being increasingly recognised. A major objective of this project is the improvement of the post-harvest characteristics of the sweetpotato crop through breeding and cultivar selection. Given the enormous genetic diversity of sweetpotato world-wide, and the fact that breeding programmes of sweetpotato are relatively new, crop improvements are expected to be rapid.

x. Diversity of existing East African Germplasm.

The diversity of the sweetpotato germplasm in East Africa is indicated by the germplasm collection initiated by the Tanzanian National Root and Tuber Crops Programme in 1992, which already includes several hundred landraces.

Informal interviews of farmers and traders prior to the start of this project indicated that cultivars in Tanzania differed significantly in their perishability (Fowler and Stabrawa, 1993, Kapinga *et al.* 1995, R. Bancroft, *pers. comm*). This was supported by the results of one year of trials conducted during collaborative work between NRI and the Tanzanian National Programme (Chilosa *et al.* 1995).

xi. Conclusions.

The work within this project concentrated on East African germplasm and conditions. The aim was to develop recommendations for appropriate cultivars and practices which improve root quality and extend shelf-life in Tanzania in the relative short-term, but also to develop an understanding of the physiological mechanisms involved in deterioration which will enable the development of improved cultivars in the long-term, both for East Africa and other areas of the world.

Review of the literature indicates that there exists quite a body of information on the metabolism and pathology of the storage root. However most of the work has been undertaken under temperate conditions and on varieties from temperate countries. A series of studies on East African varieties under tropical conditions was therefore carried out.

No practically meaningful study of deterioration is possible without an understanding of the quality characteristics considered by the consumer. This project therefore included a study of consumer preferences in Tanzania. Obviously, consumer preferences will vary from place to place, so that studies will need to be undertaken in other areas in the future.

References

AGONA, J.A. 1995. Survey on storage pest complex of dried sweetpotato chips in Uganda. Paper presented at the 6th Triennial Symposium of the International Society for Tropical Root Crops- Africa Branch (ISTRC-AB), 22nd-28th October, 1995, Lilongwe, Malawi. In Press.

AHN, J.K., COLLINS, W.W. and PHARR, D.M. (1980) Influence of preharvest temperature and flooding on sweetpotato roots in storage. Hortscience 15: 261-263.

ARINZE, A.E. and Smith, I.M. (1982) Distribution of polygalacturonase, total phenolic substances, polyphenol oxidase and peroxidase in rot zones in sweetpotato. Plant Pathology 31: 119-122.

CATALANO, E.A., HASLING, V.C., DUPUY, H.P. and CONSTANTIN, R.J. (1977) Ipomeamarone in blemished and diseased sweetpotatoes (*Ipomea batatas)* 25: 94-96

CHILOSA, N.N.V., MAYONA, C.M., RWIZA, E., NDONDI, T., KILIMA, M.S., MBILINYI, L.B., KAPINGA, R., and REES, D (1995) Collaborative research between the Root and Tuber Research Programme and NRI: Post-harvest evaluation of sweetpotato varieties. Paper presented at the National Root and Tuber Coordinating Committee Meeting held at Mwanza on 16th-17th October 1995.

CIP. (1996). CIP sweetpotato facts. A compendium of key figures and analysis for 33 important sweetpotato-producing countries.
CLARK, C.A., WILDER-AYERS, J.A. and DUARTE, V. (1989) Resistance of sweetpotato to bacterial root and stem rot caused by *Erwinia chrysanthem.* Plant Disease 773: 984-987.
CLARK, C.A. (1992) Postharvest diseases of sweetpotatoes and their control. Postharvest News and Information 3: 75N-79N.
DELATE, K. and BRECHT, J.K. (1985) Impact of curing, film-wrapping and chlorination on the storability of Boniato sweetpotatoes. Proc. Fla State Hort. Soc. 98: 1877-189.
DOKE, N. and CHAI, H.B. (1985) Activation of superoxide generation and enhancement of resistance against compatible races of Phytophthora infestans in potato plants treated with digitonin. Physiol. Plant Path. 27: 323-334.
FOWLER, M.H. and STABRAWA (1993) Sweet potato marketing in Uganda: Results of a rapid appraisal. NRI Report.
GOODING, H.J. and CAMPBELL, J.S. (1964) Improvement of sweetpotato storage by sultural and shemical means. Emp. J. Exp. Agric. 32: 65-75
GULL, D.D. and DUARTE, O. (1974) Curing sweetpotatoes (*Ipomoea batatas)* under tropical conditions. Proc. Trop. Reg. Amer. Soc. Hort. 18: 166-172.
HALL, A. (1995) An overview of sweetpotato post-harvest systems and constraints in Uganda - Policy options for research. NRI Technology Policy Series. No. 1..
IMASEKI, H., URITANI, I, AND STAHMANN, M.A. (1968) Production of ethylene by injured sweetpotato root tissue. Plant &Cell Physiol. 9: 769-781
INGRAM, J.S. and HUMPHRIES, J.R.O. 1972. *Tropical Science*. **14**:131.
INOUE, H., OBA, K., ANDO, M. and URITANI, I. (1984) Enzymatic reduction of dehydroipomeamarone to ipomeamarone in sweetpotato root tissue infected by *Ceratocystis fimbriata.* Physiological Plant Pathology 25: 1-8
KAPINGA, R., EWELL, P., JEREMIAH, S. and KILEO, R. (1995) Farmers perspectives on sweetpotato and implications for research in Tanzania. A case study.(To be published jointly by the Tanzanian Ministry of Agriculture and the International Potato Center)
KILEO, R.O. and RUGIMBANA, C.K. (1995) Collaborative research between the Lake Zone FSR and Root and Tuber Research Programmes: On-farm testing of some improved sweetpotato varieties. Post-harvest evaluation of sweetpotato varieties. Paper presented at the National Root and Tuber Coordinating Committee Meeting held at Mwanza on 16th-17th October 1995.
KUMAR, G.A. and KARNAVAR, G.K. 1986. Reproductive biology of the stored product pest *Araecerus fasciculatus* (Coleoptera: Anthribidae). *Entomon.* **11** (4): 309-310.
LAWRENCE, J. (1985) Post-harvest sotrage of yam and sweetpotato. Carib. Farming July p. 32.
MARTIN, W.J., HASLING, V.C., CATALANO, E.A. and DUPUY, H.P. (1978) Effect of sweetpotato cultivars and pathogens on Ipomeamarone content of diseased tissue. 68: 863-865
NAKAYAMA, T.O.M., ALLEN, J.M., CUMMINS, S. and WANG, Y.Y.D. 1982. Disinfestation of dried foods by focused solar energy. *Journal of Food Processing and Preservation,* **1**: 1-8.
NWANA, I.E. 1993. A survey of storage Coleoptera which attack dried coco-yam chips in Nigeria. *J. stored Prod. Res.* 29 (1): 95-98.
NWANA, I.E. and AZODEH, I.C. 1984. The effect of variety and processing method on damage to dried yams by *Araecerus fasciculatus* Degeer (Coleoptera: Anthribidae). *Tropical stored Products info*. **49**: 3-7.
PILLAI, K.S. 1977. Proc. *4th Symposium International Society of tropical Root Crops.* CIAT, Cali, Ottawa:IDRC, 202.
PILLAI, K.S. and RAJAMMA, P. 1987. Storage pests of tuber crops. *Annual progress report 1986 (January-December, 1986),* pp 89-90. Trivandrum, Kerala, India, Central Tuber Crops Research Institute.
ST AMAND, P.C. and RANDLE, W.M. (1991) Ethylene production as a possible indicator of wound healing in roots of several sweetpotato cultivars. Euphytica 53: 97-102
SILIM, M.N. and AGONA, J.A. 1993. Integrated bean bruchid management. In *Proceedings of Workshop to Plan and Prioritise Post-Harvest Research*, p. 20, 6th-7th December, 1993, Kampala, Uganda.

TAKAHATA, Y., NODA, T., and NAGATA, T. (1992) Varietal diversity of free sugar composition in storage root of sweetpotato. Japan. J. Brees. 42: 515-521

THOMPSON, A.K. (1972) Report on an assignment on secondment to the Jamaican government as food storage advisor. TPI Report R278.

WALKER TS & CC CRISSMAN. 1996. Case studies of the economic impact of CIP related technologies. Lima (Peru). International Potato Center (CIP).

WALTER, W.M. and SCHADEL, W.E. (1982) A rapid method for evaluating curing progress in sweetpotatoes. J. Amer. Soc. Hort. Sci. 108: 1129-1130

WALTER, W.M. and SCHADEL, W.E. (1983) Structure and composition of normal skin (periderm) and wound tissue from cured sweetpotatoes. J.Amer. Soc. Hort. Sci. 108: 909-914

WILSON, D.D., SON, K.C., SEVERSON, R.F. and KAYS, S.J. (1990) Effect of a pentacyclic triterpene from sweetpotato storage roots on oviposition by the sweetpotato weevil.

WOOLFE, J. (1992) Sweetpotato: An Untapped Food Resource. Cambridge University Press, Cambridge, UK

PROJECT PURPOSE

The Programme purpose addressed by this project is "Improved storage techniques for fresh produce within specific farming systems developed and promoted. "

As set out in the *Background* sweetpotato is an important food security crop in many developing countries, including those of East Africa which was the focus of this project. However, the full potential of the crop is limited by its perishability. This project sought to improve the storage of sweetpotato in both fresh and dried forms. In the case of fresh sweetpotato the main objective was to determine whether there was sufficient diversity among the available germplasm to allow selection of cultivars with improved keeping qualities. Furthermore, if this were the case, the project sought to determine what characteristics such cultivars might have, to allow easy selection. In addition a better understanding of the factors controlling perishability would allow improvement of handling techniques and storage conditions. In the case of dried storage the main emphasis was to identify methods to control insect pests, which are the main factor limiting storage time.

RESEARCH ACTIVITIES

Research activities conducted to achieve the outputs of the project are summarised here. Full details are given in publications as indicated at the top of each section. These publications are provided with this report in both hard form and electronic form wherever possible.

Output 1. Quality criteria of sweetpotato roots for fresh consumption and simple processing identified and disseminated to national programmes and international organisations, so contributing to more effective cultivar selection.

The work for this output was conducted as a collaboration between NRI and LZARDI Ukiriguru.

1.1 Collection of existing information on preference and selection criteria of sweetpotato varieties at farm level in Tanzania:

Kapinga *et al.* (1996)

During 1996 existing information on consumer preferences from institutes throughout Tanzania was collated and reviewed by staff of the Root and Tuber Crops Programme of LZARDI Ukiriguru.

1.2 Survey of preferences and selection criteria of sweetpotato for consumers and traders in urban areas of the Lake Zone of Tanzania.

Kapinga *et al.* (1997)

A study using informal survey techniques was carried out in order to gain an insight on the preferences of sweetpotato varieties by urban consumers. The survey was conducted in September/October 1996 in three districts: Mwanza, Meatu and Ukerewe, all of which are known to be important for sweetpotato production and marketing. Semi-formal interviews with a checklist were used. A total of 58 sweetpotato consuming households and 35 sweetpotato traders (primarily retailers) were interviewed. Interviewees were selected on the basis that they were known to be sweetpotato consumers or traders.

The information collected from urban households included the following:

⇒ sweetpotato consumption patterns
⇒ the quantity and frequency of purchase of sweetpotato
⇒ acceptance and rejection of specific sweetpotato varieties
⇒ utilization practices for sweetpotato roots
⇒ post-harvest handling of sweetpotato
⇒ sweetpotato cultivation and the varieties commonly grown
⇒ marketing of sweetpotato

For market agents the information collected included:

⇒ the nature of markets and categories of traders
⇒ marketing of sweetpotato
⇒ storage after purchase
⇒ varietal preferences.

1.3 Testing the potential for using an on-station trained taste panel to assess the sensory characteristics of sweetpotato cultivars

Rwiza *et al.* (2000), Tomlins (1998), Kapinga *et al.* (1998)

Trained taste panels can be used to produce sensory profiles of varieties. This study was carried out in order to investigate whether such panels could be used as a means of screening new varieties for consumer acceptability. The aim was to identify a sensory profile that accurately represented the preferences of consumers.

The initial trained taste panel consisted of 10 staff from LZARDI-Ukiriguru, although the panel size was reduced to 8 for the subsequent studies. The panel agreed on 12 terms to describe the sensory characteristics. In subsequent taste tests on cooked samples each panel member scored for each of these 12 characteristics. For each tasting, each panellist was presented with between 4 and 6 samples at random. Sessions were repeated until each cultivar was assessed two times by each panellist. The two assessments were averaged for subsequent analyses.

In each of three districts chosen for consumer tests (Mwanza, Meatu and Misungwi) cooked samples of 5-6 locally available varieties were assessed and ranked by 100 individual consumers. Samples of the same varieties were then assessed and profiled by the trained taste panel. In this way a profile of the most and least popular cultivars could be obtained and compared.

Samples were analysed for dry matter content and for sugar composition using HPLC.

Output 2. Cultivar differences and effect of environmental factors (pre- and post-harvest) with respect to quality and perishability of fresh roots identified.

Output 3. Physiological characteristics of storage roots associated with good quality, long shelf-life and resistance to pests and diseases identified and disseminated.

The activities for these two outputs were frequently common, and will therefore be considered together. The work for this output was conducted as a collaboration between NRI, Cranfield University and several institutes in Tanzania, namely LZARDI Ukiriguru, Sugarcane Institute, HortiTengeru, MARTI-Uyole, Chollima-Dakawa and Sokoine University of Agriculture. Work was also conducted by Quirien van Oirschot as a PhD programme, (registered at Cranfield University and supervised by the project manager and Dr Julia Aked) and by Marton Muhanna as an Mphil programme (registered at Cranfield University and supervised by Dr Julia Aked and the project manager).

3.1 Assessment of damage of sweetpotatoes in urban markets of Tanzania

Rees *et al.* (2001a), Mtunda *et al.* (2000)

Observations were made in markets of Dar es Salaam, Morogoro and Mwanza, and also on Ukerewe Island, a sweetpotato supply area, during months of peak and low supply in 1996 and 1997. For each market, samples of wholesale sweetpotatoes were collected twice in each of the high and low seasons of sweetpotato supply. In order to obtain an estimate of the levels of damage for roots arriving at market, the roots in each sack were sorted into damage categories. In order to determine the effect of damage on shelf-life roots were selected from each damage category and stored under simulated marketing conditions (open sacks, rolled down to half height, in a well ventilated room). The extent of root deterioration was then assessed weekly in terms of rotting and loss of fresh weight. (see section 3.3)

3.2 Assessing the sensory characteristics of five sweetpotato cultivars and their changes during storage under simulated tropical conditions

van Oirschot (2000), van Oirschot *et al.* (2001)

A taste panel of 13 NRI staff members was used to measure cultivar variation in taste and to test how sensory properties change when stored under simulated tropical conditions. Five sweetpotato cultivars were tested: Kemb 10, KSP 20, Zapallo, Yan Shu 1, and SPK004. These were assessed at 1, 4 and 8 weeks after harvesting. A principal component analysis was applied to summarise the findings.

The roots were grown by the International Potato Center (CIP) in Nairobi, Kenya, and air-freighted to the UK. The roots from consignment 1 were used to generate descriptors and select panellists from NRI staff, and the roots from consignment 2 were used to assess profiles during storage.

The sweetpotato roots were stored under simulated tropical storage conditions in controlled temperature rooms at 26°C. The roots were piled on racks inside plastic bins (0.6 x 0.37 m), suspended above a layer of water, through which air was bubbled providing ventilation and a relative humidity of approximately 80% RH.
All five sweetpotato cultivars were assessed during four tasting sessions at 1, 4 and 8 weeks of storage. All of the thirteen panellists tasted all five cultivars at every session.

3.3 Germplasm evaluation trial to assess the post-harvest characteristics of a wide range of sweetpotato cultivars (LZARDI-Ukiriguru)

Rees *et al.* (2001b)

This trial was conducted at LZARDI-Ukiriguru during 1997 and 1998. 22 sweetpotato cultivars, including local landraces, new crosses and introduced germplasm were selected to provide a wide range of root characteristics (see below). The field trial was planted as complete randomised block design with two replicates with plots of 6 m x 2 rows (3 plants/m).

Cultivars used for trial

1. Kagole
2. Polista
3. Tula Omushako
4. 440088
5. Kombegi
6. 440037
7. 440215
8. 440025**
9. 440144/440121*
10. 440113
11. Nyamwisekeleja
12. Bagalanentukulu
13. Bilagala
14. Ipembe hja ngh’dongo
15. Lutambi
16. Shinamugi
17. Tabu waseka
18. TIS 8250
19. Luganza
20. Itemue
21. SPN/0
22. Mwanamonde

*440121 was used in 1997 and 440144 in 1998
** omitted in 1998

Following harvest, roots of marketable size (greater than 2.5 cm diameter) and low levels of visible damage were selected for post-harvest evaluation. 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 two 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.

At the start of the trials samples of roots from each cultivar were taken to measure dry matter content, root size (weight, length and girth), hardness and sap sugar content. In 1998 further samples were freeze dried and transported to the UK for subsequent analysis of sugar composition by HPLC.

In order to assessing keeping qualities, roots were assessed at weekly intervals for weight loss and rotting (internal and external).

Assessment methods

The following methods for root assessment were used for many trials within this project and are therefore outlined in more detail below.

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 6 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.

Surface insect damage
External insect damage was due to the rough weevil (*Blosyrus* spp.), which grazes on the root surface. Damage was recorded using a 1- 5 scale depending on the % of the surface damaged (1: 0%, 2: 0-25%, 3: 25-50%, 4: 50-75%, 5:75-100%). This form of damage only occurs prior to harvest, so that damage for each sack could be calculated as the average of all roots assessed in the course of the trial (2 per week).

Root hardness, cortex thickness, latex production
Hardness was measured using a handheld 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 mm 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).

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

HPLC anlaysis for sugar content
Freeze-dried samples were ground and extracted in water (1 g sample in 20 ml water) by shaking for one hour at room temperature. The extract was filtered through muslin and filter paper, diluted with acetonitrile to 80% aceteonitrile and further filtered through a 0.45 um PTFE syringe filter. 10 µl samples were injected onto an amino-bonded 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.

3.4 Uniform multilocational trial to assess environmental effects on post-harvest characteristics

(Rees *et al.* (2001b), Rees *et al.* (2001c)

Trials were conducted in 1997 and 1998 at five sites around Tanzania. At each site 5 key Tanzanian cultivars were included, together with additional local varieties. The sites and cultivars used are given in the Table below. The five key cultivars are shown in bold.

LZARDI-Ukiriguru	Sugarcane Institute	HortiTengeru	MARTI-Uyole	Chollima-Dakawa
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				

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

The assessment of post-harvest characteristics and keeping qualities was as for the trial described in 3.3, except that roots were also subjected to standardised damage treatments to test the cultivar susceptibility to damage. In 1997 the damage treatment consisted of a diagonal cut to halfway across each root. In 1998 the damage treatment consisted of dropping a sack of roots from a height of 1 m 4 times.

3.5 Trials conducted to determine the physiological basis of differences in keeping qualities

Van Oirschot (2000)

14 Trials were conducted as part of the study to determine the physiological basis of differences in keeping qualities among sweetpotato cultivars. The cultivars, location and storage methods used are summarised in the tables shown on the following pages.

A wide range of methods were used during these trials. Of particular note are the staining methods used to assess the progress of wound-healing and the use of a modified porometer to measure directly the rate of water loss through the surface of a root. Further details are given in van Oirschot (2000).

a) Head of the porometer with round aperture and padding.
b) Taking measurements upon sweetpotato roots.

Overview of the cultivars used in each of the trials

Trial	Cultivars				
Trial 1	Kemb 10	KSP 20	SPK 004	Yan Shu 1	Zapallo
Trial 2	Kemb 10	KSP 20	SPK 004	Yan Shu 1	Zapallo
Trial 3	440025 440037 440088 440113 440121 440215	Bagala Bilagala Budagala Budagala mpya Iboja Ipembe	Itemve Kagole Kombegi Luganza Lutambi Nyamwisekeleya	Polista Shinamugi SP/93/34 Tabu Waseka TIS 8250 Tula Omushako	Mwanamonde Sinia B SPN/0 SP/93/2 SP/93/23
Trial 4	Mwanamonde	Sinia B	SPN/0	SP/93/2	SP/93/23
Trial 5	Kemb 10	KSP 20	SPK 004	Yan Shu 1	Zapallo
Trial 6	Kemb 10	KSP 20	SPK 004	Yan Shu 1	Zapallo
Trial 7	BP1-SP-2 Caplina	Julian Kemb 10	KSP 20 Salyboro	SPK 004 Yarada	Yan Shu 1 Zapallo
Trial 8	BP1-SP-2 Caplina	Julian Kemb 10	KSP 20 Salyboro	SPK 004 Yarada	Yan Shu 1 Zapallo
Trial 9	BP1-SP-2 Caplina	Julian Kemb 10	KSP 20 Salyboro	SPK 004 Yarada	Yan Shu 1 Zapallo
Trial 10	BP1-SP-2 Caplina	Julian Kemb 10	KSP 20 Salyboro	SPK 004 Yarada	Yan Shu 1 Zapallo
Trial 11	BP1-SP-2 Caplina	Julian* Kemb 10	KSP 20 Salyboro	SPK 004 Yarada	Yan Shu 1 Zapallo
Trial 11B	BP1-SP-2 Caplina	Julian Kemb 10	KSP 20 Salyboro	SPK 004 Yarada	Yan Shu 1 Zapallo
Trial 12B	Santa Amaro, Mugande	SPK 013, NIS/94/320	Sowola, Naveto,	KSP 20, Yan Shu 1	
Trial 13	BP1-SP-2 Caplina	Julian Kemb 10	KSP 20 Salyboro	SPK 004 Yarada**	Yan Shu 1 Zapallo
Trial 14	BP1-SP-2 Caplina	Julian Kemb 10	KSP 20 Salyboro SPK 004	Yarada Yan Shu 1 Zapallo	Polista SPN/0 SP/93/2

* *not in trial 11b*
** *not in trial 13b*

Overview of location, field design and planting and harvesting dates for each of the trials.

	Location	Number of cultivars	Field design	Date of planting	Date of harvesting
Trial 1	CIP	5	-	15-7-96	22-1-97
Trial 2	CIP	5	-	15-7-96	17-3-97
Trial 3	ARTI (Station)	22 9	CRD*, 3 rep 2 rows x 6 m CRD*, 2 rep 6 rows x 6 m	28-12-96**) 28-12-96**)	23-6-97 23-6-97
Trial 4	On Farm Trial	5	2 rows, 2 farms	Jan 97	7-7-97
Trial 5	CIP	5	-	July 97	27-11- 97
Trial 6	CIP	5	-	July 97	Jan 98
Trial 7	CIP	10	3-4 rows 100 plants per row	20-11-97	28-4-98
Trial 8	CIP	5	3-4 rows 100 plants per row	20-11-97	12-5-98
Trial 9	CIP	10	CRD*, 3 reps 90/120 plants per cult	25-5-98	27-10-98
Trial 10	CIP	10	CRD*	25-5-98	4-11-98
Trial 11	CIP	10	CRD*, 3 reps 90/120 plants per cult	June 98	11-11-98
Trial 11B **Trial 12B**	CIP	8	-	July 98	1-12-98
Trial 13	CIP	9	-	July 98	21-12-98
Trial 13B	CIP	10	-	July 98	7-1-99
Trial 14	CIP ARTI (Lake Site)	10 3	-	Nov 98 Nov 98	March 99 March 99

**) CRD = Complete Randomised Design*
***) replanted on the 17th of January due to poor establishment of some vines.*

Overview of storage set-up and conditions for each of the trials

	Storage	Location	Temperature	RH	
Trial 1	Bins with humidification by airflow	NRI	26.1 ± 0.5°C	82.2 ± 4 %	
Trial 2	Bins with humidification by airflow	NRI	26.1± 0.1°C	73.2±-7.3%	
Trial 3	Polythene woven storage bags	ARTI Ukiriguru	24.2 ± 0.6°C	84.1 ± 7.6%	Ambient: T= 24.2 ± 1.4°C, RH= 56.1 ± 5.7% Wound healing: T = 24.5 ± 6.0, RH = 97.2 ± 6.0%
Trial 4	Polythene woven storage bags	ARTI Ukiriguru	23.5 ± 0.9°C	64.5 ± 8.8%	Ambient: T=23.1 ± 0.9°C, RH= 49.1± 11.9%
Trial 5*	Bins with humidification by standing water	NRI	≅26°C	≅ 95%	
Trial 6*	Bins with humidification by standing water	NRI	≅26°C	≅ 95%	
Trial 7	Plastic crates (lined with plastic for 2 days)	NARL – Nairobi, Kenya	20.7 ± 1.4°C	85.9 ± 6.5%,	
Trial 8	Plastic crates (lined with plastic for 2 days)	NARL – Nairobi, Kenya	20.7 ± 1.6°C	83.3 ± 6.5%,	
Trial 9	Plastic crates (lined with plastic for 2 days)	NARL – Nairobi, Kenya	21.1 ± 1.7°C	68.6 ± 10.5%	
Trial 10	Plastic crates (lined with plastic for 2 days)	NARL – Nairobi, Kenya	21.0 ± 1.9°C	67.6 ± 12%	
Trial 11 **Trial 11B**	Plastic crates (lined with plastic for 2 days)	NARL – Nairobi, Kenya	20.7 ± 1.9°C	72.3 ± 11.2%	
Trial 12B	Plastic Crates	NARL – Nairobi, Kenya	21°C	67.3%	
Trial 13	Plastic Crates	NARL – Nairobi, Kenya	26°C	85-90%	
Trial 14	Controlled relative humidity chambers	CT-room, NRI	T = 26°C,	Low 58% Intermediate 65% High 95%	

- *Data estimated from regular readings*

3.6 Identification of the main post-harvest rotting pathogens for sweetpotato in Morogoro region Tanzania

Muhanna (2001)

From January to May 1998, sweetpotato roots of cultivar SPN/0, one of the most pupular cultivars in Tanzania, were collected from farmers fields in four locations of Morogoro region, and also from urban markets. These roots were stored. Developing disease symptoms were noted. Lesions were isolated and the rotting pathogens identified. Koch's postulate for verifying the identity of rotting pathogens was tested by re-infecting clean roots with the isolated pathogen to test that the same symptoms were observed.

3.7 Trials conducted to assess sweetpotato cultivars for susceptibility to *Rhizopus oryzae*, and physiological basis for differences.

Muhanna (2001)

Initial trials were conducted in 1998 and 1999 on Tanzanian cultivars grown on-station at Sokoine University. Later experiments were conducted at Silsoe College using roots which had been grown by CIP in Nairobi, and air-freighted to the UK. A summary of the trials grown and cultivars used is given below.

Cultivars used during trials grown in Tanzania,

Experiments 1, 2 and 3 conducted in 1998	Experiments 4,5 and 6 conducted in September 1999	Experiments 7 and 8 conducted in Nov/Dec 1999
Mwanamonde SPN/0 Iboja Budagala Sinia Hali ya mtumwa Chenzeru Sindano Elias Ukerewe	Mwanamonde SPN/0 Iboja Sinia Ukerewe	SPN/0 Iboja Sinia Budagala

Cultivars used during trials grown by CIP and conducted in the UK

Experiments 9, 10 and 11 conducted in May/Aug 2000
KSP 20 SPK004 Kemb 10 Yan Shu 1 Zapallo

Roots were innoculated by removing a disc of root tissue and inserting a disc of mycelia obtained from the edge of a culture grown on agar. Roots were then stored under controlled conditions and the growth of the rotting pathogen assessed in terms of lesion size and weight

During experiments conducted to determine the physiological basis of resistance, several methods were used. These included staining for lignin production, sugar analysis by HPLC, measurement of phenolics and production of growth agar containing sweetpotato tissue, to test for the presence of chemical inhibitors of pathogen growth. Further details of all these methods are given in Muhanna (2001).

3.8 Testing the effects of storage environment on keeping qualities of sweetpotato cultivars.

Mbilinyi *et al.* (2000)

A study was conducted to examine the effect of storage environment on the keeping qualities of five sweet potato cultivars. Five clones of sweet potato, namely Budagala, Iboja, Mwanamonde, Sinia and SPN/O were harvested and divided into four sub-plots and subjected to four different storage environments. These consisted of an open sack rolled down, closed sack, double closed sack and lined closed sack (water proof polythene bag closed in closed sack). Roots were assessed weekly throughout the experiment for weight, external appearance (rotting) and internal appearance by cutting the roots into longitudinal and cross sections. Data on weight, rotting, sprouting, rooting, wetting, smell, sweet potato weevil infestation, withering and fungal growth were recorded weekly for a period of six weeks. After three to fours weeks of storage, the percentage relative humidity and carbon dioxide build up were also recorded.

Output 4: The identification of appropriate methods for reducing losses due to insect infestation of dried sweetpotato chips during storage in Uganda.

The work for this output was conducted by Ambrose Agona of the National Agricultural Research Organisation (NARO) of Uganda, as part of his PhD programme (registered at the University of Zimbabwe, supervised by Professor D.P. Giga of the University of Zimbabwe and co-supervised by Dr Silim M Nahdy of NARO).

4.1 A survey of post-harvest practices and constraints of dried sweetpotato chip processing, storage and utilisation

Agona (1998)

The survey was conducted by Mr Agona with help from staff of the National Agricultural Research Organisation (NARO) in Kumi district of Uganda. The main objectives of the survey were:

- To establish the major types of food crops grown in Kumi district, and to determine the relative importance of sweet potato in the area;
- To determine farmers' methods of processing, utilisation, storage and marketing of dried sweet potato chips;
- To identify storage loss-causing organisms of economic importance on dried sweet potato chips;
- To identify the major insect pest species of dried chips for further research;
- To establish farmers' perceptions of storage losses and management methods;
- To identify resistant sweetpotato varieties under farmers' storage conditions.

4.2 Studies on aspects of the biology of *Araecerus fasciculatus* on dried sweetpotato chips.

Agona (1998)

The biology of *Areacerus fasciculatus* was studied on-station at Kawanda Research station, to enable more effect methods of control to be developed. Methods used are described in Agona (1998).

4.3 Development and validation of novel pest control methods against *Araecerus fasciculatus* infestation of dried sweetpotato chips.

Agona (1998)

Control methods assessed were salting, parboiling and solar disinfestation. In addition, the relative susceptibility of a range of sweetpotato cultivars were tested.

OUTPUTS

The Outputs of the project are summarised here. Only the main results considered most pertinent to the achievement of the output are includeds. The main publications covering the work are given at the start of each section and in addition the source of each Table and Figure is included. These publications are provided with this report in both hard form and electronic form wherever possible, and can be consulted for further details.

Output 1. Quality criteria of sweetpotato roots for fresh consumption and simple processing identified and disseminated to national programmes and international organisations, so contributing to more effective cultivar selection.

1.1 Overview for output 1

The sweetpotato breeding programmes in Tanzania and other East African countries have developed significantly in the last few years, and have started to release cultivars with substantially improved production characteristics. For these new cultivars to be successful, it is clearly vital that they have post-harvest characteristics acceptable to consumers. The overall aim of this Output was to develop a practical strategy that sweetpotato breeders for East Africa (both within National Programmes and within International Institutions) could use to select such cultivars. This includes both determining what characteristics are important, and developing methods for assessing cultivars within breeding programmes. The development of such methods was not specified in the original output, but was considered vital for its achievement.

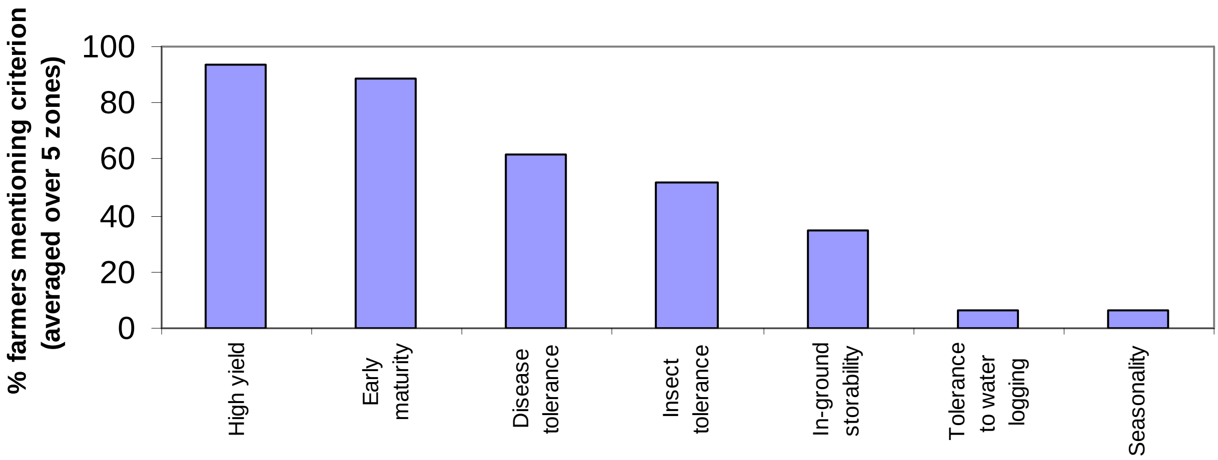
For this work, the focus was on Tanzania. Existing information on consumer preferences was collected and reviewed. As anticipated, it was found that although there was information on criteria for cultivar selection by farmers, very little information existed on the preferences of urban consumers. As a result, survey work was conducted in Lake Zone of Tanzania to identify key criteria. Once these criteria were identified, the next step was to determine how to use this information to assess cultivars. Given that many of the criteria, such as "good taste" could not be measured by standard analytical methods, a study was carried out to determine whether trained taste panels could provide a practical way to do this. The results obtained were very promising.
The least successful part of this Output has been dissemination of the findings. So far, this has occurred primarily through conference presentations. More effective methods are being explored in a follow-on project, as discussed in *Contribution of Outputs*.

1.2 Existing information on consumer preferences

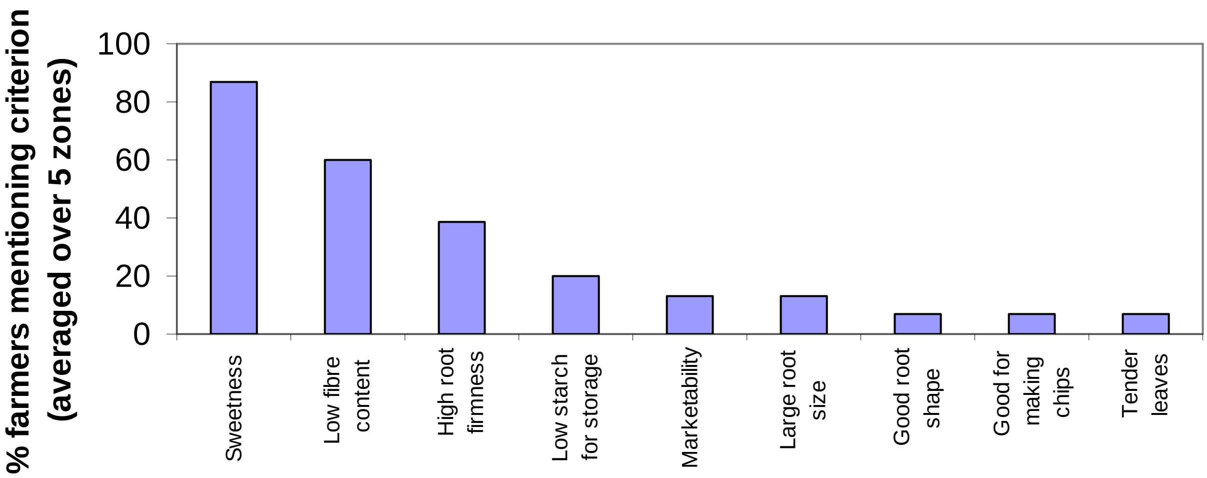
Kapinga *et al*. (1996)

Data was collected from institutes throughout Tanzania by the Tanzanian National Root and Tuber Crops Programme (TNRTCP). The existing information essentially consisted of results from surveys of farmers. Figure 1.1 shows the main selection criteria for sweetpotato cultivars as mentioned by farmers interviewed in five zones of sweetpotato producing zones of Tanzania. Their relative importance is indicated as the percentage of farmers, averaged over the five zones, that mentioned each one. As a method of assessing relative importance of criteria, this could be criticised, but at least it gives an indication of ranking. The criteria are separated into production and post-harvest, and it can be clearly seen that several post-harvest criteria are considered by farmers to be as important as production characteristics; notably sweetness, low fibre content and high root firmness (relating to high dry matter content).

Figure 1.1 Selection criteria for sweetpotato varieties as mentioned by surveyed farmers (%). Data averaged over 5 zones. (Compiled from FSR-NCU Data file 1996.). (Figure compiled from Kapinga *et al.* 1996)
a. Production characteristics



b. Post-harvest characteristics



Data was collected from Eastern zone, Southern zone, Western zone, Southern Highlands,and Lake zone of Tanzania. For each criterion the % of farmers interviewed who mentioned that as an important criterion was calculated. The mean percentage was calculated giving equal weighting for each of the five regions. It can thus only be taken as a qualitative indication of the importance of that criterion.

Information was also obtained on existing cultivars and the extent to which farmers were happy with these. As an example, Tables 1.2, 1.3 and 1.4 show the characteristics of commonly grown cultivars in terms of root firmness, sweetness and fibre content. In all cases there is a significant spread among cultivars in these characteristics. Although the ideal levels are not clear for firmness and sweetness, it is known that preferred cultivars should have as little fibre as possible. Nevertheless, a significant number of fibrous cultivars are grown. Clearly this indicates that these cultivars are desirable for other reasons, but this underlines the potential for improvement, if good post-harvest characteristics could be combined with good production characteristics.

Table 1.2 . Root firmness of commonly grown sweetpotato varieties. (Compiled from FSR - NCU data file 1996) (Kapinga *et al.* (1996))

Zone	No. of varieties	Very firm	Med. Firm	Slightly firm
Eastern	-	-	-	-
Southern	2	2	0	0
Western	-	-	-	-
S.Highlands	36	8	22	6
Central	-	-	-	-
Lake	-	-	-	-
Total	38	10	22	6
Percentage	100	26	58	16

The overall percentage has been calculated without weighting the varieties with respect to their importance in each zone, nor weighting the zones with respect to their importance for sweetpotato production

Table 1.3. Root sweetness of commonly grown sweetpotato varieties. (Compiled from FSR - NCU datafile 1996) (Kapinga *et al.* (1996))

Zone	No. of varieties	Very sweet	Sweet	Not/Slightly sweet
Eastern	4	1	2	1
Southern	3	1	2	0
Western	4	2	0	2
S.Highlands	36	12	21	3
Central	3	0	2	1
Lake	-	-	-	-
Total	50	16	27	7
Percentage		32	54	14

The overall percentage has been calculated without weighting the varieties with respect to their importance in each zone, nor weighting the zones with respect to their importance for sweetpotato production

Table 1.4. Root texture of commonly grown sweetpotato varieties.
(Compiled from FSR-NCU data file 1996) (Kapinga *et al.* (1996))

Zone	No.of varieties	Texture		
		No fibre	Low fibre	Very Fibrous
Eastern	-	-	-	-
Southern	3	0	3	0
Western	12	6	4	2
S.Highlands	35	21	8	6
Central	3	2	1	0
Lake	-	-	-	-
Total	53	29	16	8
Percentage		55	30	15

The overall percentage has been calculated without weighting the varieties with respect to their importance in each zone, nor weighting the zones with respect to their importance for sweetpotato production

1.3 Preferences of urban consumers and traders as determined by survey

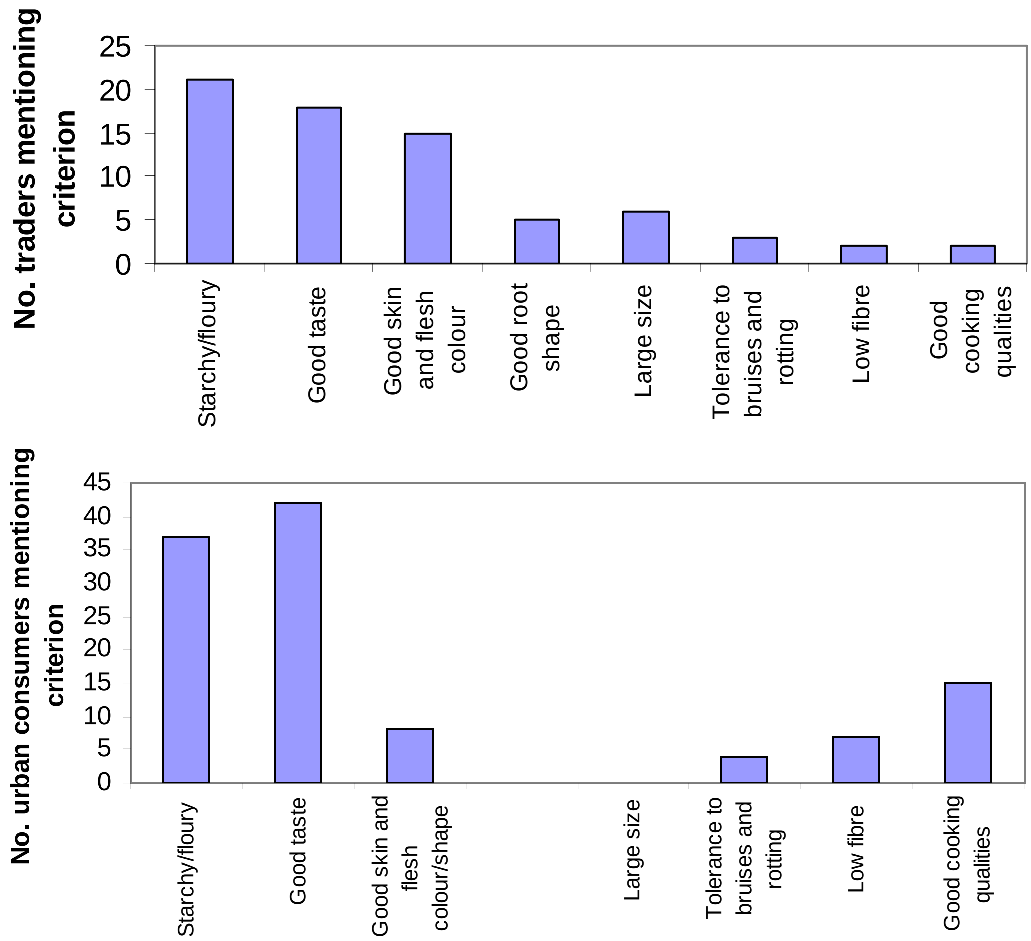
Kapinga *et al.* (1997)

The review described in section 1.2 highlighted the lack of knowledge on the preferences of consumers in urban areas where sweetpotato has recently gained market potential. Therefore a study by means of informal survey techniques was carried out to gain an insight on the preferences of sweetpotato varieties by urban consumers. The survey was conducted in September/October 1996 in three districts of Lake Zone: Mwanza, Meatu and Ukerewe all of which are known to be important for sweetpotato production and marketing. Semi-formal interviews with a checklist were used. A total of 58 sweetpotato consuming households and 35 sweetpotato traders (primarily retailers) were interviewed. Interviewees were selected on the basis that they were known to be sweetpotato consumers or traders, the conclusions from this survey cannot therefore be taken as an indication of the preferences of the population as a whole.

The main objective of the survey was to identify the characteristics that urban consumers and traders consider important in sweetpotato varieties for fresh consumption and also for processing.

Figure 1.2 shows the criteria mentioned and the number of traders (from a total of 35) and the number of consumers (from a total of 55) mentioning each. For both consumers and traders the two main criteria were starchy/floury and good taste. There was reasonable agreement for the other criteria except that not surprisingly traders seem concerned that roots have good appearance, whereas consumers are more concerned with good cooking qualities. For neither group was good processing quality specified.

Figure 1.2 Preferred criteria for sweetpotato cultivars as mentioned by traders and consumers in Mwanza, Meatu and Ukerewe regions of Lake Zone Tanzania. (Figure compiled from Kapinga *et al.* (1997))

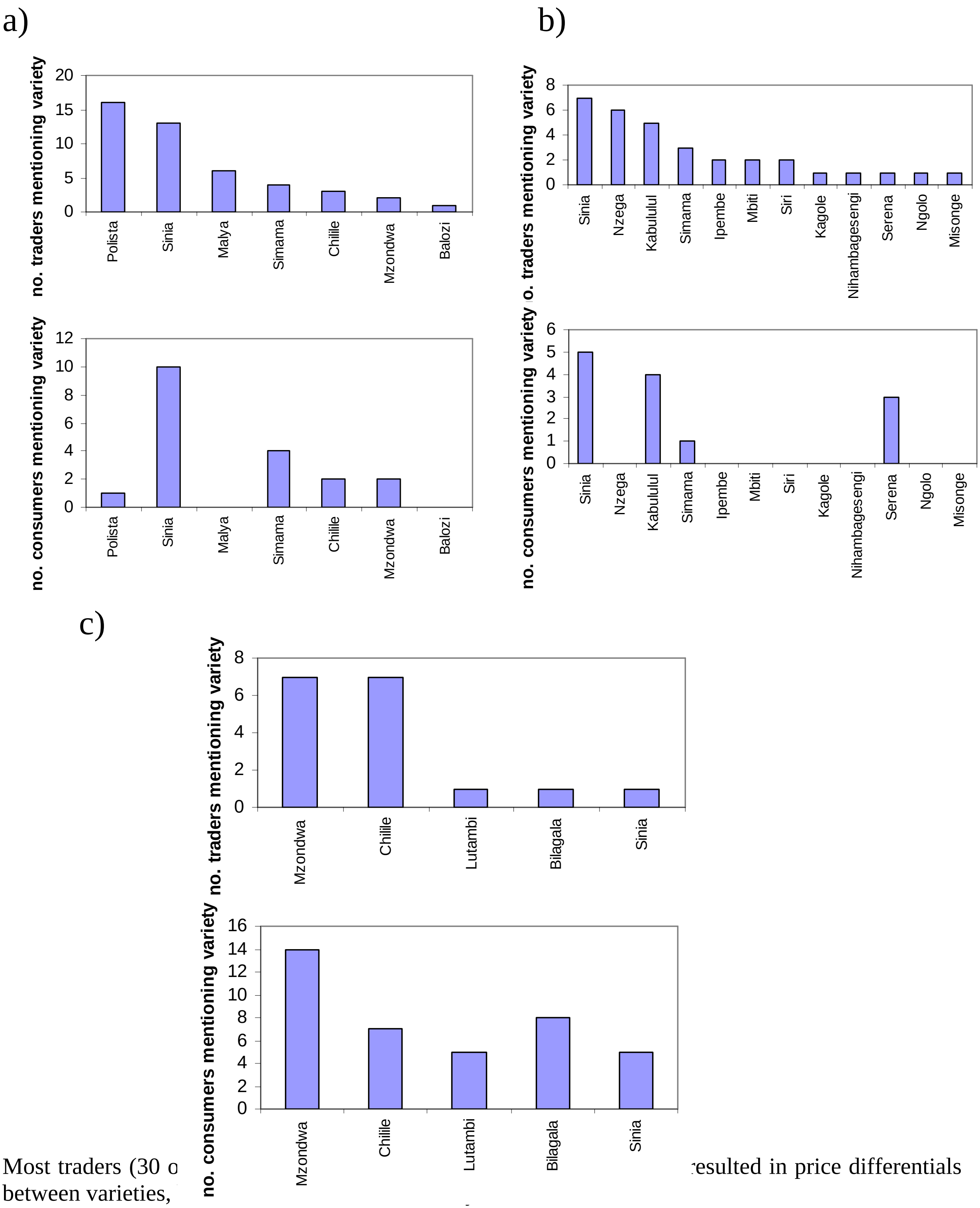


A second method used to assess desirable characteristics for sweetpotato roots was to determine which specific varieties consumers/traders preferred and why.

The total number of varieties mentioned by name was high, with over 40 varieties mentioned for the three districts. The main varieties and their relative popularity are shown in Figure 1.3 Although both consumers and traders expressed preferences for specific varieties, given the high number of varieties and the relatively small scale of this survey rankings of cultivars must be tentative. However certain varieties were notable. For example the most popular variety identified by consumers in both Mwanza and Meatu was Sinia and this variety ranked fourth in Ukerewe. On the other hand, Mzondwa was the most popular variety among consumers in Ukerewe, but was not preferred in either of the other districts. The subjective nature of consumer preferences is underlined by the fact that Mzondwa was identified as a good variety by 14 households in Ukerewe, but as a bad variety by 5 households in Ukerewe and 3 households in Mwanza (data not shown).

When comparing varietal preferences of traders with those of consumers there was reasonable agreement, but with some notable exception in Mwanza and Meatu. For example, Polista is the most popular variety among traders in Mwanza, but was not mentioned by consumers interviewed in any district. This is probably an example of a new variety that consumers have yet to learn to recognise. It was notable that agreement between consumers and traders was strongest in Ukerewe, which could be a consequence of the fact that this is a sweetpotato producing area.

Figure 1.3 Cultivars preferred by traders and consumers in a) Mwanza, b) Meatu and c) Ukerewe (Figure compiled from Kapinga *et al.* (1997))



Most traders (30 o … resulted in price differentials between varieties, Consumers who also grew their own sweetpotatoes were asked which varieties they preferred to grow. The ranking of varieties in this case was similar but not identical to the varieties preferred for buying (data not shown).

Other outputs of this project are focused on keeping qualities of sweetpotatoes. Information on this aspect, and the importance of storage was obtained from the survey. Both consumers (Table 1.5) and traders store sweetpotato roots. At the household level most consumers would not store beyond 3 days (Table 1.6), while in the market it was relatively common to store up to 5 days. 15 out of the 58 consumers interviewed said that they practised longer term pit storage. Consumers were divided as to whether some varieties stored better than others (Table 1.7), but certain varieties were highlighted as storing well, including Sinia, Simama, Ipembe, Koloboi, Chilile and Mzondwa (Table 1.8). The main forms of deterioration mentioned during storage were rotting and water loss, with no mention of sprouting or changes in taste/texture. Colour changes were noted in Ukerewe during storage.

Table 1.5 Extent of Storage of fresh sweetpotato roots after purchase by urban consumers (Kapinga *et al.* (1997))

	Number of households			
	Mwanza (N=18)	Meatu (N=20)	Ukerewe (N=20)	Total (N=58)
Sweetpotato stored	11	13	18	42
Sweetpotato not stored	7	7	2	16

Table 1.6 Normal Storage time of fresh sweetpotato fresh roots after purchase in urban households (Kapinga *et al.* (1997))

No. of days	Number of households			
	Mwanza (N = 8)	Meatu (N =11)	Ukerewe (N = 18)	**Total** (N = 37)
1-3 days	5	7	12	24
4-7 days	1	2	4	**7**
8-14 days	2	2	2	**6**

N.B. only 37 of the 42 households which practised some form of storage responded to the question about time of storage.

Table 1.7 Opinions of urban consumers on the existence of better storing varieties (Kapinga *et al.* (1997))

Existence of better storing varieties	Number of households			
	Mwanza (N=11)	Meatu (N=13)	Ukerewe (N=18)	Total (N=42)
None	3	6	10	19
Yes	8	7	8	23

Table 1.8 Sweetpotato varieties considered by urban consumers to store well. (Kapinga *et al.* (1997))

Mwanza (N = 8)	No.of households	Meatu (N = 7)	No. of households	Ukerewe (N = 8)	No. of houiseholds
Sinia	**5**	Ipembe	**2**	Chilile	**3**
Simama	2	Koloboi	2	Mzondwa	3
Budagala	1	Sengi	1	Sinia	1
Julias	1	Serena	1	Rangimbili	1
Mwiyangi	1	Ngosha atena nimo	1		

Although none of consumers interviewed in Ukerewe used processed sweetpotato, processing was carried out to some extent in Mwanza and was common in Meatu. Two types of product, *Michembe* (sliced and sun-dried) and *Matobolwa* (boiled, sliced and dried) were used. Consumers obtained their processed products either by processing at home or buying from the market in roughly equal proportions. There were distinct cultivar preferences for processing, especially in Meatu, and these did not correspond to the varieties that are preferred for fresh consumption. Most households that used processed products would store them, usually in sacks. Only consumers in Meatu were used to storing for long periods. In this case a storage period of 13-24 months was usually possible. Insect attack was said to be the most important form of loss, and various control methods were described.

1.4 The potential for using trained taste panels to assess sensory characteristics of cultivars

Rwiza *et al.* (2000), Kapinga *et al.* (1998), Tomlins (1998)

With respect to sensory quality criteria considered most important for fresh sweetpotato roots a very consistent picture emerged (Section 1.3). Both consumers and traders considered that high dry matter content (also expressed as starchy, or floury) and good taste were the most important criteria. This was followed by cooking quality (referring to the time needed for cooking) and the colour of the flesh and skin. Other criteria mentioned were low fibre content, good storability after purchase and root size.

Many of the criteria mentioned above are very complex. Many are subjective, and therefore very difficult or impossible to measure by analytical means. Direct consumer testing of new varieties is very expensive and time consuming, as, in order to get a reliable result, it is necessary to use a large number of consumers (usually at least 100). Trained taste panels can be used to produce sensory profiles of varieties. A study was carried out in order to investigate whether such panels could be used as a means of screening new varieties for consumer acceptability. The procedure would depend upon the identification of a sensory profile that accurately represented the preferences of consumers. One key question is how consistent consumer preferences are across the country, and therefore whether one consistently preferred profile exists.

The taste panel methodology was first developed and tested using a trial of 12 contrasting varieties. Following this a study was carried out using local varieties at three locations in Lake Zone to obtain "preferred" profiles.

Development of profiles for 12 varieties

Table 1.9 lists the attributes selected by the trained panel to describe fresh cooked sweetpotato. Many of the attributes were of a very subjective nature, notably *acceptability*, *appearance* and *taste*
A great range in profiles was obtained for the 12 varieties initially assessed in terms of these attributes, as illustrated by the "spider diagrams" in Figure 1.4. Analysis of variance indicates that the panel was able to distinguish between the varieties for all attributes except *Fibre*. This indicates a consistency between panel members even for the very subjective criteria. The inability to distinguish between the varieties for *Fibre* may be a consequence of the fact that all varieties tested were considered low in *Fibre* by the panel.

Table 1.9 Attributes used by trained panel to assess varieties, and the level of significance for discrimination between the 12 cultivars. (Rwiza *et al.* (2000))

Sensory attribute	Significance of discrimination between 12 cultivars as determined by trained panel
Acceptability	***
Appearance	***
External Colour	***
Internal Colour	**
Taste	***
Sugar	***
Starch	***
Texture	***
Stickiness	**
Chewiness	***
Fibre	n.s.
Odour	***

n.s. not significant. ** , *** significant to less than 1%, and less than 0.1% respectively

The composition of the storage roots of the varieties profiled was analysed in terms of dry matter content and sugar content. The attribute described by *Starch*, refers to the texture of the root, and is sometimes described as *Mealiness* or *Flouriness.* Although a complex attribute, it is thought to be related to the dry matter of the roots. Figure 1.5 shows the *Starch* score obtained by the panel for each variety plotted against the measured dry matter content. Apart from one variety, Kagole, which has an exceptionally low *Starch* score, there is a significant relationship ($p<0.01$) between the two parameters.

Sugar, or sweetness, of the roots is considered an important taste attribute. This can also be a complex characteristic, not necessarily related directly to sugar content. The sugar content of roots increases during cooking, as the process promotes the breakdown of starch. Figure 1.6 shows the

Sugar score obtained by the panel plotted against the actual sugar content of cooked roots as analysed by high performance liquid chromatography (HPLC) analysis. There is a significant ($p<0.05$) correlation between the two parameters.

The consistency of the panel's scores with compositional analysis gives us further confidence in the validity of the assessments.

Figure 1.4: Sensory profiles created by the trained taste panel for twelve sweetpotato varieties (Rwiza *et al.* (2000))

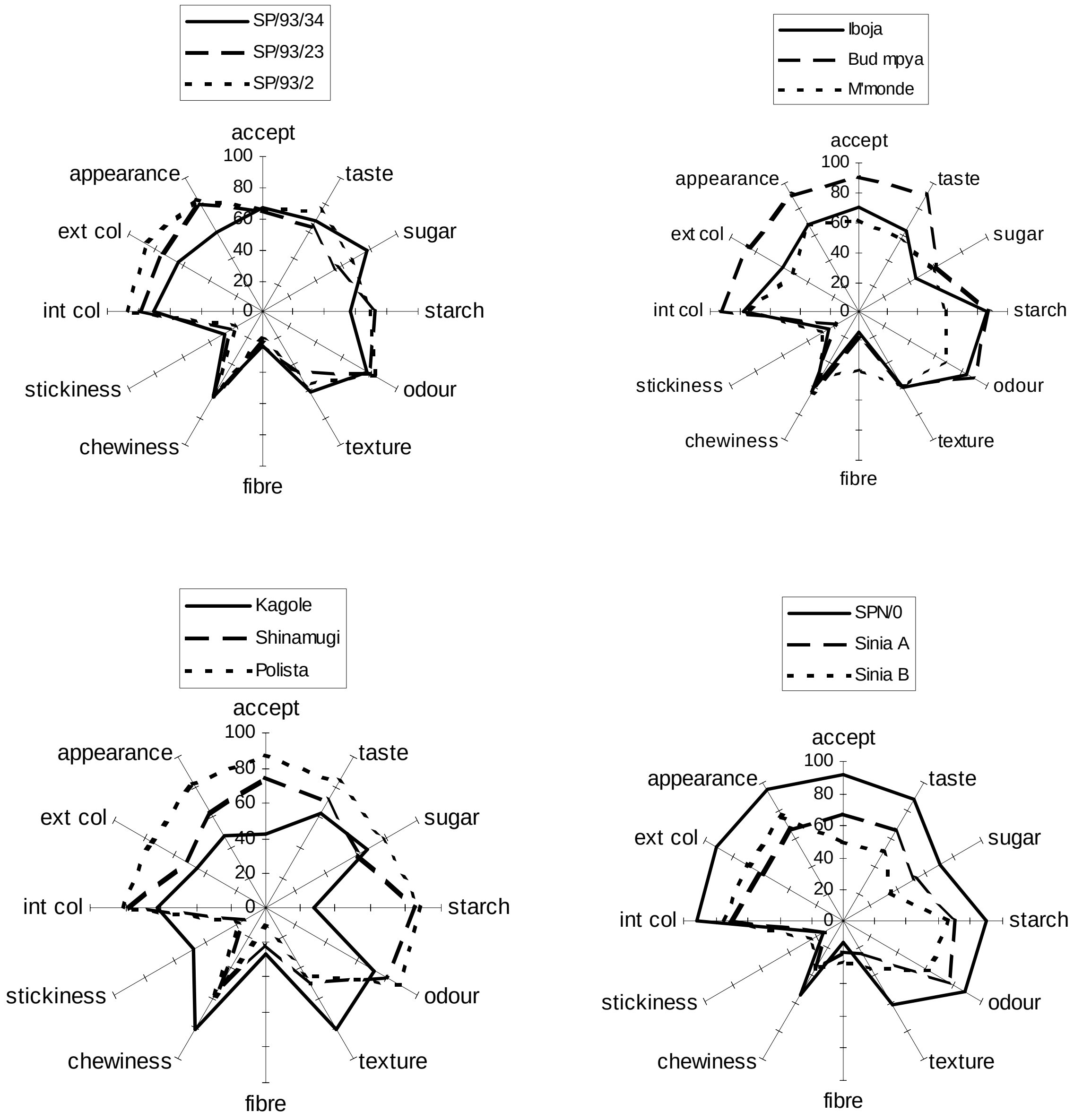


Figure 1.5: The relationship between *Starch* score given by the panel and dry matter content of roots of a range of sweetpotato varieties. (Rwiza *et al.* (2000))

The square symbol indicates the data for Kagole.

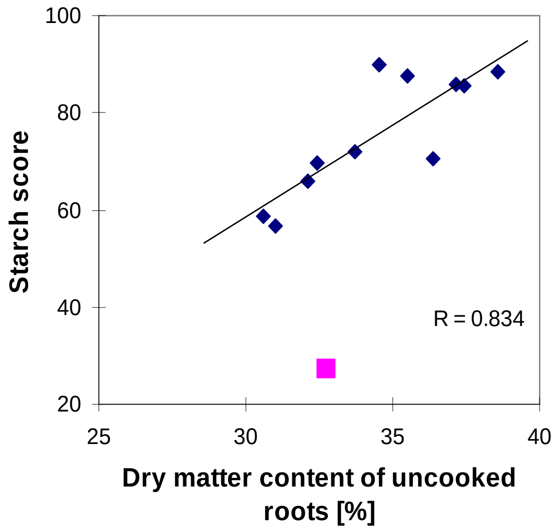
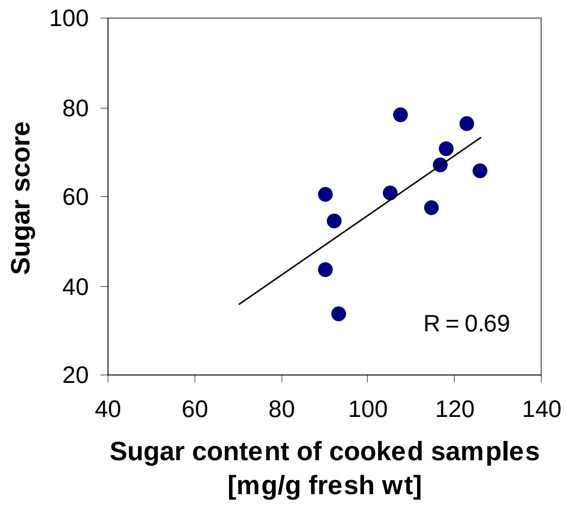


Figure 1.6: The relationship between *Sugar* score given by the panel and sugar content of cooked roots a a range of sweetpotato varieties. (Rwiza *et al.* (2000))



Consumer tests on local varieties in Mwanza, Meatu and Misungwi

The sweetpotato varieties available at the three sites chosen for consumer tests were not the same. Table 1.10 shows the varieties used and also their ranking by the consumers. In all cases the ranking was statistically significant (analysed by rank sum)

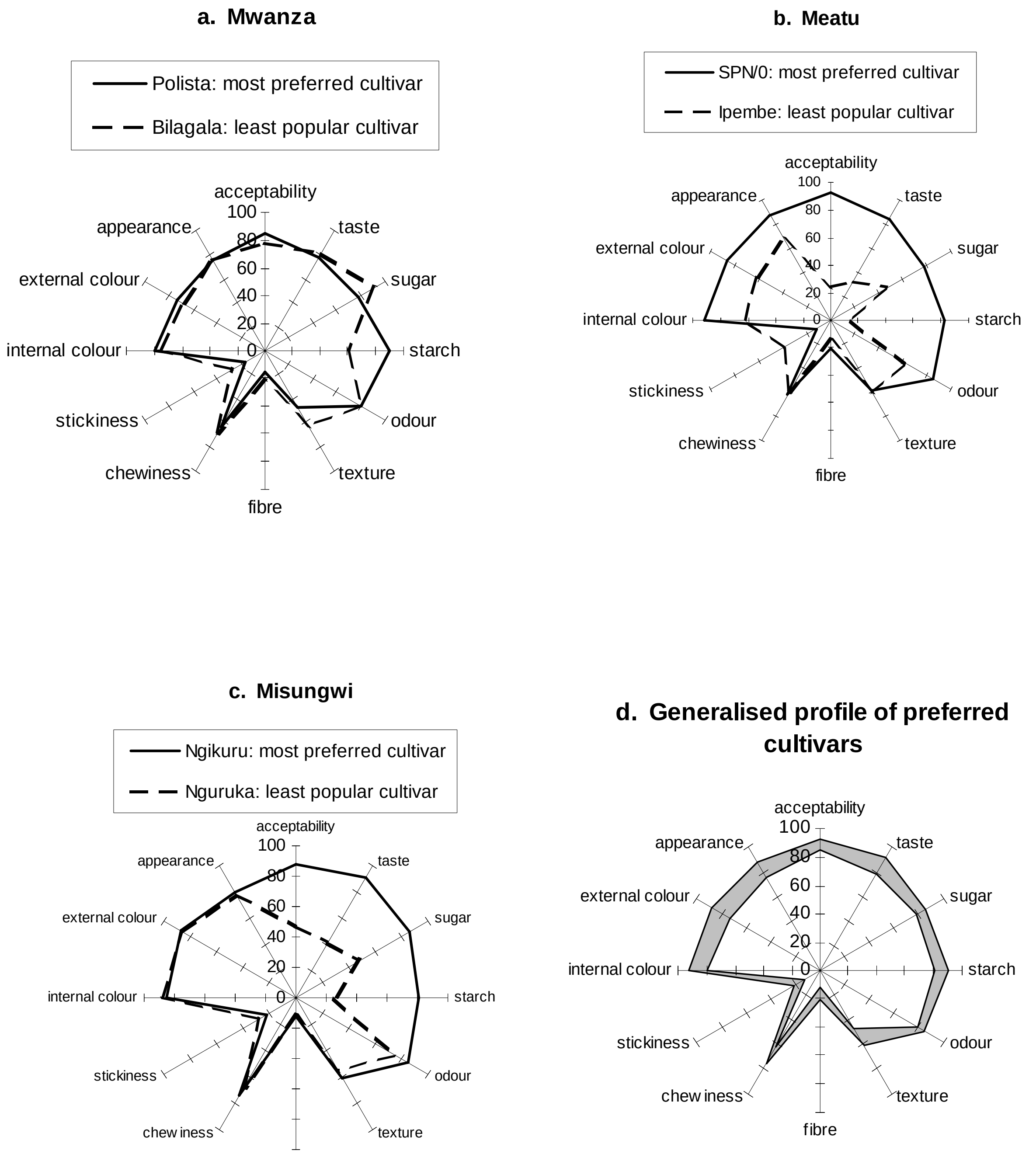
Table 1.10: Ranking of local varieties at three locations in Lake Zone, Tanzania (Rwiza *et al.* (2000))

Ranking	Location of consumer study		
	Mwanza	Meatu	Misungwi
Most preferred	Polista	SPN/0	Ngikuru
	Sinia B	Ngosha	SPN/0
	SPN/0	Polista	Polista
	Mzondwa	Serena	Toniki
		Sinia B	Sinia B
Least preferred	Bilagala	Ipembe	Nguruka

All of these varieties were then assessed by the trained panel and profiles created. For all locations a large range in profiles was obtained. However, it can be seen from Figure 1.7, which shows the profiles of the most and least preferred variety for each location, that although not the same cultivars, the most popular varieties have a very similar profile in the three locations. This enables us to produce a profile of a generalised variety that would be expect to be popular in all of the locations assessed (Figure 1.7d). Comparison of this profile with those shown in Figure 1.4 allows predictions to be made as to which varieties will be most acceptable to consumers. For example the three cultivars SP/93/23, SP/93/34 and SP/93/2 are close to the preferred profile, while Kagole is very different. Further work needs to be done to confirm these findings.

In conclusion, this study has showed that a trained panel can be used to assess sensory attributes of sweetpotato varieties. The finding that the most popular varieties in three locations have similar sensory profiles is very encouraging. However, these three locations were all in one Zone of Tanzania. It will now be important to determine whether the preferences of consumers remain consistent over the whole country, and also how much they change with time.

Figure 4: Sensory profiles of the most preferred and least preferred variety for each location, and the generalised profile of preferred varieties. (Rwiza *et al.* (2000))



Output 2: Cultivar differences and effect of environmental factors (pre- and post-harvest) with respect to quality and perishability of fresh roots identified.

2.1 Overview for output 2

For this output we were primarily interested in whether cultivars differed in their keeping qualities, and whether such differences were stable over environments. We considered keeping qualities under two situations; firstly marketing conditions, where roots are exposed to rough handling and storage under sub-optimal humidities, and secondly long-term storage conditions, where roots can be stored at higher humidities to reduce water loss.

Before comparing cultivars we had to establish the main forms of deterioration in the two situations. We demonstrated that under marketing conditions, water loss is the driving force of deterioration. There is a wide range in rates of water loss among cultivars. This is stable over seasons, and although it is less consistent between growth environments, stable cultivars can be found. During long-term storage, rotting is the main form of deterioration. We have found that cultivars differ in their susceptibility to the main rotting pathogen, *Rhizopus oryzae*, but this characteristic is not as stable between seasons as rates of water loss. The cultivars which are resistant to water loss under marketing conditions are not the same as those which are resistant to rots during long-term storage.

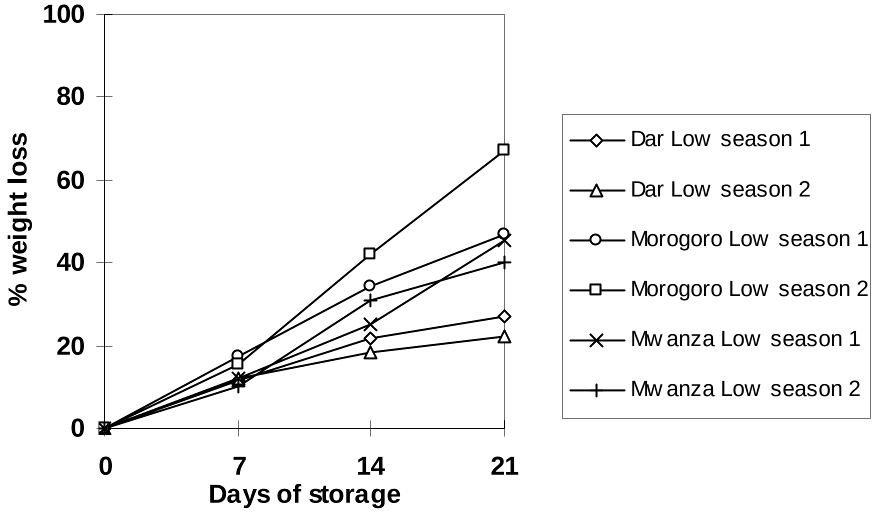
2.2 The main forms of deterioration in sweetpotato storage roots under East African marketing conditions

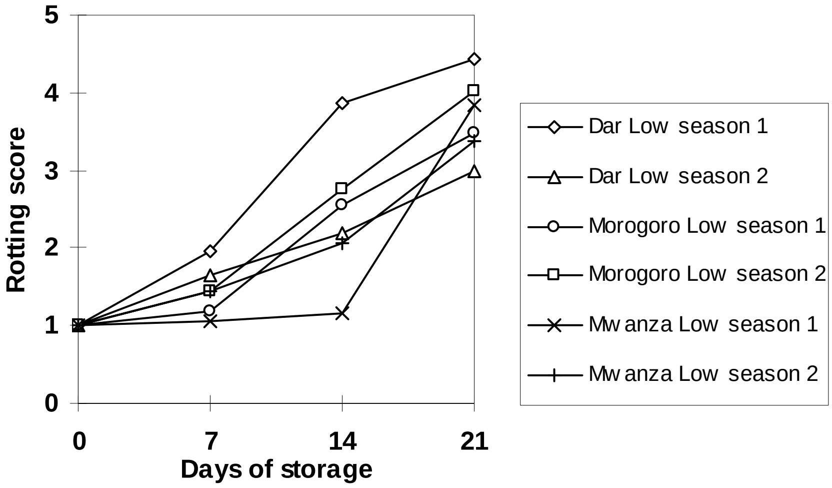
Rees *et al.* (2001a), Rees (2000), van Oirschot (2000)

Prior to examining cultivar and environmental effects on root perishability, it was necessary to determine precisely what was meant by perishability for sweetpotato roots. There are many ways in which sweetpotato roots can deteriorate: namely through weight loss (both water loss and respiratory losses), rotting, insect attack, sprouting and deterioration of eating qualities (e.g. taste, texture aroma). Throughout this project we were most interested in improving root keeping qualities during marketing, rather than during long-term storage. During marketing, roots tend to spend substantial amounts of time stored under relatively low humidities, and may also be subjected to rough handling. We therefore started by determining what were the main forms of deterioration under such conditions. The behaviour of roots under conditions to which they would be exposed during long-term storage (high humidity) is considered in section 2.8.

Roots were purchased from markets in three major towns in Tanzania; Dar es Salaam, Mwanza and Morogoro. When stored under simulated marketing conditions (open sacks under ambient conditions), it was found that weight loss (shrivelling) and rotting were the main forms of deterioration (Figure 2.1). The rate of weight loss, in particular, was very high, ranging up to 30% in one week, so that the shelf-life was very short. Sprouting was very rare, and insect loss, over this timescale was minimal.

Figure 2.1 Rates of weight loss and rotting for undamaged roots purchased from urban markets and stored under simulated market conditions (Rees (2000))





Each data point is the mean for 3 replicate sacks, each of which contained 15 roots. Mean root rotting was assessed using a scoring system of the rotting damage apparent on the root surface (1, 0%; 2, 1-25%; 3, 26-50%; 4, 51-75%; 5, 76-100%)

This study described above did not look in detail at the effects of storage on sensory properties of roots. This was carried out separately. Roots of four cultivars were stored under conditions where water loss and rotting were minimised (clean high humidity storage area). A trained taste panel was used to assess roots from each cultivar at the start of storage and after one and four weeks of storage. The sensory profiles obtained are shown in Figure 2.2. The results indicate that where weight loss and rotting are prevented sensory properties are relatively stable (van Oirschot *et al*. 1998). We take this to confirm the fact that weight loss and rotting are the main forms of deterioration under marketing conditions, and that a cultivar which is resistant to these forms of deterioration would have increased shelf-life.

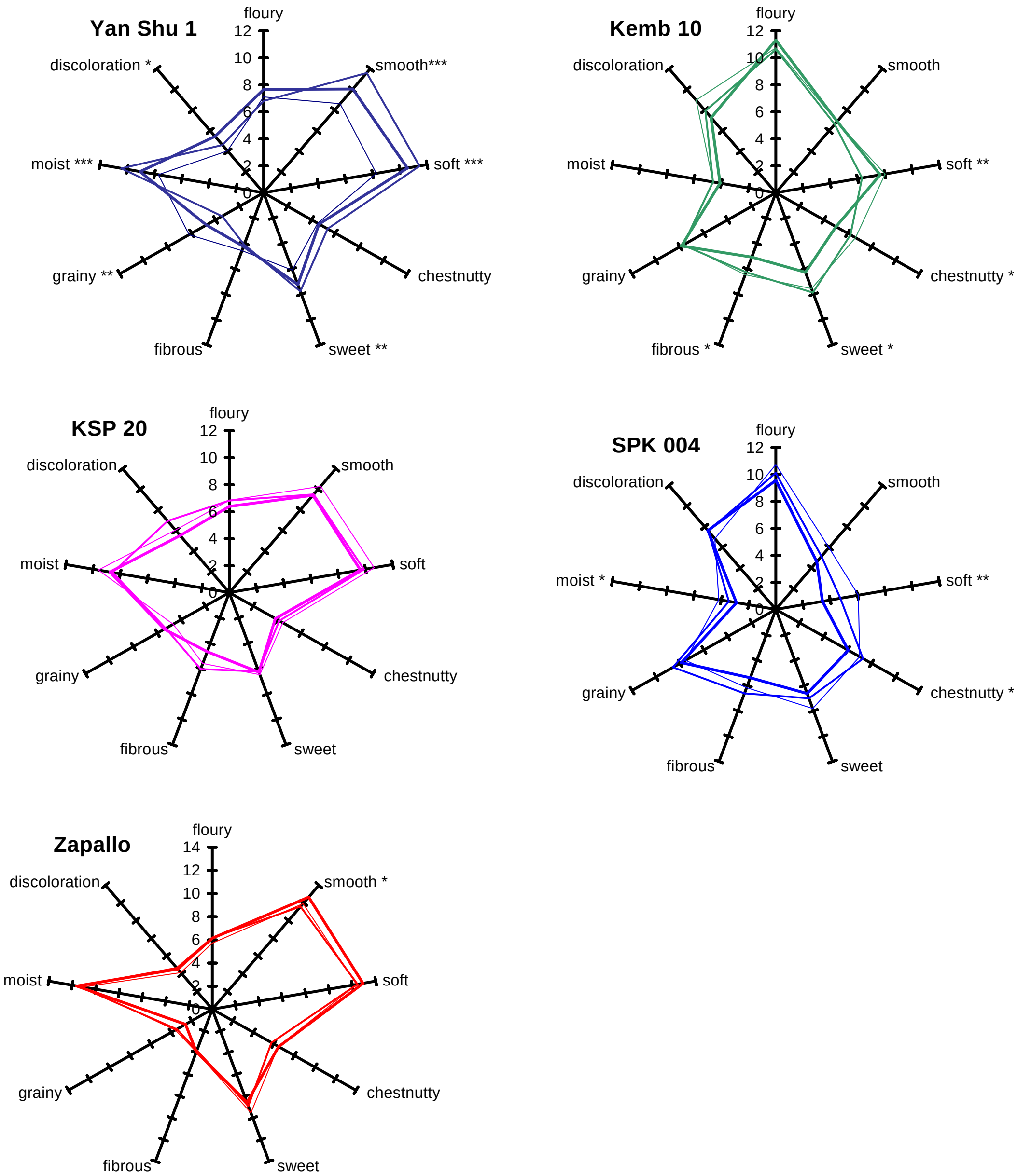
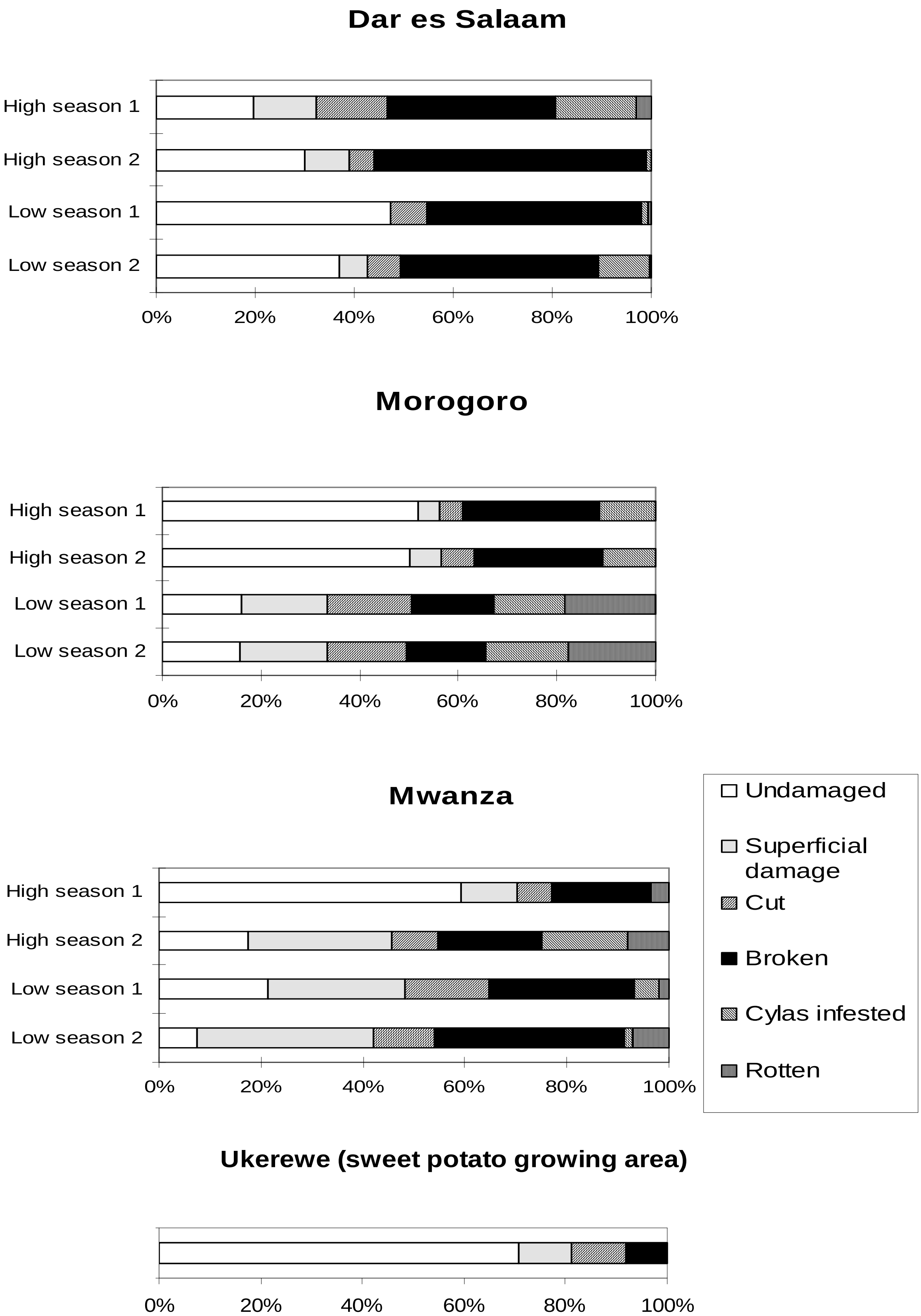


Figure 2.2 Sensory profiles of 5 sweetpotato cultivars cooked following storage at 25°C R.H 85% and assessed by a trained taste panel (a) Yan shu 1; (b) Kemb 10 etc. = 1 week = 4 weeks, (van Oirschot (2000))
= 8 weeks. The descriptors marked with *, ** or *** differ significantly during storage at P < 0.001, P < 0.01 and P < 0.05 respectively

2.3 The extent and types of damage of sweetpotato roots when they arrive at market and the effects on root shelf-life

Rees *et al*. (2001a), Rees (2000)

Figure 2.3: Levels and types of damage to marketed sweetpotato. (Rees *et al*. (2001a))



For perishable commodities physical damage increases the rate of deterioration. In order to screen sweetpotato cultivars for keeping-quality, it was considered important not only to assess shelf-life of undamaged roots, but also to develop a protocol to test cultivars for susceptibility to damage, and subsequent deterioration of damaged roots. In order to do this it was important to know what forms of damage were most prevalent, and also what forms of damage had the most serious effects on sweetpotato deterioration. A study was therefore carried out in three urban centres of Tanzania during 1996 and 1997 with the objectives: firstly, to obtain an assessment of the extent and types of damage for sweetpotato roots when they arrive at market and the economic implications of this damage; and secondly to establish which are the most serious forms of damage with respect to their effects on root shelf-life, and to quantify that effect.

Figure 2.3 summarises 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 pr0blem worldwide. Levels of damage were variable, but were generally high with 44 – 67% seriously damaged roots and total damage of 49 - 93%. In most cases, breaks, cuts and superficial scuffing accounted for most damage. 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.

Roots were selected for each form of damage, and assessed for rates of deterioration in terms of weight loss and rotting. The results obtained for low season roots are summarised in Tables 2.1 and 2.2.

Undamaged roots lose weight more slowly than damaged, but there were no clear differences between the types of damage. Superficial damage has as significant an effect on shelf-life as the other forms of damage. The data for rotting are generally consistent with those for weight loss, except that roots with only superficial damage do not rot significantly more quickly.

Table 2.1: The effect of damage on weight loss for sweetpotato roots purchased from urban markets in Tanzania (Rees *et al.* (2001a))

Sampling location	Season	% weight loss during 7 days of storage				
		Undamaged	Superficial damage	Serious damage		
				Cut	Broken	*Cylas* damage
Dar es Salaam	Low 1	11.8	n.d.	16.5	17.6	18.8
	Low 2	12.2	14.3	15.0	13.4	13.1
Morogoro	Low 1	17.4	41.6	26.8	43.1	24.1
	Low 2	15.4	42.7	29.9	45.3	38.6
Mwanza	Low 1	12.2	14.6	12.3	14.5	10.6
	Low 2	10.0	15.1	19.8	19.3	15.6
Mean		13.2	25.6	20.0	25.6	20.1

Damage class effects***, Sampling location/time effect ***, interaction ***
LSD (0.05) among damage means 5.5
LSD (0.05) among damage within locations 10.9

weight loss relative to that of undamaged roots

		Undamaged	Superficial damage	Serious damage		
				Cut	Broken	*Cylas* damage
Dar es Salaam	Low 1	1.0	n.d.	1.4	1.5	1.6
	Low 2	1.0	1.2	1.2	1.1	1.1
Morogoro	Low 1	1.0	2.4	1.6	2.5	1.4
	Low 2	1.0	2.9	2.0	3.0	2.6
Mwanza	Low 1	1.0	1.2	1.0	1.2	0.9
	Low 2	1.0	1.6	2.0	2.0	1.8
Mean		1.0	1.8	1.6	1.9	1.6

Damage class effects***, Sampling location/time effect ***, interaction **
LSD (0.05) among damage means 0.4
LSD (0.05) among damage within locations 0.9

** , *** significant to 1%, 0.1%

Table 2.2: The effect of damage on rotting for sweetpotato roots purchased from urban markets in Tanzania (Rees *et al.* (2001a))

Sampling location	Season	Rotting score after 7 days of storage				
		Undamaged	Superficial damage	Serious damage		
				Cut	Broken	*Cylas* damage
Dar es Salaam	Low 1	1.95	n.d.	2.75	2.70	2.89
	Low 2	1.64	1.71	1.87	1.78	1.73
Morogoro	Low 1	1.18	1.49	1.51	1.56	1.24
	Low 2	1.44	1.67	1.60	1.71	1.74
Mwanza	Low 1	1.06	1.39	1.11	1.06	1.58
	Low 2	1.44	1.67	1.83	1.89	2.00
Mean		1.45	1.58	1.78	1.78	1.87

Damage class effects***, Sampling location/time effect ***, interaction **
LSD (0.05) among damage means 0.20
LSD (0.05) among damage within locations 0.40

** , *** significant to 1%, 0.1%
n.d. no data

2.4 Cultivar differences in keeping qualities (weight loss and rotting) under simulated marketing conditions

Rees *et al.* (2001b) Van Oirschot (2000)

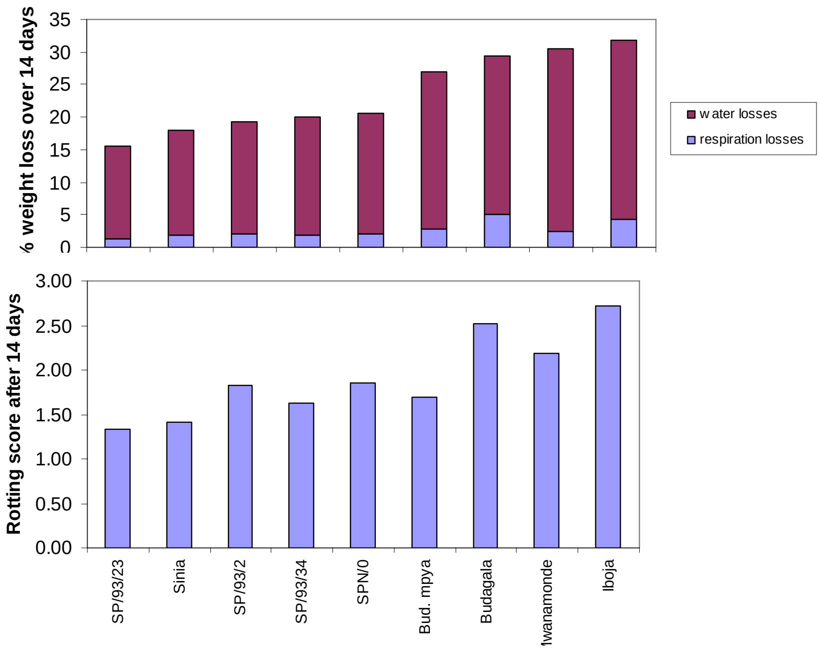
Trials conducted in Tanzania and in Kenya showed that under normal marketing conditions observed in East Africa (sub-optimal humidity, tropical temperatures) a large range in the storability of sweetpotato exists among the available germplasm. Figure 2.4 shows % weight loss and rotting observed in roots from two trials covering 10 and 22 cultivars respectively at Ukiriguru, Tanzania in 1997. Table 2.3 shows sample data obtained from a range of trials conducted in Kenya, in which rates of weight loss were followed. In all cases the cultivar effect was very significant. Rates of respiratin were also measured for the trial shown in Figure 2.4, and confirmed that most of the weight loss (90%) was water loss.

Another observation from this data was that fresh weight loss and rotting are closely related, such that cultivars that lose weight rapidly also tend to rot rapidly. This can be seen from Figure 2.4 and also from Figure 2.5 where rotting of the cultivars shown in Figure 2.4 is plotted against weight loss for various times of storage. During storage trials at various locations, this relationship was seen in environments where weight loss was significant, but not in environments with lower temperatures and higher humidities where rotting was the main form of deterioration. Our hypothesis is that water loss weakens the roots defence mechanisms and makes it more susceptible to rots. Under most conditions therefore, assessment of cultivars on their rate of fresh weight loss is sufficient to give an indication of keeping qualities.

Figure 2.4: Rates of % weight loss (with estimated contribution from water loss and respiration) and rates of rotting for sweetpotato cultivars during storage under simulated marketing conditions (Rees *et al.* (2001b))

a) Trial 1, 1997 (9 cultivars) **Tr**ial 2, 1997 (22 cultivars) Rotting for each cultivar is expressed as the mean rot score for 3 replications, each consisting of 21 roots. % weight loss was measured for 6 roots per replication and is expressed as the mean for 3 replications, while respiration losses were estimated from measurements of respiration rate made on days 5-7 on 1 and 2 roots per replicate for Trials 1 and 2 respectively.

a)



b)

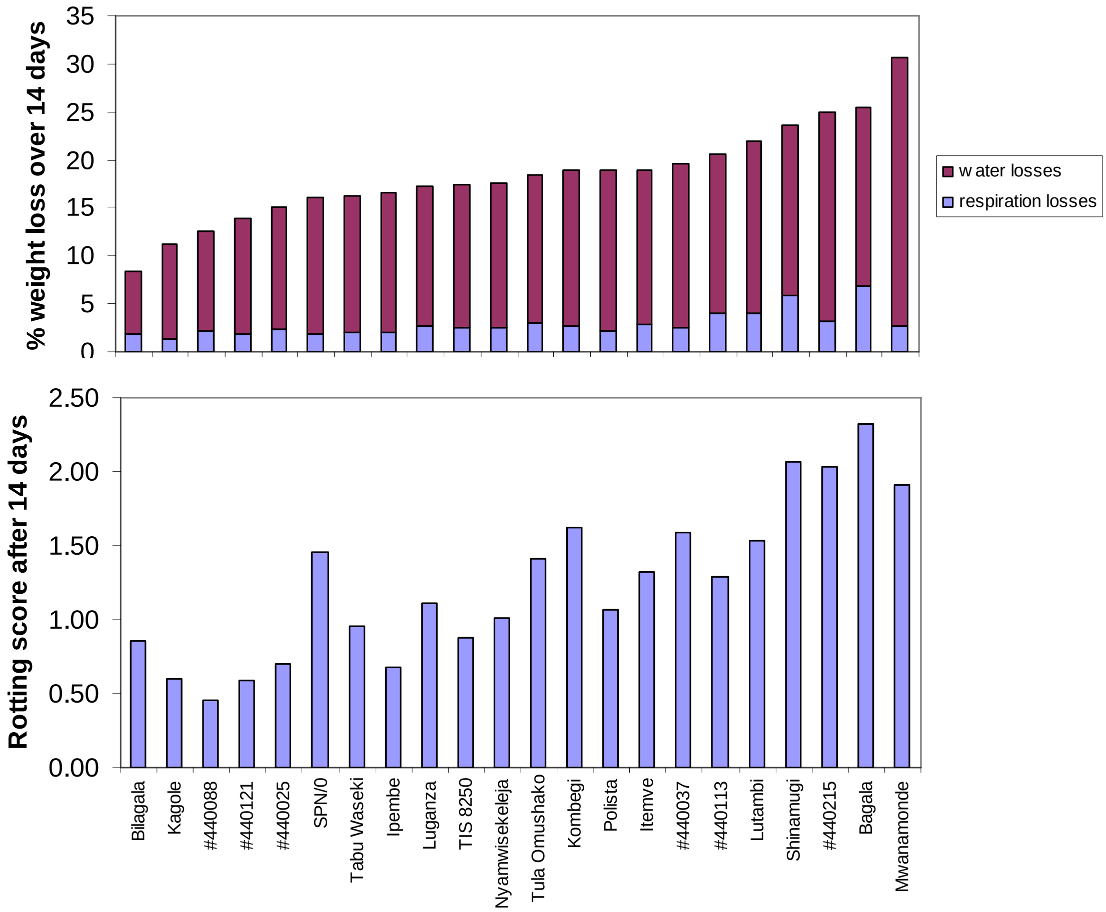


Table 2.3 Weight loss during storage for 5 and 10 sweetpotato cultivars grown in Kenya. The significance levels of cultivar, storage time and their interactions in trial 7, 8, 9 and 10. Trial 9 also included two potato cultivars. (van Oirschot (2000))

Trial 7 Nairobi April 1998

Cultivar	**6**	**12**	**27**	**Mean**
Yanshu	5.41	7.20	9.17	5.51
Kemb10	5.72	8.43	12.65	6.35
KSP20	5.03	7.02	9.72	5.35
Pumpkin	6.24	8.77	14.55	6.81
SPK004	6.58	10.49	18.04	7.90

Cultivar	P = 0.011	Storage time	P < 0.001
Sed cult	= 0.708		
Sed stor	= 0.337	Interactions	
Sed cult*stor	= 1.01	Cult*Stor	P = 0.001

Trial 8 Nairobi May 1998

Cultivar	**5**	**9**	**13**	**Mean**
Yanshu	6.72	10.08	12.59	10.23
Kemb10	8.19	13.37	18.16	14.03
KSP20	5.85	8.96	11.36	9.17
Pumpkin	7.88	12.46	15.89	12.71
SPK004	7.03	12.13	16.87	12.86

Cultivar	P = 0.0113	Storage time	P < 0.001
Sed cult	= 1.47		
Sed stor	= 0.261	Interactions	
Sed cult*stor	= 1.57	Cult*Stor	P =0.426

Trial 9 Nairobi October 1998

Cultivar	**4**	**8**	**12**	**16**	**Mean**
Yanshu	4.52	7.15	8.48	9.54	6.80
Kemb10	8.33	15.1	19.6	23.8	15.1
KSP20	5.32	8.70	10.8	126	8.53
Pumpkin	6.59	11.0	13.5	15.4	10.7
SPK004	5.96	10.8	14.1	17.6	10.9
BP1-SP2	5.72	8.61	10.3	11.6	8.32
Caplina	6.45	10.2	12.2	13.6	9.70
Salyboro	7.07	11.5	14.1	16.0	11.1
Yarada	8.99	14.8	18.2	21.0	14.3
Julian	8.31	13.3	16.4	19.0	13.1
Kihoro (potato)	1.01	1.42	1.71	1.95	1.41
Nyaya (potato)	4.10	6.0.7	7.01	7.88	5.78

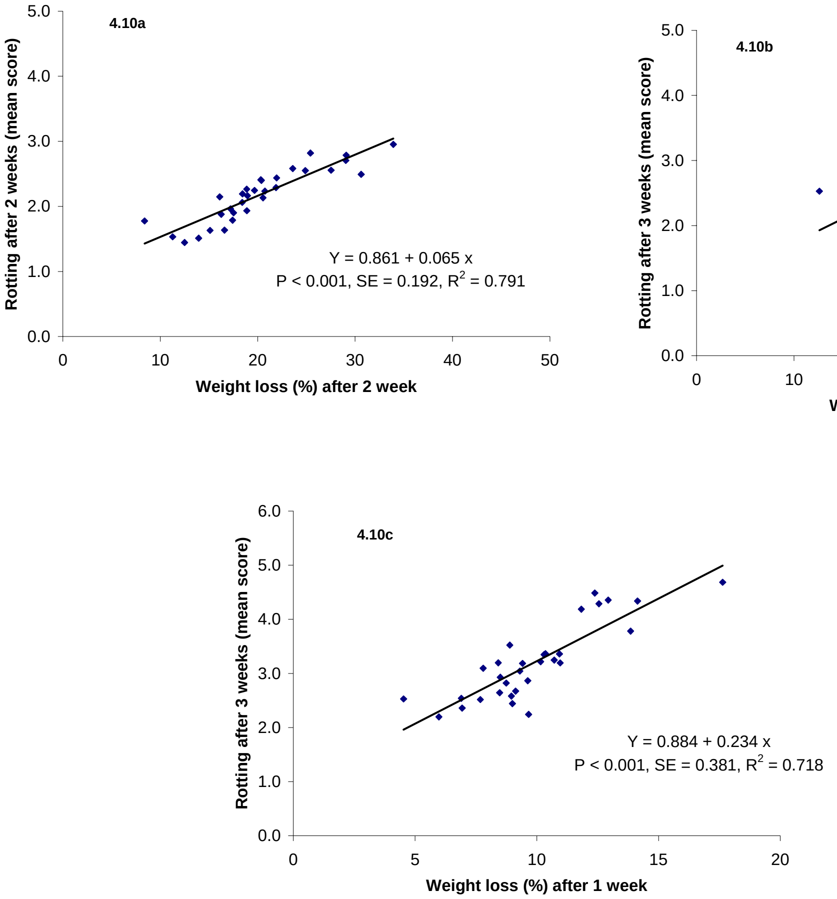
Cultivar	P < 0.001	Storage time	P < 0.001
Sed cult	= 2.21		
Sed stor	= 0.282	Interactions	
Sed cult*stor	= 2.39	Cult*Stor	P < 0.001

Trial 10 Nairobi Nov-Dec 1998

Cultivar	**8**	**26**	**41**	**Mean**
Yanshu	6.2	9.6	12.6	9.48
Kemb10	10.8	20.7	26.9	19.5
KSP20	8.1	14.6	22.0	14.9
Pumpkin	9.2	15.4	18.4	14.3
SPK004	10.4	22.9	31.4	21.6
BP1-SP2	11.0	17.0	20.7	16.2
Caplina	7.5	11.0	16	11.5
Salyboro	12.2	20.2	24.0	18.8
Yarada	17.6	28.9	34.6	27.0
Julian	15.6	29.3	37.5	27.5

Cultivar	P < 0.001	Storage time	P < 0.001
Sed cult	= 2.2		
Sed stor	= 0.509	Interactions	
Sed cult*stor	= 2.59	Cult*Stor	P < 0.001

Figure 2.5 a-c The relationship between mean scores of rotting and mean weight loss of 29 sweetpotato cultivars after 2, 3 weeks storage under marketing conditions in Tanzania. C) presents the relationship between weight loss after 1 week and rotting after 3 weeks. (van Oirschot (2000))



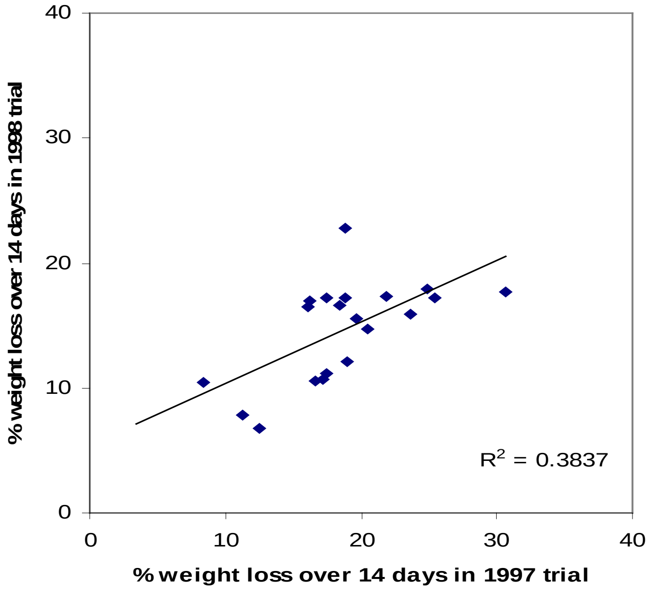
Significant relationships were found between weight loss and rotting after 14 and 21 days. The correlation coefficients varied between 0.92 and 0.98 with a significance level of $P < 0.001$. Also the relationship between weight loss after 1 week and rotting after 3 weeks was significant with a correlation coefficient of 0.85 and the significance ($P < 0.001$) suggesting that there is a causative link between weight loss and rotting.

2.5 Cultivar keeping qualities are stable between seasons and relatively stable between sites.

Rees *et al.*(2001b) Rees *et al.*(2001c)

Cultivars tested for their keeping qualities in more than one season at the same site showed consistent behaviour. Figure 2.6 shows the weight loss after 14 days for 22 cultivars plotted for 1998 *v* that for 1997. A correlation coefficient (R) of 0.619 was obtained, which is significant to 1%.

Figure 2.6 The relationship between weight loss over 14 days of storage under simulated marketing conditions in 1998 and 1997. (Rees *et al.*(2001b))



Information on the consistency of cultivars between environments is less clear, but does indicate that certain cultivars are consistently better than others. Figure 2.7 shows the weight loss over 14 days for 5 cultivars assessed during 7 different trials (including 5 sites and 2 years). The cultivas Iboja and SPN/0 are fairly stable; in 6 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 appear to have behaviour which varies by environment.

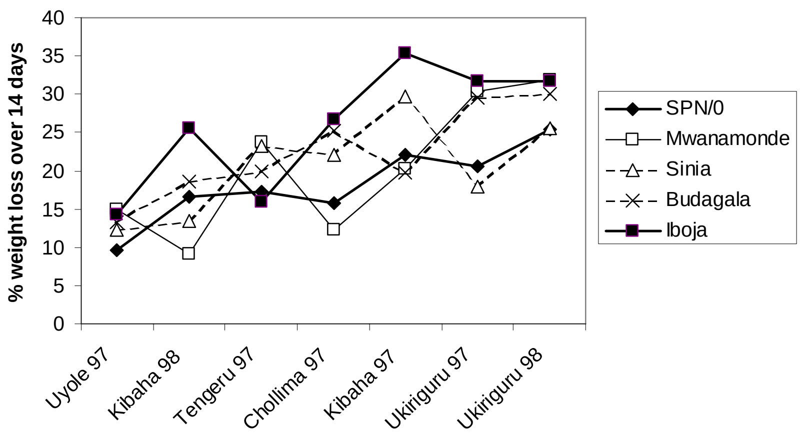


Figure 2.7 weight loss over 14 days storage under simulated marketing conditions for 5 cultivars during 7 trials. (Rees *et al.*(2001c))

2.6 Weight loss of storage roots results in loss in marketability

van Oirschot (2000)

In section 2.2 we concluded that weight loss was a major form of root deterioration and in section 2.4 that it was the driving force for deterioration in most environments. An experiment was conducted in Nairobi that confirmed the commercial importance specifically of weight loss of fresh roots.

The roots of a storage trial covering 10 cultivars were assessed by a Kenyan sweetpotato purchaser for their saleability. Figure 2.8 presents the percentage of the roots for each cultivar that were saleable after 8 weeks of storage under local storage conditions in Nairobi. Figure 2.9 shows that saleability was strongly related to the amount of weight loss.

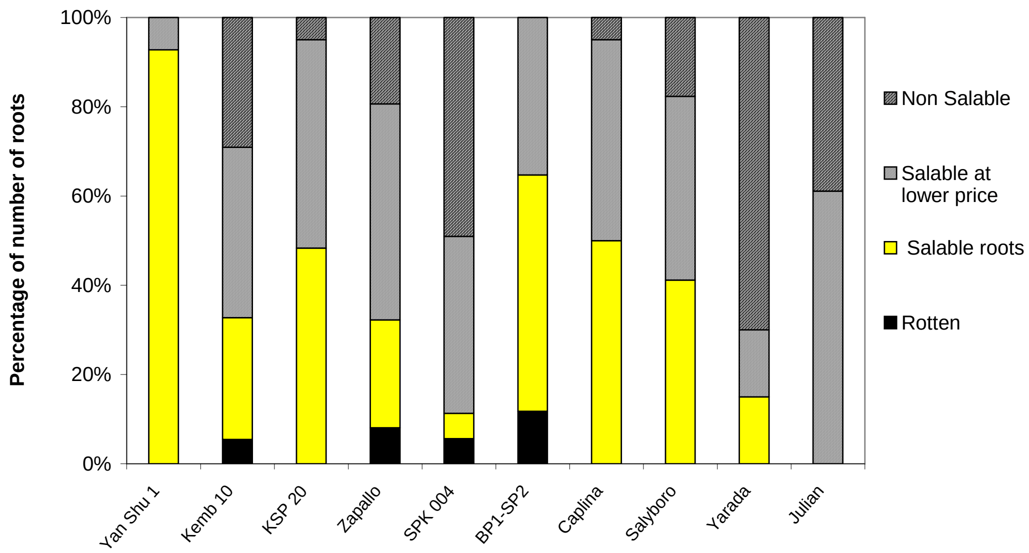


Figure 2.8 Percentage of roots of 10 sweetpotato cultivars that are saleable after 8 weeks of storage at NARL, Nairobi Kenya. (van Oirschot (2000))

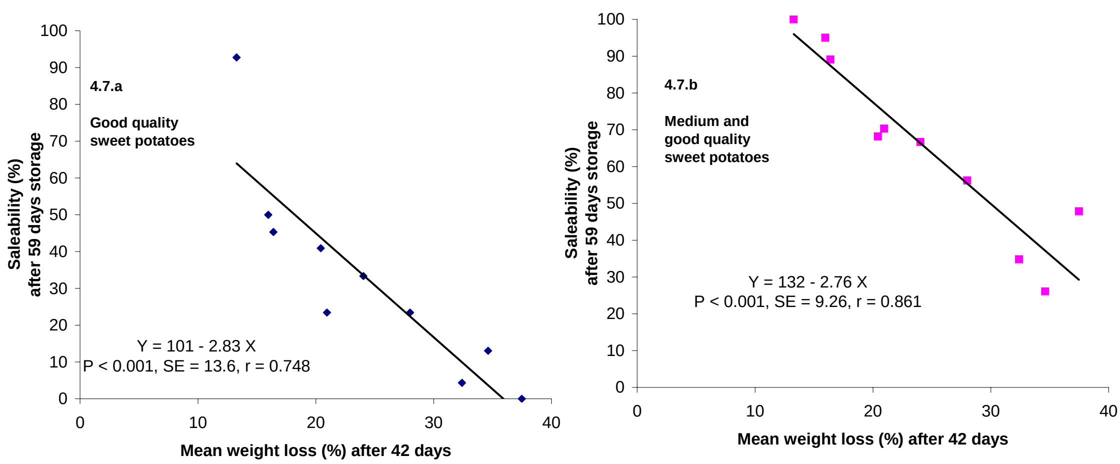


Figure 2.9a-b Relationship between the percentage saleable roots (according to a Kenyan sweetpotato purchaser) and mean weight loss. [a] presents good quality roots, and [b] presents medium and good quality roots. Each point represents saleability and weight loss of one cultivar. (van Oirschot (2000))

Non saleable roots had a weight loss mean of 35.3%, whereas the mean weight loss of saleable roots was 13.6%. These results confirm that weight loss is an important measure for storability. From these results it can be estimated that roots that have lost less than 20% of weight are still saleable, but if weight loss exceeds 35% of its initial weight, sweetpotato roots become unmarketable.

2.7 Cultivar differences in susceptibility to damage and effects on shelf-life.

Van Oirschot (2000)

In East Africa sweetpotatoes can be subjected to rough handling prior to marketing. Hence from the start of this project we considered that when assessing cultivars for their keeping qualities we should also consider their susceptibility to damage and the effects of damage on subsequent shelf-life. In section 2.3 we showed that a high proportion of roots in the markets had breaks, cuts and superficial scuffing. These forms of damage all increase the rate of weight loss.

During the course of this project three methods of standardised damage treatment were tested
a) making a diagonal cut in each root with a knife
b) scuffing by rolling in a barrel
c) dropping sacks of roots from a set height a set number of times.
It was found that the diagonal cut method had no differential effect between cultivars and also no significant effect on shelf-life. In retrospect as will become apparent in later sections this is because the resulting wound heals very rapidly.
The method of rolling in a barrel results primarily in scuffing of the root surface, while the method of dropping sacks of roots results both in scuffing and breakage of roots. Although both scuffing and breakage increase the rate of root weight loss we found that this effect is only short lived (2-3 days) for scuffing, but persists for longer for breakages. This is demonstrated by Table 2.4 which shows the correlations between weght loss and damage for individual roots. This can be explained by root wound healing characteristics which will be considered in detail in later sections.

Table 2.4. Correlation coefficients between rate of weight loss and the amount of damage for artificially damaged roots. (van Oirschot 2000)

			Correlation coefficients			
			Days after damage treatments			
Damage Treatment	N	Damage type	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 4 different experimental trials.
*** Significant at P < 0.001*
** Significant at P < 0.05*
ND Not determined

The consequence of these results is that an impact method for assessing cultivars such as dropping could be useful in breeding, while scuffing assessments would be less important.

Trials showed that cultivars differed both in susceptibility to scuffing and to breakages (Table 2.5).

Table 2.5. Overview of the mean ranks obtained for ten sweetpotato cultivars for various forms of damage. A high rank corresponds with a high susceptibility to the particular form of damage, and corresponds with a dark grey shading . (van Oirschot 2000)

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

2.8 Cultivar keeping qualities under long-term storage conditions

Mbilinyi *et al.* (2000), Muhanna (2001)

In the previous sections we have shown that under marketing conditions where storage humidities can be relatively low, the driving force for deterioriation is water loss. Sweetpotato roots can be storaed for substantially longer periods, even under tropical temperatures, when high humidities are maintained. Under these conditions we have found that rotting, rather than water loss is the main limiting factor. We have also demonstrated that cultivar differences in susceptibility to rotting exist. Figure 2.10 shows data obtained from an experiment in which five key Tanzanian cultivars were tested for their keeping qualities under a range of storage environments.

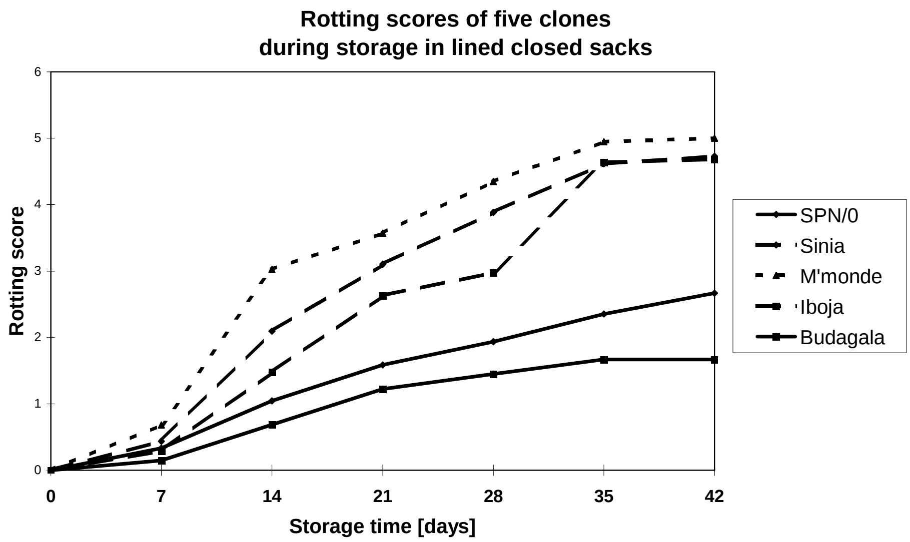


Figure 2.10 The rate of rotting for five key Tanzanian cultivars stored under high humidity conditions. (Mbilinyi *et al.* (2000))

The incidence of rotting increased with humidity, however, cultivar were affected differently. At the highest humidities the cultivar Budagala appeared to be the least susceptible to rotting., while at lower humidities this cultivar did not keep well. To minimize weight loss and rotting, the optimum storage humidity will therefore depend on the cultivar/clone.

A detailed study of the susceptibility of sweetpotato cultivars to rotting was carried out in Morogoro region Tanzania using artificil innoculation methods. In that region, the main storage rot was identified as *Rhizopus oryzae*. Screening of cultivars over successive seasons indicated that cultivar differences in susceptibility did exist, but for many cultivars susceptibility varied with gorwing conditions. Some cultivars were more stable. Budagala, mentioned above, and Sinia were consistently resistant, while SPN/0 was consistently susceptible (Table 2.6). The basis of this resistance is considered in section 3.?.

Table 2.6 Ranking of cultivars in terms of decreasing susceptibility to *Rhizopus oryzae* as measured by rot weight following artificial innoculation (Muhanna (2001))

Experiments 1, 2 and 3 conducted in 1998	Experiments 4,5 and 6 conducted in September 1999	Experiments 7 and 8 conducted in Nov/Dec 1999
Ukerewe	SPN/0	Iboja
SPN/0	Iboja	SPN/0
Elias	Mwanamonde	Sinia
Chenzeru	Ukerewe	Budagala
Sindano	Sinia	
Iboja		
H/mtumwa		
Budagala		
Sinia		
Mwanamonde		

Output 3: Physiological characteristics of storage roots associated with good quality, long shelf-life and resistance to pests and diseases identified and disseminated.

3.1 Overview for output 3

A cultivar has good quality and long shelf-life under marketing conditions if it has a slow rate of water loss under such conditions. We have demonstrated that this depends on two things; the susceptibility of the roots to damage during handling and the ability of the roots to heal their wounds under the environmental conditions to which they are exposed during marketing. The former finding is not surprising, and our finding that roots with long shapes are more susceptible to breakages is completely as expected. The practice of curing sweet potato roots (i.e. placing under conditions which promote wound-healing) is commonplace in developed countries. However, the finding that cultivars differ very greatly in their ability to heal under environments found during marketing (i.e.sub-optimal humidities) is new. We have attempted to find out what physiological attributes of a cultivar affect this ability. So far we have shown that among the germplasm tested, low dry matter cultivars have a higher wound-healing efficiency at lower humidities. Given that East African consumers prefer high dry matter roots, this finding is unwelcome.

With respect to susceptibility to rotting under high humidities, we have shown that inhibitory chemicals are at least partly responsible, but have not identified these chemicals.

As for Output 1, dissemination of these results has been primarily through conference presentations.

As discussed in *Contribution of Outputs,* further work and dissemination is addressed in a follow-on project.

3.2 Initial observations of roots characteristics associated with good keeping qualities

Rees *et al.* (2001b)

For the shelf-life trials conducted at Ukiriguru in 1997 and 1998, a wide range of cultivar root characteristics were measured as part of an investigation to find out which, if any, were related to cultivar keeping qualities. The main characteristics considered are given in Table 3.1. An initial indication of their importance is shown by correlation analysis to root weight loss by cultivar.

Table 3.1: Correlation (r) of cultivar root characteristics with % weight loss of cultivar after 14 days of storage under simulated marketing conditions. (Rees *et al.* (2001b)

	Trial 1 1997 (9 cultivars)		**Trial 2 1997 (22 cultivars)**		**Trial 1 1998 (10 cultivars)**		**Trial 2 1998 (22 cultivars)**	
	r	**Cult. effect**	**r**	**Cult. effect**	**r**	**Cult. effect**	**r**	**Cult. effect**
% dry matter content	0.815 **	***	0.600 **	***	0.665 *	n.d.	0.364 +	**
Fructose+Glucose (/Dry Weight) [mg/g dry weight]	n.d.	n.d.	n.d.	n.d.	-0.721 *	**	-0.471 *	***
Fructose+glucose(/Fresh Weight) [mg/g fresh weight]	n.d.	n.d.	n.d.	n.d.	-0.723 *	n.d.	-0.446 *	n.d.
TSS of root sap at start of storage	0.752 *	+	n.s.	**	n.s.	*	n.s.	***
Initial root weight [g]	-0.667 *	+	-0.566 **	***	n.s.	*	-0.391 +	***
Root surface area/wt [cm^2/g]	n.d.	n.d.	n.d.	n.d.	n.s.	**	0.486 *	***
Surface insect damage (Rough weevil)	n.s.	**	0.381 +	*	n.s.	n.s.	n.s.	*
Root tissue hardness [KgF]	n.s.	*	-0.377 +	***	n.s.	**	-0.454 *	***
Latex production	n.s.	**	-0.391 +	***	n.s.	**	-0.403 +	***
Cortex thickness	n.s.	*	n.s.	***	n.s.	*	-0.486 *	***

n.s. not significant
*+, *, **, *** significant to 10, 5, 1 and 0.1% respectively*
n.d. no data
Root sugar content was measured for 3 roots per cultivar and only measured in 1998
Initial root weight and surface area/weight were calculated from 6 roots per cultivar per replicate. Surface area was only estimated in 1998
Surface insect damage due to rough weevil was estimated as the overall average of two roots assessed after each week of storage.
TSS, Total soluble solids

Multiple regression models for %weight loss after 14 days were tested for each trial in terms of the characteristics identified in Table 3.1. Those characteristics which were interrelated, for example initial root weight and root area/weight (Trials 1 and 2 in 1998), monosaccharide levels/dry weight and monosaccharide levels/fresh weight (Trials 1 and 2 in 1998), monosaccharide levels and % dry matter content (Trials 1 and 2 in 1998) were not included together, but were tested in separate models

The best models obtained for % weight loss over 14 days for each trial are given below:

Trial 1 1997
-26.02 + 1.32 *dry matter content*
(62% variance accounted for)

Trial 2 1997
5.17 + 0.97 *dry matter content* – 0.02 *initial root weight* – 1.79 *root tissue hardness*
(65% variance accounted for)

Trial 1 1998
a) 1.50 + 1.91 *dry matter content* – 5.19 *root tissue hardness*
(59% variance accounted for)
c) 34.24 – 0.66 *monosaccharide levels (per fresh weight)*
(46% variance accounted for)

Trial 2 1998
a) - 18.68 + 0.81 *dry matter content* + 9.76 *root surface area/wt* + 16.4 *surface insect damage* – 3.03 *root tissue hardness*
(65% variance accounted for)
d) Wt loss = 27.86 – 0.42 *monosaccharide levels (per fresh weight)*+ 15.23 *surface insect damage* – 5.38 *root tissue hardness* + 1.81 *initial TSS of root sap*
(82% variance accounted for)

Thus for all the trials, good models could be obtained for weight loss using cultivar dry matter content as a factor. Cultivars with high dry matter content lost weight more rapidly. For 1998, where cultivar sugar content was also measured, equally good or better models could be obtained by replacing dry matter content with monosaccharide levels.

A factor that appeared in several models was root tissue hardness that tended to decrease rates of weight loss. For Trial 2, 1998, initial TSS of root sap appeared. This is assumed to relate to total sugars, but in these trials there was no relationship.
Interestingly surface insect damage was found to contribute to rates of weight loss in Trial 2 in 1998. Damage to the root surface due to grazing by the rough weevil is generally not considered a problem by local traders, but in this case appears to have a significant detrimental effect on shelf-life.

Initial root weight (high weights reduced weight loss) and estimated surface area/weight (high values increased weight loss) each appeared in one model. In both cases, this can be explained by the fact that smaller roots have larger surface areas per volume and therefore more opportunity for losing water from the surface. In fact it is surprising that these parameters did not contribute in more cases. It is notable that they only appeared in models for Trial 2, that had a wider range of cultivars, and correspondingly a wider range in root size. Thus the range in mean cultivar root weight was 133 – 269 g, and 177 – 384g for Trial 1 in 1997 and 1998 respectively, while it was 209 – 519 g and 127 - 411g for Trial 2.

IN conclusion any explanation of the physiological basis of the cultivar differences would need to be consistent with these observations i.e. would need to explain why dry matter content and monosaccharide levels appear to relate to low rates of water loss.

3.3 The effect of root size/shape on rates of water loss
Van Oirschot (2000)

For any commodity we would expect the surface area to volume ratio to affect rates of water loss. Smaller roots and elongated roots would have a larger surface are to volume ratio, and would therefore be expected to have higher rates of water loss.

For the trials conducted in Nairobi, the surface area of each root was estimated by the equation of an ellipse, assuming that it was a perfect ellipsoid, using the length and diameter data of each root. A linear regression analysis was carried out between the surface area/ mass ratio and the weight loss after 27 days (Table 3.2). Overall the surface area/ mass ratio did affect weight loss of the sweetpotato roots. The linear regression analysis was significant in both trial 7 and 8 ($P < 0.001$ and $P = 0.011$ respectively). However, the adjusted R^2 representing the percentage variability accounted for was low (17.1 and 1.3%). When cultivar was added as grouping factor to the model, the R^2 adjusted increased. In trial 7 more than 40% of the variability was explained by cultivar effect, and in trial 8 this was almost 40%.
This means that weight loss and storability are not fully explained by the surface area/ mass ratio of the roots, but that other cultivar related factors appear to be more important. The effect of root shape on susceptibility to damage is considered in section 3.?

Table 3.2 Significance levels of the regression between weight loss and rate of weight loss as explained by surface area/ mass ratio and grouping factor cultivar (van Oirschot (2000)

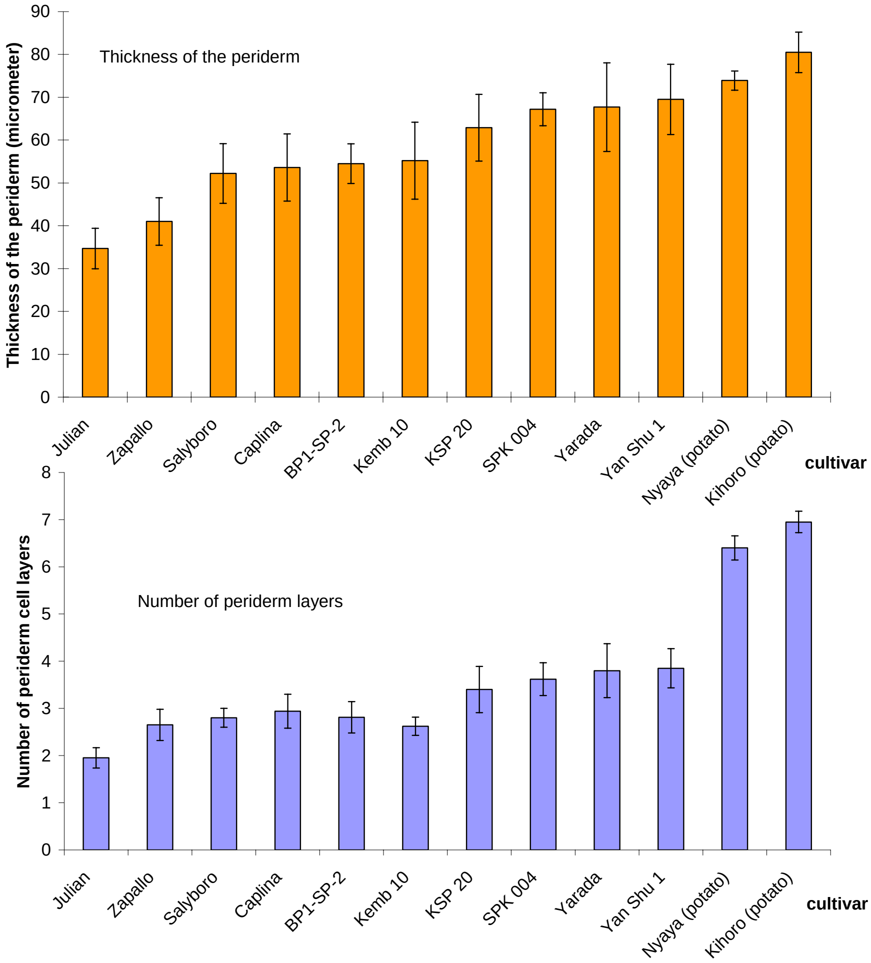
	Regression model for explanatory value for	P value	R^2 adjusted (%)
Trial 7	Surface area/mass ratio explained by initial mass	< 0.001	59.6
Trial 7	Weight loss after 27 days explained by		
	♦ Surface area / mass ratio	= 0.011	1.3
	♦ Surface area /mass ratio + Cultivar	< 0.001	40.5
	♦ Surface area /mass ratio + Cultivar + Suma*Cult [1)]	< 0.001	40.8
Trial 8	Weight loss rate at day 7 explained by		
	♦ Surface area / mass ratio	< 0.001	17.1
	♦ Surface area /mass ratio + Cultivar	< 0.001	38.4
	♦ Surface area /mass ratio + Cultivar + Suma*Cult [1)]	< 0.001	45.7

1) Suma = Surface area/ mass ratio; Cult = cultivar

3.4 Root periderm thickness is not related to permeability to water loss.
Van Oirschot (2000)

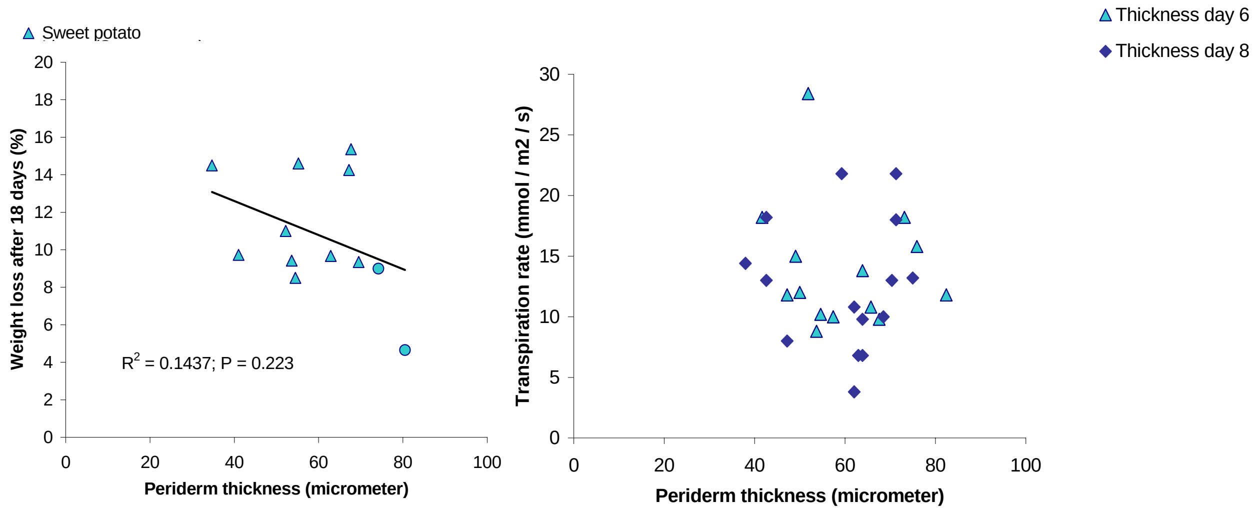
The thickness of the root periderm, in terms of measurement and number of cell layers was assessed for ten cultivars in Nairobi.. Figure 3.1 shows that there is a wide range in periderm thickness. Cultivars were found to be consistent in two trials. Two potato cultivars were included in this trial, and were found to have thicker periderms.

Figure 3.1 Periderm thickness (a) and number of periderm layers (b) for 10 sweetpotato and 2 potato cultivars on day 6 after harvest. Each value is the mean of 5 roots, 4 readings each. Bars give the standard error of the mean. Data from embedded tissue samples from trial 9 and 11. (van Oirschot (2000))



However when transpiration rates through the periderm were measured using a porometer no relationship with periderm thickness could be found (Figure 3.2). A weak relationship between periderm thickness and overall weight loss was found, but this is probably related to susceptibility to damage.

Figure 3.2 a) Periderm thickness in relation to weight loss after 18 days (%). Each point represents one cultivar and is the mean of 5 roots
b) Periderm thickness in relation to transpiration rates. Each value represents one cultivar, data were obtained from Trial 7. (van Oirschot (2000))



3.5 Most water loss occurs through wounds

Van Oirschot (2000)

The use of a porometer enabled us to demonstrate that most water occurs through unhealed or incompletely healed wounds (Figure 3.3).

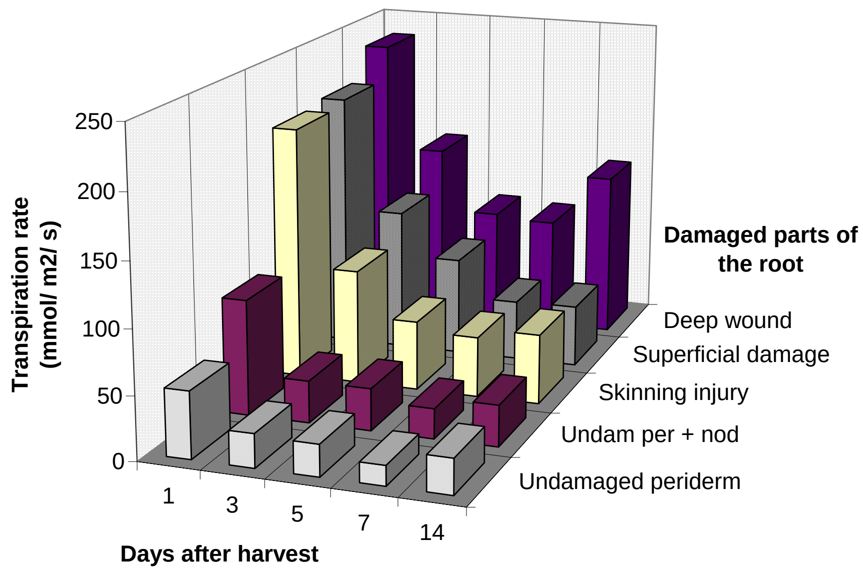


Figure 3.3 Transpiration rate through root surface with different kinds of damage measured at 1, 3, 5, 7 and 14 days after harvest. Cultivar: KSP 20. (Note that the time scale is not linear). (van Oirschot (2000))

3.6 Wound healing in sweetpotatoes. The development of a Lignification Index to assess efficiency.

Van Oirschot (2000), Van Oirschot *et al.*(2001b)

Figure 3.4 shows the rate of water loss over time through wounds as measured using a porometer. Immediately after wounding, the rate of water loss from the wounds ranged between 200 and 400 mmol·m^{-2}·s^{-1}. This is many times higher than the rate of water loss through undamaged periderm which ranges between 12 and 18 mmol·m^{-2}·s^{-1}. Two potato cultivars are included for comparison. The water loss profiles of potato were significantly different from those of sweetpotato. The transpiration rate through potato wounds decreased rapidly after wounding, while for sweetpotato the transpiration rates decreased more slowly. Thus the barrier under a potato wound forms more rapidly, or has a more effective sealing capacity than in sweetpotato. The barrier formed in potato stains positive with Sudan III but not with phloroglucinol/HCl, and is therefore assumed to consist mainly of suberin. The barrier in sweetpotato on the other hand stains bright red with phloroglucinol/HCl and only lightly with Sudan II and is believed to be a ligno-suberin-like substance with more lignin character.

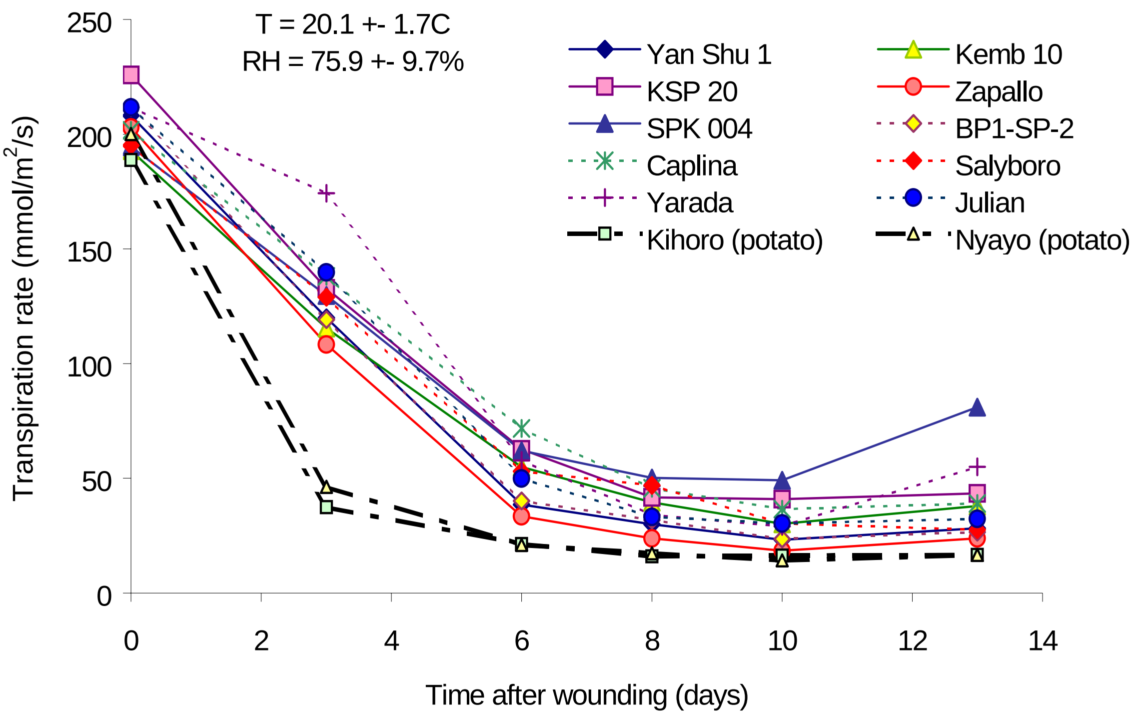


Figure 3.4. Transpiration rate across artificially inflicted wounds on ten sweetpotato and two potato cultivars during. Each value is the mean of measurements on ten roots. Sweetpotatoes were grown by CIP Nairobi and potatoes purchased in Nairobi. (van Oirschot *et al.* (2001b))

Among the sweetpotato cultivars, there were significant differences. The transpiration rates through wounds in Zapallo and Yan Shu 1 were always lower than for Kemb 10, KSP 20 and SPK 004. At all time points, the differences among cultivars were significant.

Lignification under the wound surface

Lignification started generally at the periphery of the wounds under the periderm, and subsequently developed towards the centre of the wound . When roots were kept at high humidity, the lignified layers were closer to the surface than at lower humidity. At low humidity, some of the cultivars did not produce a continuous lignin layer, but the layer would be patchy, or even absent. In roots with patchy lignification, lignin is generally present near the periderm but discontinuous at the centre of the wound.

In order to compare cultivars for wound healing efficiency, the thickness of the lignified layer was initially used as in St Amand and Randle (1991). However, it seemed more appropriate to investigate the continuity of a lignified layer. The physiological relevance of this was confirmed by the data obtained as described below.

Lignification corresponds to reduced water loss

The same wounds that had been assessed for water loss using the porometer were also assessed for lignification, and it was found that the two were related. The level of water loss was significantly related to the presence of lignin under the wound surface. Table 3.3 presents a contingency table using the paired data on lignin and water loss of individual roots, irrespective of the cultivar. For simplicity, the data for transpiration rate were divided into three categories (low, intermediate and high) and the data for lignification into two categories (complete lignification, and incomplete/absence of lignification). Using Pearsons tests, significant associations ($P<0.05$) were found at 6, 8, 10 and 13 days after wounding. Thus complete lignification under the wound is important for reducing the evaporation of water through the wound surface. Only at day 3, when wound healing had not proceeded very far, was there no association. Whether a continuous lignin layer itself prevents water loss or whether its formation immediately precedes that of a wound periderm (St Amand and Randle, 1991), which is the effective layer, is unclear. It should be noted that unlignified wounds also exhibited a decrease in their transpiration rate. This is probably the result of drying out of the upper cells which forms a physical barrier for water loss.

Lignification prevents microbial infection

Wounds were also assessed for their susceptibility to microbial infection. Table 3.4 presents a contingency table of paired data of sweetpotato roots that illustrates that susceptibility to rotting is more often found for wounds that have not lignified than in lignified wounds. The table presents data analysed in two ways, discriminating the completeness of the lignified layer versus the presence of lignin. In the former case, two categories considered were presence of lignin (patchy or continuous) and absence of lignin, while in the latter case the two categories were complete lignification as opposed to absence or patchyness of lignification. Completeness was significantly related while the presence of lignin did not relate. This association was more significant at day 6 than at day 3 ($\chi^2 = 6.71$; $P = 0.010$; $\chi^2 = 25.33$; $P < 0.001$). There was no association between absence as opposed to presence of lignin. It may be concluded that lignification plays an important role in preventing microbial attack, but as in the case of water loss it is vital that the lignification is continuous to function as an effective barrier.

Table 3.3. Association between lignification and the rate of water loss through wounds at 3, 6, 8, 10 and 13 days after wounding. (van Oirschot *et al.* (2001b))

Time after Wounding	Transpiration (T) ($mmol/s/m^2$)				No. of roots: No lignin or Patchy lignin	No. of roots: Continuous Lignin layer	χ^2-Value	P value
3 days	Low	76	> T		5	9	3.26	= 0.196
	Intermediate	76	< T <	89	7	4		
	High		T >	89	10	5		
6 days	Low	43	> T		0	12	11.80	= 0.003
	Intermediate	43	< T <	58	8	4		
	High		T >	58	5	8		
8 days	Low	37	> T		3	9	17.20	< 0.001
	Intermediate	37	< T <	64	1	10		
	High		T >	64	10	1		
10 days	Low	30	> T		1	9	8.36	= 0.015
	Intermediate	30	< T <	69	3	8		
	High		T >	69	7	3		
13 days	Low	14	> T		2	9	8.71	= 0.013
	Intermediate	14	< T <	19	0	12		
	High		T >	19	6	6		

Table 3.4 Contingency table using the incidences of roots rotting and/or lignification. In (A) patchy lignified roots were grouped with complete lignified roots, and in (B) patchy lignification was grouped with 'no lignin'. (van Oirschot *et al.* (2001b))

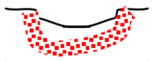
Time after wounding	Rotting	(A) Presence of lignin: No Lignin	(A) Presence of lignin: Patchy lignin Complete lignification	(B) Completeness of lignified layer: - No lignin – Patchy lignin	(B) Completeness of lignified layer: Complete lignification
Day 3	**No Rotting**	11	26	14	23
	Rotting	18	31	28	21
		Pearson Chi Square = 0.46 P = 0.496 Fisher's exact test: P = 0.6455		**Pearson Chi Square = 6.71 P = 0.010 Fisher's exact test: P = 0.01544**	
Day 6	**No Rotting**	5	28	5	28
	Rotting	15	19	26	8
		Pearson Chi Square = 3.14 P = 0.076 Fisher's exact test: P = 0.0861		**Pearson Chi Square = 25.33 P < 0.001 Fisher's exact test: P < 0.001**	

The lignification index

Two major conclusions can be drawn from previous sections. Firstly, lignification is (or is associated with) a crucial step in the wound healing process. Continuous lignification is directly associated with reduced water loss and reduced microbial infection. Secondly, not all wounds lignify under the conditions tested. It should be noted that the conditions tested are not optimal for curing as the relative humidity is not high enough. Other scientists have described lignification under curing conditions (Walter and Schadel 1983; St Amand and Randle 1991), and in these cases the lack or failure of lignification was not described.

To describe the extent of lignification more accurately a lignification index was used, for which the continuity of the lignin layer as seen by phloroglucinool/HCl staining was expressed on a scale from 0 to 1 (Table 3.5).

Table 3.5. Scores for lignification of sweetpotato wound sections (van Oirschot *et al.* (2001b))

	Score	Completeness of the lignin layer		
	Lignification score	Presence of lignin	Completeness of lignification	Distribution of lignin in wound  = lignin
Complete lignification	1	1	1	
Patchy lignification	0.5	1	0	
No lignification at all	0	0	0	

3.7 Cultivars differ in their wound-healing efficiency at lower humidities

Van Oirschot (2000), Van Oirschot *et al.* (2001b*)*

Figure 3.5 presents the lignification indices of 13 sweetpotato cultivars obtained at different relative humidities: high - 97%, intermediate - 65% and low - 58%. At high RH, all cultivars had a lignin index close to 1.0. This is in agreement with findings from Strider and McCombs (1958) who reported that under optimal curing conditions there was no difference in the rate of wound phellem formation between a range of cultivars. However at the lower humidities there was a very significant difference between the cultivars in ability to lignify wounds

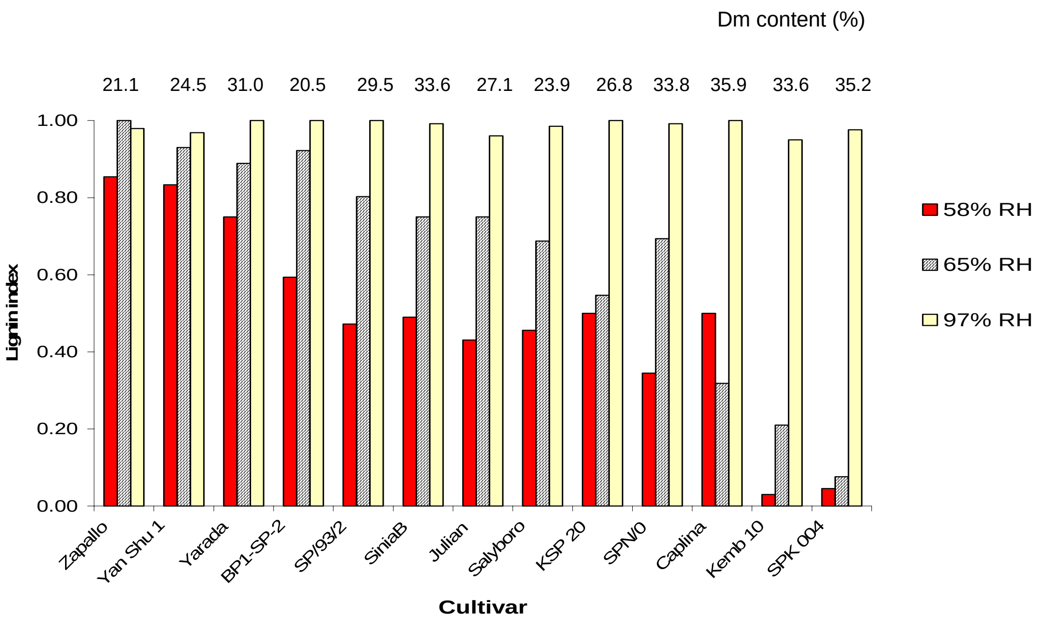


Figure 3.5. The lignification index of 13 sweetpotato cultivars as stored under three different relative humidities. Van Oirschot *et al.* (2001b)

3.8 The relationship between root dry matter content and wound healing efficiency.

Van Oirschot (2000), Van Oirschot *et al.* (2001b)

In Figure 3.5, the dry matter content of each cultivar is given at the top of the figure. Regression analysis indicates that high dry matter cultivars heal less efficiently. The regression was significant at the $p < 0.005$.

The mechanism by which the DM content affects wound healing is not understood. It is possible that wound healing ability is directly related to the rate of desiccation of the tissue. Porometer readings indicate that tissue with a high DM content initially loses water at the same rate as tissue with a low DM content, and might therefore reach a critical level of moisture content more rapidly than tissue with a low DM content. The hypothesis would be that below a critical level of moisture content the tissue is too stressed, resulting in failure to form the protective lignified layer under the wound.

Desiccation of several outer cell layers of the wound occurs normally prior to lignification. Observations upon the thickness of the desiccated cell layer correspond with the above hypothesis (Van Oirschot, 2000). The desiccated tissue at the wound surface was thicker for roots with high DM content , and also in cases where wounded roots were stored at low relative humidity (58-65%). Tissue of unhealed wounds stained with safranin, which indicated the presence of phenolics. This might indicate that the healing mechanism was initiated by the synthesis of lignin precursors but was not completed.

The rate of desiccation may not, however, be the only factor affecting the wound healing ability since there were some consistent outlying cultivars. The cultivar KSP 20 consistently healed less well than predicted from the DM/lignin index relationship, while Caplina and Yarada consistently healed better than expected.

3.9 The basis for cultivar differences in susceptibility to damage

Van Oirschot (2000), Van Oirschot *et al.* (2000a)

Although we believe that the main factor affecting shelf-life of cultivars is their ability to wound heal under marketing conditions, susceptibility to damage appears also to be signficant. In a previous section we showed that cultivars differ in susceptibility to scuffing and in susceptibility to breakage. We showed that scuffing affected rates of weight loss short-term and breakage long-term. In the light of our findings on wound-healing, the reasons for this now become clear. Scuffing damage can heal rapidly, whereas break take much longer, and healing may be incomplete.

Figure 3.6 shows that susceptibility to scuffing depends on periderm thickness.

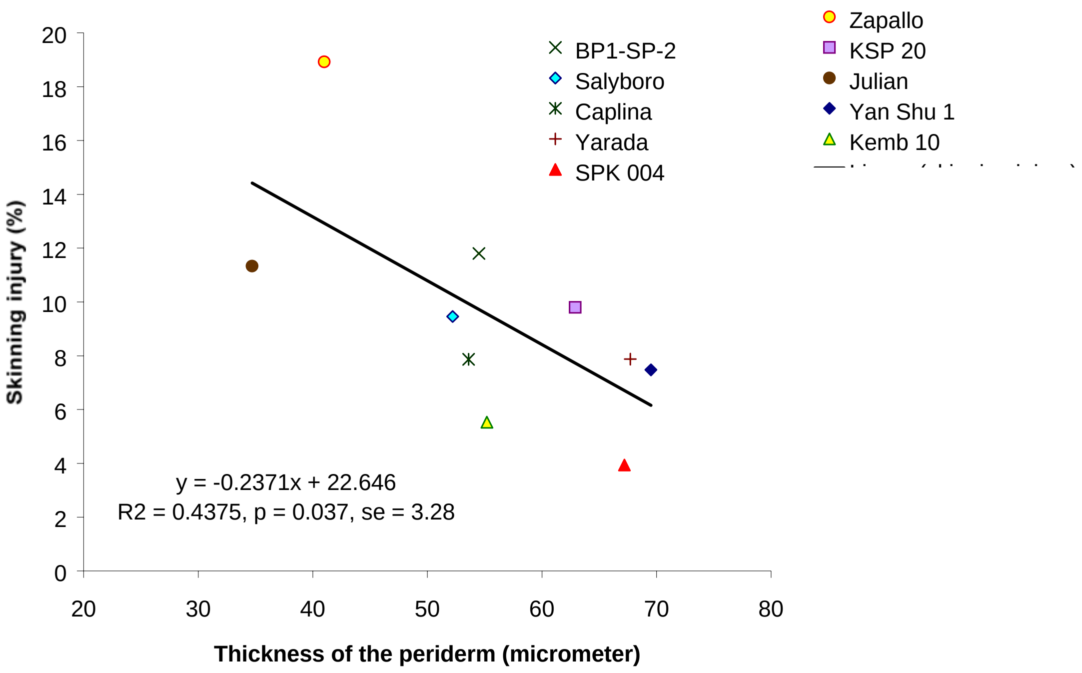
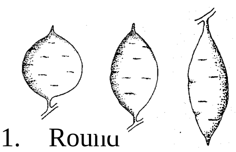
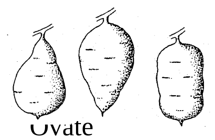
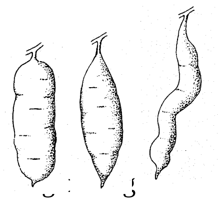


Figure 3.6 Relationship between periderm thickness and percentage skinning injury (percentage surface area of the root) after scuffing treatment. Each point represents a cultivar. (Van Oirschot (2000))

Not surprisingly susceptibility to breakage was found to relate to root shape, as indicated by Table 3.6

Table 3.6 Contingency table showing significant association between shape and susceptibility to breakage. Breaks are in the categories of 0, 1 or ≥2 (Van Oirschot (2000))

	 1 2 3 1. Round 2. Round elliptic 3. Elliptic		 4 5 6 4. Ovate 5. Obovate 6. Oblong		 7 8 9 7. 8. Long elliptic 9. Long irregular curved		
0	35	*27%*	50	*38%*	46	*35%*	
1	11	*19%*	15	*25%*	33	*56%*	χ^2= 30.4
≥2	3	*11%*	2	*7%*	23	*82%*	
0	12	*39%*	13	*41%*	6	*19%*	
1	5	*25%*	1	*5%*	14	*69%*	χ^2= 23.5
≥2	1	*5%*	1	*5%*	19	*90%*	

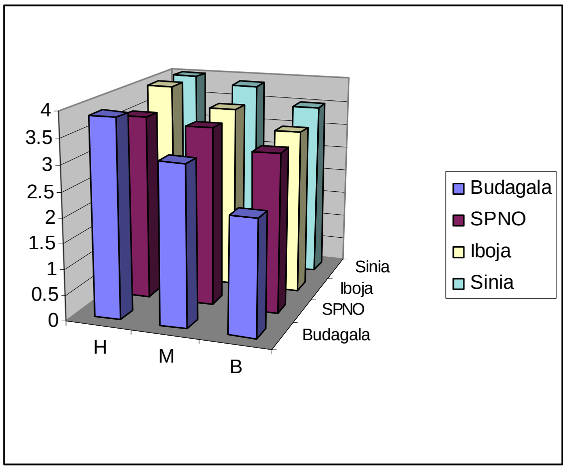
3.10 The basis for cultivar differences in susceptibility to rots under high humidity conditions.

Muhanna (2001)

In order to determine the basis of cultivar resistance to rots under high humidity, experiments were conducted to distinguish between the possibilities that resistance was due to tissue mechanical characteristics, chemical characteristics or barrier formation.

Figure 3.7 shows the results of an experiment in which extracts were made of tissue isolated from infected sweetpotato roots. It was found that agar made from tissue extracted on the border of lesions inhibited growth of *Rhizopus oryzae*, and that the effect was cultivar specific. The greatest effects were seen for Budagala, a cultivar noted for its resistance to *Rhizopus oryzae*.

Figure 3.7
Effect of interaction between cultivars and SMA agar types on the extent of growth of *R. oryzae.*
LSD = 0.8 Interaction significant at 5% level of probability.
H, M and B – Agar made from root tissue 10, 5 and 1 cm from the disease lesion respectively.
(Muhanna 2001)



Output 4: The identification of appropriate methods for reducing losses due to insect infestation of dried sweetpotato chips during storage in Uganda.

4.1 Overview for output 4

In northern district of Uganda, due to a unimodal rainfall pattern, sweetpotato production is limited to only one season in a year. Once mature, the crop cannot be stored in the ground. Farmers are therefore forced to process the mature roots into dried chips for long-term storage. The dried chips are a very important staple in the region, especially as the cassava crop failed for many years due to the spread of African Cassava Mosaic Disease Complex. Insect infestation is a serious limitation to storage. Within this Output, the main infesting insect was identified as *Araecerus fasciculatus.* Several methods of control were tested. The most successful were identified as salting and parboiling. It is envisaged that the importance of dried sweetpotato chips as a form of food security will be significantly increased at smallholder agriculture, once the IPM strategies developed in this study are implemented on-farm.

4.2 Identification of the main infesting insects

Agona (1998)

A baseline survey was conducted to establish the post-harvest practices and constraints affecting dried sweetpotato chip processing, storage and utilisation in Kumi district, Uganda. Survey results suggest that the food security status of dried sweetpotato chips is under threat. Insect pests were identified as the major loss causative agents of dried chips in storage, and six species viz. *Araecerus fasciculatus, Rhysopertha dominica, Dinoderus minutus, Sitophilus zeamais, Tribolium castaneum* and *Lasioderma serricorne,* in order of importance, were identified. *A. fasciculatus* was identified as the most damaging pest of dried chips at smallholder subsistence farming systems in Uganda. Information on the biology and control methods of the pest on dried sweetpotato chips is, however, lacking. Farmers' traditional methods of pest management that included regular inspection, re-drying, opening of granary roof, sorting and removal of infested chips were considered insufficient for controlling and maintaining stored chip quality.

4.3 Investigation into the lifestyle of *A. fasciculatus*

Agona (1998)

Investigations on the biology of *A. fasciculatus* showed that it is a major pest of dried sweetpotato chips, and both adults and larvae feed. The adults, however, do not feed on sweetpotato flour. All the larval stages feed on flour and successfully develop into pupae and adults. The larvae are capable of re-infesting whole dried chips and developing into pupae and adults. Larval development is more favoured on sweetpotato flour than on chips, especially when not disturbed, and this was shown by reduced larval development period (36.7 $\pm$ 0.6 days), reduced generation time (50.4 $\pm$ 0.9 days) and all larvae developing into adults (100%). Growth is prolonged when larvae are disturbed during growth. Larval disturbance resulted into delayed larval developent period (73.0 $\pm$ 2.4 days); increased development time into adults (86.0 $\pm$ 2.5 days) and high mortality (85%). The mean development period of *A. fasciculatus* on whole chips from egg to adult was 63.6 $\pm$ 1.1 days under ambient temperature and relative humidity conditions of about 26 °C and 70% respectively. The ability of larvae to survive on sweetpotato flour implies that flour is important in sustaining carry-over residual populations, while physical agitation of developing larvae could reduce subsequent chip damage. The sex ratio of *A. fasciculatus* on dried sweetpotato chips is unitary.

4.4 Development of a scale to assess damage to dried chips

Agona (1998), Agona *et al.* (1998)

Five damage class categories due to *A. fasciculatus* infestation were established based on the number of adult emergence holes and chip weight reduction. Class 1 chips were not damaged, and Class 5 the most severely damaged. The severity of infestation of the different class categories was 0, 0.06, 0.23, 0.60 and 0.74 holes cm^{-2} of chips, which corresponded to weight losses of 0, 17.6, 24.6, 60.5 and 86.2% inclass categories 1, 2, 3, 4 and 5, respectively. The end-uses of each class category were defined to help small-scale Ugandan farmers in decision making.

4.5 Varietal resistance to damage of dried chips by *A. fasciculatus*

Agona (1998)

Varietal screening for resistance against *A. fasciculatus* showed that all the varieties screened were susceptible, but to varying degrees. Differences existed in time required for the pest to complete its life cycle on the different varieties. The susceptibility levels of the varieties varied significantly, and variety Mbiyombiyo had the highest Susceptibility Index (SI) (4.00 $\pm$ 0.65), while variety Haraka the lowest SI (1.83 $\pm$ 0.13). The dry matter content (DMC) if the different varieties screened was significantly different, but the relationship between DMC and SI was weak and insignificant. A wide range of sweetpotato germplasm is recommended for screening in order to identify resistant varieties and isolate specific mechanisms for resistance.

4.6 Testing control methods against attack by *A. fasciculatus*

Agona (1998)

There was a significant reduction in damage by *A. fasciculatus* when the sweetpotato chips were either salted, parboiled or solarised. Total mortality of the pest; low adult emergence; increased generation time and/or reduced weights of emergent adults depending on the treatment applied demonstrated the effectiveness of these control methods. Salting at 2-3% w/w, parboiling for 5 minutes and solarisation for 3 hours of chips are recommended for on-farm adoption. As an example Table 4.1 shows the effect of salting using a range of doses. On-farm trial results showed that the three methods are effective against the insect pest spectrum of dried sweetpotato chips, with parboiling and salting methods being the most effective. Furthermore, the consumer-acceptability quality test results showed that parboiled and salted chips had better organoleptic qualities than solarised chips.

Table 4.1. Mean number of *A. fasciculatus* that emerged and final Moisture Content (MC) of treated chips at different salt dosage levels

Salt dosage level (%)	Transformed means of adults that emerged‡	Actual means of adult that emerged	Final MC (%)
0	2.462	5.750	13.837
0.25	1.868	3.500	14.112
0.50	1.896	3.250	14.850
1	1.117	1.250	16.225
2	0.837	0.250	16.400
3	0.998	0.750	16.925
4	0.707	0.000	17.200
5	0.707	0.000	17.300
s.e.d. (24 d.f.)	0.372	1.265	0.339
c.v.	39.770%	96.990%	3.020

‡Square root data transformation: $\sqrt{(x + 0.5)}$, was adopted.

Overall, there were significant differences ($p<0.05$) in the mean number of adult A. fasciculatus that emerged in the chips treated at different salt dosage levels prior to drying.

CONTRIBUTION OF OUTPUTS

Short shelf-life of fresh storage roots is a major constraint for the use of sweet potato as a food security crop and for income generation through marketing. This project has made considerable progress in determining the range of perishability among cultivars and in developing our understanding of why cultivars differ in rates of deterioration under the normal handling conditions encountered in East Africa. We have shown that the range in perishability is such that selection of cultivars with better keeping qualities is a feasible strategy. The fact that the rate of water loss is the main factor controlling perishability under marketing conditions means that appropriate cultivars can be relatively easily selected by assessing rates of weight loss. At the same time, other important post-harvest quality characteristics have been defined and appropriate selection methods (using trained taste panels) have been tested.

Dissemination of the findings has occurred primarily through conference presentations. However, there is a need for further dissemination. The Crop Post-Harvest Programme has already recognised this and is funding a follow-on project (R7520) in which a report of the findings and methods used is to be published for circulation to sweetpotato breeding programmes throughout the world.

Within the project, it was also found that the variation in shelf-life observed among locally available germplasm was associated with dry matter content. High dry matter cultivars tend to have lower wound-healing efficiency and therefore shorter shelf-life. Given that high dry matter has been identified as an important criterion for consumer acceptability in East Africa, this is an unwelcome finding. At this stage it is not clear whether there is a causative link between dry matter content and wound-healing efficiency. If cultivars with high wound-healing efficiency and high dry matter content can be found, these would provide very useful breeding material. There is therefore a need to look more widely among sweetpotato germplasm worldwide and to seek out sources of variation in shelf-life that are not associated with dry matter content. The Crop Post-Harvest Programme is funding such a screening in a follow-on project (R7520).

This project also considered the extension of storage life under conditions where roots are stored in purpose built long-term storage structures. In this case roots can be stored under higher humidities and case rotting was found to be the main limitation to storage life. Cultivar differences were found, but were less stable, than those for shelf-life during marketing. This suggests that there may be less potential for breeding for better cultivars for long-term storage. More work in this field would be useful, but is so far not funded.

The work conducted to compare the storage life of roots under different conditions showed, not surprisingly, that considerable extension of shelf-life can be obtained through improving storage environment – increasing humidity but maintaining sufficient ventilation. These findings will be disseminated as described above.

Work on dried sweetpotato chips identified two methods for controlling insect infestation; salting and parboiling. Both methods were validated through on-farm testing in Kumi District, Uganda. Further dissemination of these methods has already been carried out in Soroti District as part of a DFID funded project (Competitive Research Fund).

PUBLICATIONS PRODUCED DURING THIS PROJECT

* electronic copy not provided with this report

*AGONA A. (1998) PhD thesis University of Harare, Zimbabwe "Studies on aspects of the biology and control of *Araecerius fasciculatus* [De Geer (coleoptera: anthribidae)] on dried sweetpotato." (E)

*AGONA, J.A., SILIM NAHDY, M., GIGIA, D.P. and REES, D. (1998) The effect of salting sweetpotato chips prior to drying on infestation by *Araecerus fasciculatus* Degeer (Coleoptera: Anthribidae). *Trop Agric. (Trinidad)* **75**, 208-211 (A)

*AGONA, J.A., NAHDY, S.M., GIGA, D.P. AND REES, D. (1999) A visual scale of loss assessment for dried sweetpotato chips due to *Araecerus fasciculatus* Degeer (Coleoptera: Anthribidae) infestation on-farm. *Uganda Journal of Agricultural Sciences*, **4**: 1-5 (A)

KAPINGA, R.E., JEREMIAH, S.C., RWIZA, E.J. and REES, D. (1996) Preference and selection criteria of sweetpotato varieties at farm level in Tanzania: Secondary information compiled. NRI Technical Report (C)

KAPINGA, R.E., JEREMIAH, S.C., RWIZA, E.J. and REES, D. (1997) Preferences and Selection Criteria of Sweetpotato in Urban Areas of the Lake Zone of Tanzania. NRI Technical Report. (C)

*KAPINGA, R., RWIZA, E., TOMLINS, K.I. and D. REES (1998) The potential for using on-station trained consumer panels to assess the acceptability of sweetpotato cultivars in Tanzania. NRI Technical report (C)

*KAPINGA, R. KULEMBEKA, H., CAREY, T., REES, D., KIFLEWAHID, B., AMOUR, A. , RUGUTU, C., RWIZA, E. AND NYANGO, A. (2000) Tanzanian sweetpotato varieties and their associated acceptable qualities by end-users. Fifth Triennial Congress of the African Potato Association May 29 – June 2, 2000 (B)

MBILINYI, L.B., MULUNGU, L.S., REUBEN, S.O.W.M., SENKONDO, F.J. , MABAGALA, R.B., REES D. and KAPINGA R. (2000) The effect of storage environment on the shelf-life of sweetpotato. Presented at the Fifth Triennial Congress of the African Potato Association. Kampala, Uganda May 29 – June 2 2000. APA Conference Proceedings **5**, 513-519 (A)

MTUNDA, K., CHILOSA, D., RWIZA, E., KILIMA, M., KIOZYA, H., MUNISI, R., KAPINGA, R., and REES, D. (2001). Damage reduces shelf-life of sweetpotato during marketing. *African Crop Science Journal*, 9: 1-8 (A)

MUHANNA, M. (2001) Physiological and biochemical factors determining resistance of sweetpotatoes to post-harvest pathogens in Tanzania. MPhil thesis. Cranfield University. 152 pp. (F)

REES, D. (2000) An assessment of sweetpotato damage and implications for shelf-life in selected urban markets of Tanzania. NRI Report no. 2488 30 pp (C)

REES, D., POLLARD, A, MATTERS, D. and CAREY, E. (1996) Post-Harvest Physiology of Sweetpotato Storage Roots Related to Storability. Poster presented at the Second International Symposium on the Biology of Root Formation and Development.
Short paper in Biology of root formation and development, Altman and Waisel, Eds p315 (B)

*REES, D., KAPINGA, R., JEREMIAH, S., RWIZA, E., and NYANGO, A (1998a)
Preferences and selection criteria of sweetpotato varieties in Tanzania
Presented at the International Society for Tropical Root Crops - Africa Branch, Benin (B)

REES, D., KAPINGA, R., RWIZA, E., MOHAMMED, R., VAN OIRSCHOT, Q., CAREY, E. and WESTBY, A. (1998b) The potential for extending shelf-life of sweetpotato in East Africa through cultivar selection. *Trop Agric. (Trinidad)* **75**, 84-88 (A)

REES, D., VAN OIRSCHOT, Q.E.A, and AKED, J. (1999) Addressing the problems of sweetpotato in East Africa. Presented at the American Society for Horticultural Science Southern Region, Memphis, Tennessee Feb 1999, abstract published in conference proceedings. (B)

REES, D., KAPINGA, R., MTUNDA, K., CHILOSA, D., RWIZA, E., KILIMA, M., KIOZYA, H., and MUNISI, R. (2001a) Damage redues both market value and shelf-life of sweetpotato: a case study of urban markets in Tanzania. *Tropical Science.* **41**, 1-9 (A)

REES, D., VAN OIRSCHOT, Q.E., AMOUR, R., RWIZA, E., KAPINGA, R., and CAREY T. (2001b) Modelling cultivar effects on perishability of sweetpotatoes. Submitted to Post-Harvest Biology and Technology. (G)

*RWIZA, E., NDONDI, T., CHOTTA, M., KILIMA, M.S., CHILOSA, D.N.V., MAYONA, C.M., MTUNDA, K., , REES, D., and KAPINGA, R.E (1996) Post-Harvest Evaluation of Sweetpotato Varieties. Methods Manual. (M*anual of trial methods circulated round participating institutes*.) (C)

RWIZA, E., NDONDI, T., CHOTTA, M., KILIMA, M.S., CHILOSA, D.N.V., MAYONA, C.M., MTUNDA, K., VAN OIRSCHOT, Q., REES, D., and KAPINGA, R.E (1997) Post-Harvest Evaluation of Sweetpotato Varieties. Methods Manual 1997. (*Updated manual of trial methods circulated round participating institutes*.) (C)

RWIZA, E., AMOUR, R., NDONDI, T., CHOTTA, M., KILIMA, M.S., CHILOSA, D.N.V., KITELEKI, M., MAYONA, C.M., MENDE, D., MULUNGU, VAN OIRSCHOT, Q., REES, D., and KAPINGA, R.E (1998) Post-Harvest Evaluation of Sweetpotato Varieties. Methods Manual 1998. (*Updated manual of trial methods circulated round participating institutes*.) (C)

RWIZA, E., NYANGO, M.,. MUNISI, R. KAPINGA, R.,. TOMLINS, K.,. REES, D., NDENGELLO, T. ,and WESTBY A. (2000) The potential for using trained taste panels for screening sweetpotato varieties: Experiences in Tanzania. Presented at the Fifth Triennial Congress of the African Potato Association. Kampala, Uganda May 29 – June 2 2000 APA Conference Proceedings **5**, 521-526. (A)

*TOMLINS, K.I. (1998) Methods for evaluating the sensory properties and consumer preference of sweetpotato cultivars. NRI Report. (C)

VAN OIRSCHOT, Q.E.A. (2000) Storability of sweetpotatoes (*Ipomoea batatas* (L.)) under tropical conditions: physiological and sensory aspects. PhD thesis. Cranfield University. 205 pp. (E)

*VAN OIRSCHOT, Q.E.A., REES, D. and AKED, J. (1998A) The effect of storage under simulated tropical conditions on sensory properties of five East African sweetpotato cultivars. Poster presented at the eighth Post-Harvest Convention, Silsoe College, Cranfield University. 25th March 1998. (B)

*VAN OIRSCHOT, Q.E.A., REES, D. and AKED, J. (1998b) Shelf-life of sweetpotatoes under tropical conditions; effect of storage-time on sensory properties and importance of water loss. Talk presented at the National Sweetpotato Collaborator's Meeting, Little Rock, Arkansas January 31 - February 4 1998 *HortScience Abstract* (B)

VAN OIRSCHOT, Q.E.A., REES, D. and AKED, J (1999)
The role of damage and wound healing in sweet potaot storability under tropical conditions
Presented at the American Society for Horticultural Science Southern Region, Memphis, Tennessee Feb 1999, abstract published in conference proceedings. (B)

VAN OIRSCHOT, Q.E.A., NDENGELLO, T., AMOUR, R., RWIZA, E., REES, D., TOMLINS, K.I., JEFFRIES, D., BURNETT, D., and WESTBY A. (2000a) Cultivar variation of sweetpotatoes in susceptibility to damage. Presented at International Society for Tropical Roots Crops, Japan, Sept 2000 [Scientific poster] (B)

VAN OIRSCHOT, Q.E.A. REES, D., AKED, J. AND KIHURANI, A.W. (2000b) Cultivar variation in wound healing efficiency of sweetpotato and Irish potato and the effect on shelf-life. Presented at the International Society for Tropical Root Crops, Japan 2000 10pp (A)

VAN OIRSCHOT, Q. W. A. , REES, D. and AKED, J. (2001) Sensory characteristics of five sweetpotato cultivars and their changes during storage under tropical conditions. Submitted to Food Quality and Preference. (G)

Journal publications in preparation

REES, D.., KAPINGA, R., CHOTTA, M., KILIMA, M.S.,KIOZYA, H. MAYONA, C.M., MBILINYI, L. B., MTUNDA, K., AMOUR, R., NDONDI, T.,RWIZA, E. and CHILOSA, D.N.V (2001c) The effect of environment on post-harvest characteristics of sweetpotato cultivars in Tanzania. (G)

*REES, D.., KAPINGA, R., CHOTTA, M., KILIMA, M.S.,KIOZYA, H. MAYONA, C.M., MBILINYI, L. B., MTUNDA, K., AMOUR, R., NDONDI, T.,RWIZA, E. and CHILOSA, D.N.V (2001d) Evaluation of sweetpotato cultivars for production characteristics across environments in Tanzania**. (G)**

*TOMLINS, K., REES, D., KAPINGA, R., RWIZA, E., NYANGO, M. and AMOUR, R., (2001) Sensory characteristics of key cultivars of sweetpotato in Tanzania (G)