Screening sweetpotato cultivars for wound-healing efficiency

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Introduction

Short shelf-life is a major constraint for the use of sweetpotato as a food security crop in East Africa. Previous work has indicated that under normal handling and marketing conditions in East Africa (moderately rough handling, sub-optimal humidity, tropical temperatures) a large range in the storability of sweetpotato exists among the available germplasm (Rees *et al.*, 2003). Under these conditions deterioration is dominated by water loss through unhealed or incompletely healed wounds. An important factor in the variation between cultivars is their ability to heal wounds under non-ideal curing conditions, specifically at sub-optimal humidities(van Oirschot *et al.* 2003).

A rapid protocol has been developed to assess wound-healing at low humidity by staining for lignin, which forms an important part of the new wound periderm that grows beneath the wound (van Oirschot *et al.* 2003). Roots are scored (Lignification index) on the basis of the continuity of the lignin layer. It has been demonstrated that the lignification index (LI) indictes "functional" wound-healing in that it relates both to a reduction in water loss through wounds, and a reduction in susceptibility to pathogen invasion.

Trials so far have indicated that there is a relationship between shelf-life and root dry matter content (Rees *et al.* 2003), with a tendency for high dry matter cultivars to have shorter shelf-life. Likewise there appears to be a tendency for high dry matter cultivars to have reduced ability to wound-heal at sub-optimal humidities (Van Oirschot *et al.* 2003). At this time the physiological mechanism for these relationships is unknown.

The finding that cultivars with higher dry matter content have less efficient wound healing is unwelcome. Mealiness, associated with high dry matter content was one of the main consumer criteria for sweetpotato cultivars identified in East Africa (Kapinga *et al.* 1997). High dry matter content is also very important where roots are used for processing, and world-wide the characteristic is considered so important that CIP has a specific initiative to breed for higher dry matter cultivars. It thus becomes very important to determine whether it is possible to breed for cultivars with high dry matter content AND good wound-healing characteristics. . We already have some evidence that this might be successful. Three cultivars tested in Tanzania (two Tanzanian cultivars (Kagole, Bilagala) and one clone introduced by CIP (440088)) were found to have better keeping qualities than predicted from their dry matter content (Rees *et al.* 2003). However their wound healing efficiency was not specifically determined. There are also indications that North American germplasm has better keeping qualities than East African germplasm (J. Bohac, USDA, pers. comm.).

In this study a wide range of cultivars originating from different areas of the world has been screened in order to determine to what extent wound healing efficiency is linked to DMC, and in particular to look for cultivars with high DMC and efficient wound healing.

Materials and Methods

Sweetpotato supply

Three sets of cultivars were included in the screening programme, each of which was assessed twice.

Set A (GxE cultivars) consisted of 15 cultivars, sourced from many regions of the world grown by CIP at Kabete, Nairobi, Kenya. These cultivars were chosen to cover a wide range of characteristics, and have also been included in a set of trials conducted by CIP at several locations around the world to test germplasm by environment interactions. Trials were planted in early January 2000, and were harvested after 4 and 6.5 months on 8th May and 26th June 2000. Screening was initiated on 17th May and 6th July respectively. Five additional cultivars, grown in a separate field trial were included in the assessments of the roots from the first harvest.

Set B (US cultivars) consisted of 18 cultivars sourced mainly from North, South and Central America grown at the US Vegetable Laboratory, USDA-ARS, in South Carolina, USA. Trials were grown during the normal sweetpotato season in 1999 and 2000 (Harvested in early November 1999, and late October 2000). Following the harvest in 1999 roots were stored for three months in the USA before being air-freighted to the UK for screening. Screening was initiated on 16th February 2000 and 28th November 2000 respectively.

Set C (East African cultivars) consisted of 18 cultivars primarily of East African origin grown by CIP at Kabete, Nairobi Kenya. Field trials were planted in early February 2000 and late August 2000 and harvested in early September 2000 and early March 2001 respectively. 6 of the cultivars were only screened in the second season as supplies were delayed due to quarantine restrictions as cultivars were transferred from Tanzania to Kenya. Screening was initiated on 14th September and 16th March respectively.

The cultivars within each set are listed in Table 1.

After harvest, roots were packed into boxes, with padding to prevent mechanical damage, and air-freighted to the UK in a livestock hold so that temperatures were maintained above chilling levels (>15°C). Once at NRI, roots were stored at ambient temperatures (about 20°C), and high humidity. Screening was always initiated within two weeks.

Screening for wound-healing efficiency

For assessment of wound-healing efficiency at moderate humidity roots were maintained in three humidity controlled chambers at 65-70% R.H., 25-26ºC. After one day a shallow wound (approximately 2 x 5 cm and 1.5 mm deep) was cut using a potato peeler. Staining for lignin was carried out using phloroglucinol after a further 5 days. For staining, three or four thin cross sections with a depth of 10 mm and approx 0.5 mm thick were cut from each wound using a razorblade. These sections were stained with phloroglucinol (1% in 95% ethanol) for 1 min, followed by concentrated HCl for 1min and washed in water. Each wound was scored subjectively between 0 and 1 on the basis of the extent and continuity of lignification seen in the 3-4 sections.

In each screening experiment 12 roots were assessed per cultivar. Roots were arranged in a complete randomised block design, with each shelf considered as a block. Thus one root per cultivar was placed on each of 4 shelves per chamber.

For assessment of wound-healing efficiency at high humidity the same protocol was used, but roots were placed in an enclosed chamber with four shelves and water in the base. Measured

relative humidity was greater than 95% throughout. In each screening experiment 4 roots were assessed per cultivar, with one root per cultivar on each of the four shelves.

Analysis of 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% acetonitrile and further filtered through a 0.45 µm 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.

Measurement of dry matter (DM) content

Cultivar DM was assessed using three randomly selected roots within a few days of roots arriving in the UK. Each root was cut into cubes approximately 1 cm^3, after thorough mixing, approximately 15g was weighed, dried for 48 h at 80°C in a fan-assisted oven, and rewieighed.

For some screening experiments the DM content of individual roots was assessed. In this case, due to time constraints, thin (approximately 5mm) transverse sections were cut from the centre of the root and dried as above immediately after the wound had been assessed for lignification.

Results and discussion

Lignification efficiency, range and stability of cultivars

Figures 1, 2 and 3 summarise the cultivar characteristics for sets A, B and C respectively. For all three sets of cultivars a wide range in LI at moderate RH was found. The consistency of L.I. at moderate RH over harvests/seasons was tested by simple correlation analysis (Table 2). In all cases the correlation is significant. The weakest correlation (significant to only 5%) is found for set B. It this case the first assessment was carried out on roots which had been stored for 2 months, so that we have less confidence in this data set.

As observed previously, (van Oirschot *et al.* 2003), in contrast to root behaviour at moderate RH, most cultivars showed high wound healing efficiency (high LI) when assessed at high RH. There are however exceptions, notably Beau Regard (in both set B and set C) and L86-33 and Hernandez in set C. There is no relationship between low LI measured at high RH and low LI at moderate humidity. It has been observed that the lignification following healing at high RH is often thinner than that following healing at lower RH, presumably because it is easier for the tissues to create a continuous layer. For this reason it is more difficult to assess LI at high RH, and flesh colour may influence th score. *Note: we are in the process for obtaining flesh colour records to check whether the low L.I. scores at high RH occurred mainly in orange fleshed cultivars.*

A range of DM content was found for all sets of cultivars (Figures 1-3). US cultivars (set B) tended to have lower DM content. The widest range was found in set C. For set A the DMC tended to be higher for the later harvest as would be expected. Correlation analysis (Table 2) indicated very high stability of DM content between harvest/seasons.

Relationship between L.I. and DMC

Table 2 shows the relationship between LI and DM content for each set of cultivars and each season. A negative relationship always seen, but only significant in about 50% of cases. Notably, the strongest relationships are seen for set C which has the largest range in cultivar DM content.
Generally the relationship is not as strong as has been observed in previous studies (Rees *et al.* 200, van Oirschot *et al.* 2003), but this may be related to a smaller range in DM content for cultivar sets A and B.

Accuracy and reliability of the screening method

The accuracy and reliability of the screening method can be assessed by considering the individual screening experiments. (Note: The data and statistical analysis for each individual experiment is given in *Further data*.) As it was not possible to assess all cultivars within each set simultaneously, the LI shown for each cultivar is the mean value from between 2 and 4 experiments. For the individual experiments a very significant cultivar effect ($P<0.001$) was seen in all but one case, and the 95% confidence limit for differences between cultivars was below 0.27 for all but one case. There were three cases where exactly the same cultivar set was assessed in consecutive screening experiments. Although there were significant differences between the experiments in two of the three cases, the differences were generally small (<0.2), and there were no significant cultivar x experiment interactions. From this data we deduce that the practice of using 12 roots per cultivar is sufficient.

Cultivars considered by location

Table 3 shows the mean LI (measured at moderate RH) and DM content for each cultivar, sorted by origin. Where cultivars were grown in both locations (Nairobi and South Carolina) both sets of data are included. Figure 4 shows the mean LI for each cultivar plotted against mean DM content. (cultivars grown in different locations are included more than once). There is a fairly clear grouping of cultivars, with those from East Africa having higher DM content and lower LI than those from other regions. We suspect that the difference in DM content may have been accentuated by breeding. Pressure for high root fresh weight yield would tend to favour lower root DM, except in regions where high DM content is an essential characteristic for consumer acceptability, as it is in East Africa.
Note: we need to check some of these origins again. I have a suspicion that some cultivars said by CIP to be from the US have original origin in S. America.

Table 4 shows the DM content and L.I. for two cultivars which were assessed after being grown at both locations (Nairobi and South Carolina). Beau Regard was grown in Nairobi and South Carolina. Kemb 10, SPN/0 and Tanzania are considered to be the same cultivar (reference), and was also grown in both locations. In both cases good consistency was seen. This supports the previous evidence that there is reasonable cultivar stability for both attributes.

Factors controlling wound-healing efficiency

One objective of this screening programme was to obtain more information about the factors controlling wound-healing efficiency, specifically to consider the role of DM content. Considering all the cultivars, a very significant negative correlation is found between LI and DM content ($r = -0.5$ significant to 0.1%). However, when the cultivars within each region of origin are considered separately, no significant relationship is seen. This could be partly because the range in both LI and DM within each collection of cultivars is smaller.

The theory has been put forward that the relationship seen between DM content and LI can be explained if there are two classes of sweetpotato depending on their origin, those with low DM and high LI (from America and China), and those with high DM and low LI (from East

Africa). In this case there would not need to be any physiological link between the two characteristics. However, we have additional data that does not support this theory.

In order to look at DM content effects more directly, five experiments were carried out in which both the L.I. at moderate RH and the dry matter content of each individual root was measured. Regression analysis was then used to model L.I. in terms of cultivar and dry matter content. For four of the five experiments DM content was measured at the end of the experiment at the time of assessment of lignification. This introduces a bias to the data, as bad wound-healers would tend to lose more water during the assessment, and would therefore have increased final DM content. In an attempt to correct for this, an initial DM content was estimated assuming that all weight loss during the experiment was water loss. For experiment 5 a different method was used. In this case the root was cut into two longitudinally. One half was assessed for DM content and the other half was assessed for ability to lignify under moderate RH. Thus initial DM content was measured directly.

The best regression models obtained are shown in Table 5. The percentage variance accounted for by the models differ between experiments, but a common pattern emerges. In all cases, cultivar is the the more important factor controlling LI. However, in all cases a model including both DM and cultivar accounts for more of the data variance than cultivar alone, but less than the sum of the variances when cultivar and DM are considered individually. This indicates two things; firstly that DM content differences between cultivars is a factor controlling LI, and secondly that within each cultivar differences in DM content are related to differences in LI (i.e. roots with lower DM tend to have higher LI). These two factors strongly suggest that there is a physiological link between DM content and LI.

We have not determined a mechanism by which DM might affect wound-healing efficiency at moderate RH. However, there have been previous observations that sugar levels are strongly related to DM content and might be related to wound-healing efficiency (Rees *et al.* 2003). This will be examined in more detail in a subsequent paper.

Selection of cultivars for high DM content and high LI

Another important objective of this screening programme was to identify cultivars with high DM and yet good wound-healing efficiency that would be good parents for subsequent breeding. From our data, imposing arbitrary lower limits of 25% DM content and 0.5 LI, the following cultivars emerge: From the USA W364, W341 and Sumor, both cultivars included from China; Yan Shu 1 and Xu Shu 18 (DM 24.9%), from South/Central America; Santo Amaro, Cemsa 74-228 and PI 595856, from Japan; Tinian, from Papua New Guinea; Naveto and two related cultivars from East Africa; Sinia and Sinia B.

Conclusions

We have demonstrated that there is a wide range in wound-healing efficiency among cultivars.

We have shown that wound-healing efficiency can be accurately and reliably assessed in a single experiment using 12 roots per cultivar.

We have provided evidence suggesting that DM content is physiologically linked to wound healing efficiency, althoug other cultivar factors may be more important.

We have identified several cultivars with high DM content and high efficiency of wound-healing.

Notable cultivars are Sinia, Sinia B, Tinian, Naveto, PI 595856, Sumor, W364 97k-11

References

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Table 1. Cultivars included in screening programme

Set A			Set B			Set C		
No.	Name	Origin	No.	Name	Origin	No.	Name	Origin
6	Blesbok	SA	15	Beau Regard	USA S/C	4	Beau Regard	USA
7	Brondal	SA S/C	4	PI 538354	Am S/C	22	Budagala	EA S/C
10	Cemsa 74-228	Am	10	PI 595856	Am S/C	12	Hernadez	Am
21	Kemb 10	EA	5	PI 595873	Am S/C	15	Iboja	EA
11	Kemb 37	EA	3	Picadito	Am	1	Jewel	USA
9	Mafutha	SA	13	Regal	USA	9	Kemb 10	EA
20	Mogamba	EA	11	SC 1149-19	USA	20	KSP 20	EA
8	Mugande	EA	7	Sumor	USA	19	L86-33	USA
13	Naveto	PNG	8	Tanzania	EA	18	Mwanamonde	EA
17	NC 1560	USA S/C	12	Tinian	J	5	Sinia	EA
15	Santo Amaro	Am	1	W287 Ruddy	USA	11	SPN/0	EA S/C
19	Tainung No 64	T	14	W-308	USA	10	Zapallo	Am
18	Xu Shu 18	CH	6	W-317	USA	17	Bilagala**	EA
16	Yan Shu 1	CH S/C	16	W-325	USA	14	Kagole**	EA
14	Zapallo	Am	17	W-341	USA	13	Polista**	EA
2	Kemb 10*	EA	18	W-345	USA	7	Sinia B**	EA
3	KSP 20*	EA	2	W364 97k-11	USA	21	SPK 004**	EA
5	SPK 004*	EA	9	White Regal	USA	3	Yanshu 1**	CH
1	Yan Shu 1*	CH S/C						
4	Zapallo*	Am						

CH, China; EA, East Africa; J, Japan; PNG, Papua New Guinea; SA, South Africa; S/C Am, South/Central America; T, Taiwan; USA, United States of America.

*Screened for first harvest only

** Screened for second season only

Table 2. The relationship between LI (at low RH) measured for different harvests, and between LI and DM content for each set of cultivars.

	Set A (12/17 cultivars)	Set B (18 cultivars)	Set C (12/18 cultivars)
L.I. 2nd harvest v. 1st harvest	0.795 ***	0.473 *	0.903 ***
DMC 2nd harvest v. 1st harvest	0.860 ***	0.941 ***	0.979 ***
L.I. v DMC			
1st harvest	-0.535 *	-0.361 n.s.	-0.654 *
2nd harvest	-0.312 n.s.	-0.227 n.s.	-0.486 *
Combined analysis	-0.390 n.s.	-0.397 n.s.	-0.627 *

Table 3. LI, DM content and origin for all cultivars screened

Set	Origin	Cultivar name	DMC	L.I.
A	CH	Xu Shu 18	24.93492	0.769792
AC	CH	Yan Shu 1	26.42131	0.881976
C2	EA	Bilagala	35.88925	0.291667
C	EA	Budagala	30.13484	0.145833
C	EA	Iboja	34.98481	0.065417
C2	EA	Kagole	31.62517	0.075
AC	EA	Kemb 10	30.36941	0.275042
A	EA	Kemb 37	24.2216	0.302904
AC	EA	KSP 20	25.76727	0.280208
A	EA	Mogamba	28.99355	0.352083
A	EA	Mugande	31.06695	0.386806
C	EA	Mwanamonde	32.16361	0.064583
C2	EA	Polista	37.00709	0.1
C	EA	Sinia	34.28382	0.669129
C2	EA	Sinia B	35.24156	0.525
AC	EA	SPK 004	31.04031	0.074306
C	EA	SPN/0	32.93535	0.335417
B	EA	Tanzania	29.85256	0.15
B	J	Tinian	27.06265	0.583333
A	PNG	Naveto	27.77775	0.580556
A	S/C Am	Cemsa 74-228	26.33759	0.761458
C	S/C Am	Hernandez	22.33026	0.17125
B	S/C Am	PI 538354	25.70938	0.175
B	S/C Am	PI 595856	28.04583	0.8
B	S/C Am	PI 595873	26.71725	0.433333
B	S/C Am	Picadito	30.65277	0.45
A	S/C Am	Santo Amaro	26.50703	0.686458
AC	S/C Am	Zapallo	20.13725	0.803125
A	SA	Blesbok	18.69342	0.867708
A	SA	Brondal	21.49438	0.655208
A	SA	Mafutha	26.13529	0.453472
A	T	Tainung No 64	21.9591	0.690625
B	USA	Beau Regard	19.38985	0.708333
C	USA	Beau Regard	19.25069	0.833333
C	USA	Jewel	21.30764	0.758333
C	USA	L86-33	17.59867	0.60928
A	USA	NC 1560	20.35308	0.200852

B	USA	Regal	22.36818	0.675
B	USA	SC 1149-19	24.47905	0.391667
B	USA	Sumor	27.44282	0.858333
B	USA	W287 Ruddy	19.57324	0.833333
B	USA	W-308	23.22642	0.908333
B	USA	W-317	20.47	0.495833
B	USA	W-325	19.8845	0.383333
B	USA	W-341	25.5703	0.566667
B	USA	W-345	28.70146	0.375
B	USA	W364 97k-11	30.687	0.733333
B	USA	White Regal	24.08674	0.579167

Table 4. Consistency of cultivars between sites.

Set	Origin	Location of field trial	Cultivar name	DMC	L.I.
AC	EA	Nairobi, Kenya	Kemb 10	30.4	0.28
C	EA	Nairobi, Kenya	SPN/0	32.9	0.34
B	EA	South Carolina, USA	Tanzania	29.9	0.15
B	USA	South Carolina, USA	Beau Regard	19.4	0.71
C	USA	Nairobi, Kenya	Beau Regard	19.3	0.83

Table 5: Regression models for root LI in terms of cultivar and root DM content

Expt	Variance accounted for	Regression models for LI
1	34.3%	0.303 + cultivar
	2.5%	1.020 – 0.016 DMCi
	36.0%	1.182 – 0.030DMCi + cultivar
2	23.1%	0.625 + cultivar
	2.5%	0.874 – 0.015 DMCi
	28.2%	1.276 – 0.036DMCi + cultivar
3	40.0%	0.272 + cultivar
	14.8%	1.27 – 0.031 DMCi
	41.7%	0.902 – 0.021 DMCi + cultivar
4	43.1%	0.224 + cultivar
	17.6%	1.287 –0.034 DMCi
	45.4%	1.075 – 0.027 DMCi + cultivar
5	7.2%	0.37 + constant *cultivar
		No model found in terms of DMC alone
	18.3%	1.59 – 0.058 DMC + cultivar

Figure 1: Characterisation of cultivar set A: a) L.I. at moderate RH for two harvest times of a single trial planted in 2000. b) L.I. at high R.H. for the first harvest c) DMC for both harvest times.
Error bars for a) are s.e.m. using individual LI measurements

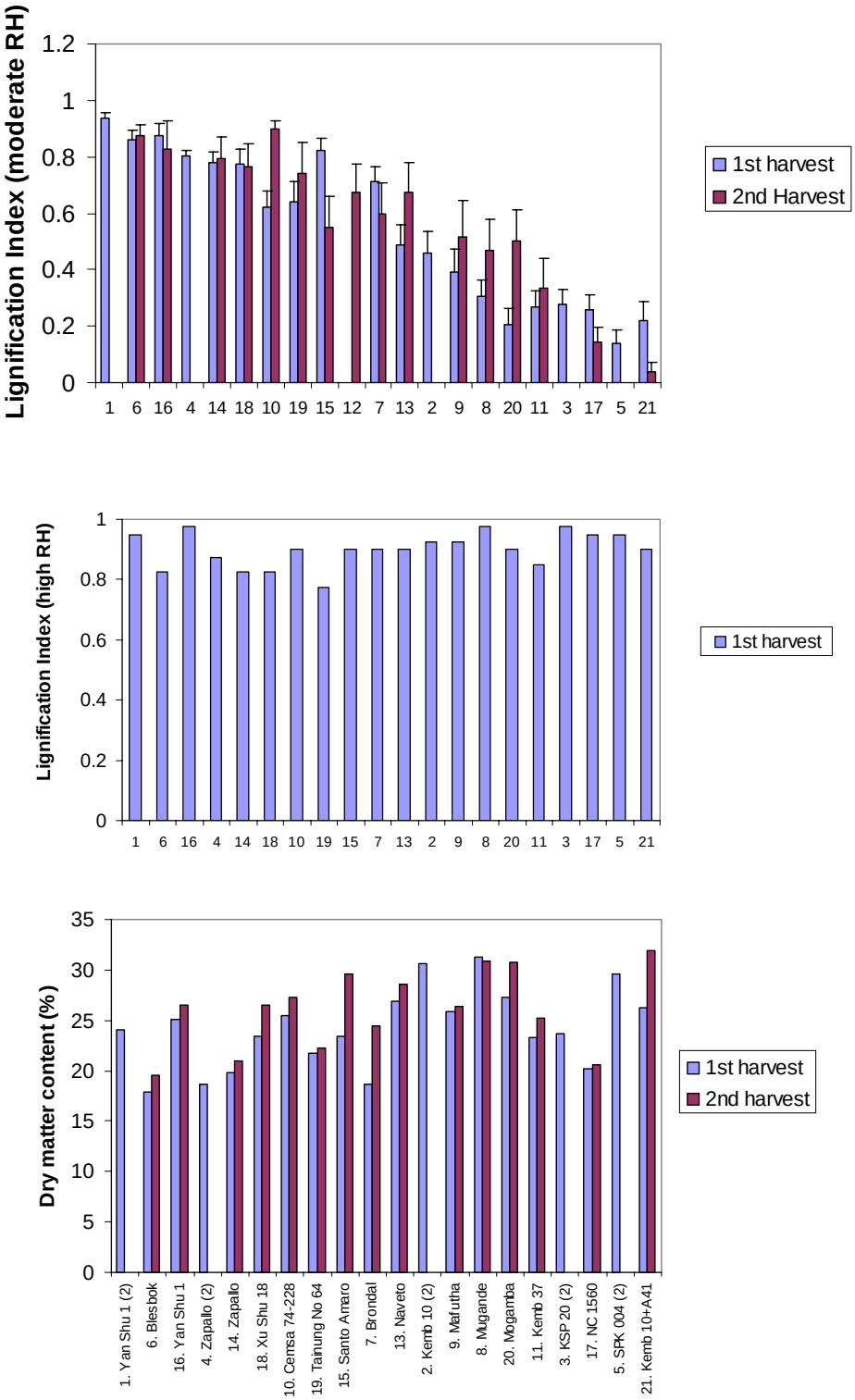


Figure 2: Characterisation of cultivar set B: a) L.I. at moderate RH for two seasons. b) L.I. at high R.H. for two seasons c) DMC for two seasons.

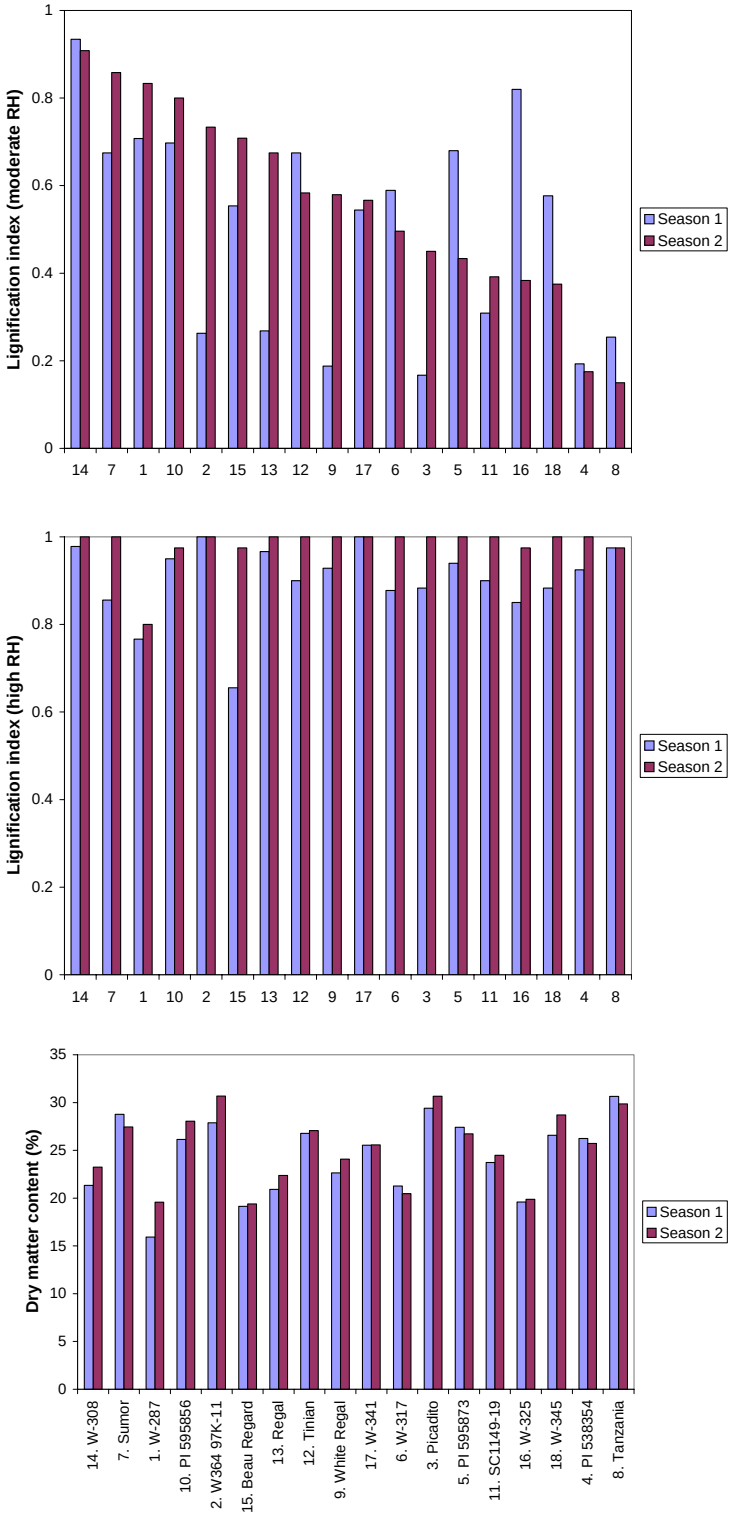


Figure 3: Characterisation of cultivar set C: a) L.I. at moderate RH for two seasons. b) L.I. at high R.H. for two seasons c) DMC for two seasons.

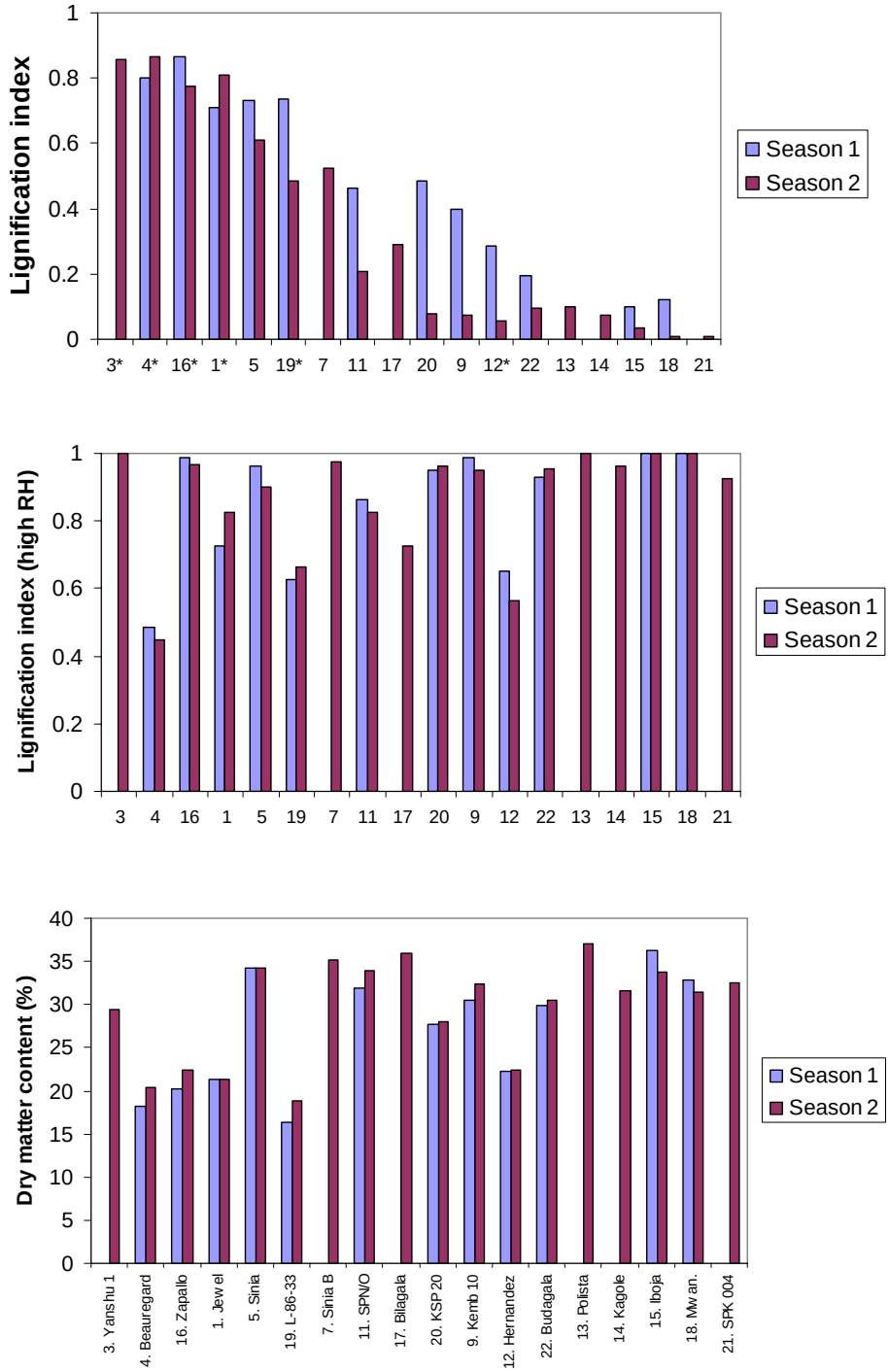
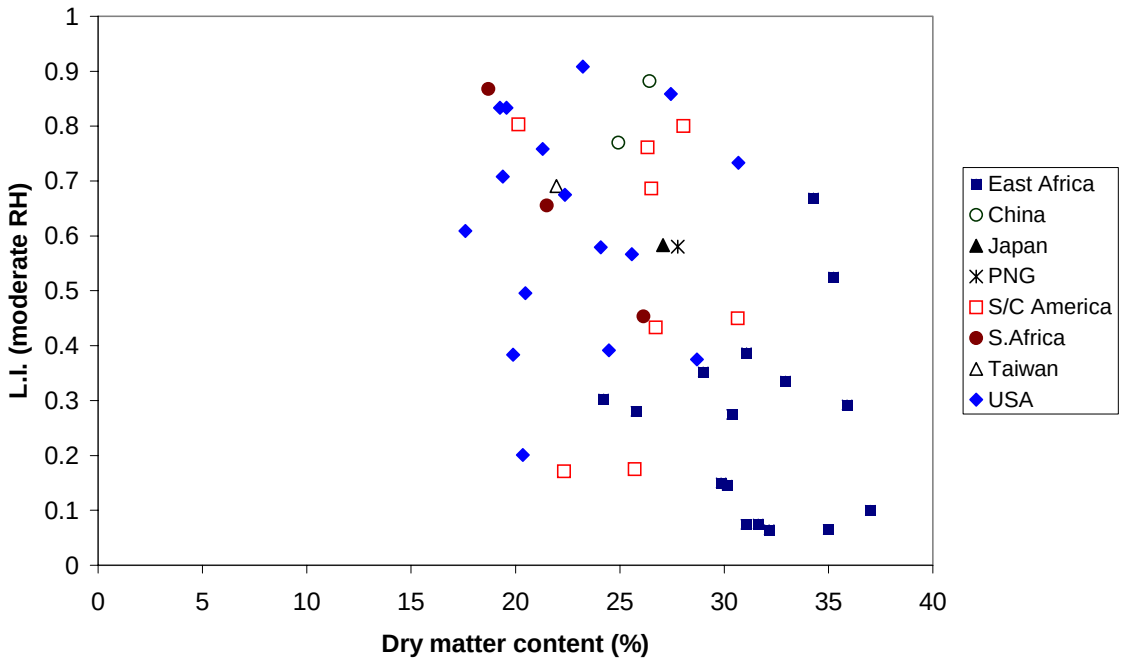


Figure 4: The LI and DM content by cultivar for the complete set of screened germplasm, with indication of cultivar origin.



Correlation (r) between L.I. and DMC

Overall	-0.500 ***
East African cultivars	0.039 n.s.
S/C American cultivars	0.014 n.s.
US cultivars	0.014 n.s.

Further data

LI for individual screening experiments for set A, first harvest.

Cultivar	no.	Expt 1	Expt 2	Expt 3	Expt 4
Yan Shu 1 (2)	1	0.925			0.95
Kemb 10 (2)	2	0.65		0.267	
KSP 20 (2)	3		0.275	0.312	
Zapallo (2)	4	0.808			0.8
SPK 004 (2)	5		0.192	0.089	
Blesbok	6	0.858			0.863
Brondal	7		0.708		0.825
Mugande	8		0.325	0.289	
Mafutha	9		0.358	0.422	
Cemsa 74-228	10	0.733			0.513
Kemb 37	11		0.383	0.156	
Naveto	13	0.38		0.589	
Zapallo	14	0.792			0.763
Santo Amaro	15	0.808			0.838
Yan Shu 1	16		0.858		0.888
NC 1560	17	0.25		0.257	
Xu Shu 18	18		0.758		0.788
Tainung No 64	19		0.817		0.463
Mogamba	20	0.308		0.06	
Kemb 10	21		0.3	0.144	
	mean	0.651	0.498	0.258	0.769
	cult effect	***	***	**	***
	p value	<0.001	<0.001	0.006	<0.001
	LSD	0.146	0.202	0.266	0.189

For experiments 1 and 2 12 replicate roots were assessed for each cultivar and for experiments 3 and 4 9 replicate roots were assessed. The trial design was a complete randomised block.

LI for individual screening experiments for set A second harvest

cultivar	no.	Expt 1	Expt 2
Blesbok	6	0.827	0.95
Brondal	7	0.593	
Mugande	8	0.467	
Mafutha	9	0.517	
Cemsa 74-228	10	0.9	
Kemb 37	11		0.328
Jayalo	12		0.675
Naveto	13	0.675	
Zapallo	14	0.792	
Santo Amaro	15		0.55
Yan Shu	16	0.732	0.901
NC 1560	17	0.156	
Xu Shu 18	18		0.767
Tainung No.64	19		0.742
Mogamba	20	0.5	
Kemb 10	21		0.028
	mean	0.616	0.617
	cult effect	***	***
	p value	<0.001	<0.001
	LSD	0.226	0.22

For both experiments 12 replicate roots were assessed for each cultivar. The trial design was a complete randomised block.

LI measured at high humidity for set A, first harvest

Cultivar	no.	LI
Yan Shu 1 (2)	1	0.95
Kemb 10 (2)	2	0.92
KSP 20 (2)	3	0.98
Zapallo (2)	4	0.88
SPK 004 (2)	5	0.95
Blesbok	6	0.82
Brondal	7	0.90
Mugande	8	0.98
Mafutha	9	0.92
Cemsa 74-228	10	0.90
Kemb 37	11	0.85
Naveto	13	0.90
Zapallo	14	0.82
Santo Amaro	15	0.90
Yan Shu 1	16	0.98
NC 1560	17	0.95
Xu Shu 18	18	0.82
Tainung No 64	19	0.78
Mogamba	20	0.89
Kemb 10	21	0.90
Overall mean		0.90
Cultivar effect		*
P value		0.031
LSD		0.12

4 roots were assessed per cultivar. Trial design was a complete randomised block.

DM by cultivar for first and second harvest of set A.

		DM	
Cultivar name	Number	1st harvest	2nd harvest
Yan Shu 1 (2)	1	24.0	24.4
Kemb 10 (2)	2	30.6	30.1
KSP 20 (2)	3	23.7	23.9
Zapallo (2)	4	18.7	18.4
SPK 004 (2)	5	29.6	30.0
Blesbok	6	17.9	19.5
Brondal	7	18.6	24.4
Mugande	8	31.2	30.9
Mafutha	9	25.9	26.4
Cemsa 74-228	10	25.4	27.2
Kemb 37	11	23.2	25.2
Jayalo	12		32.1
Naveto	13	27.0	28.6
Zapallo	14	19.8	30.0
Santo Amaro	15	23.5	29.6
Yan Shu 1	16	25.1	26.6
NC 1560	17	20.2	20.6
Xu Shu 18	18	23.4	26.5
Tainung No 64	19	21.7	22.2
Mogamba	20	27.2	30.8
Kemb 10	21	26.3	31.8
	Overall mean	24.2	26.2
	Cult effect	***	***
	P value	<0.001	<0.001
	LSD	2.3	2.9

LI from individual screening experiments for set B first season

Cultivar	label	Expt 1	Expt 2	Expt 3	Expt 4
97K-11	A	0.292		0.272	0.218
Beaux	B	0.428	0.625	0.667	0.494
PI538354	C		0.194		
PI595856	D		0.702		
PI595873	E		0.690		
Picadito	F			0.189	0.144
Regal	G	0.233	0.383	0.306	0.150
SC1149-19	H	0.253	0.278	0.385	0.322
Sumor	I	0.650	0.672	0.711	0.667
Tanzania	J		0.211		
Tinia	K		0.675		
W-287	L	0.650		0.683	0.789
W-308	M	0.939		0.944	0.919
W-317	N	0.558	0.598	0.578	0.627
W-325	O			0.889	0.750
W-341	P	0.478	0.658	0.439	0.603
W-345	Q		0.570		
White Regal	R	0.175	0.222	0.222	0.135
	mean	0.465	0.498	0.528	0.485
	cult effect	***	***	***	***
	p value	<0.001	<0.001	<0.001	<0.001
	LSD	0.189	0.201	0.185	0.187

For all experiments 18 replicate roots were assessed for each cultivar. The trial design was a complete randomised block.

Combined analysis of experiments 3 and 4 indicate no significant differences between experiments.

LI for individual screening experiments for set B second season

Cultivar	Label/no.	Expt 1	Expt 2
97K-11 (W364)	A/2	0.733	
Beaux	B/15	0.708	
PI538354	C/4		0.175
PI595856	D/10	0.800	
PI595873	E/5		0.433
Picadito	F/3	0.450	
Regal (culls)	G/13		0.675
SC1149-19	H/11		0.392
Sumor	I/7	0.858	
Tanzania	J/8		0.150
Tinia	K/12		0.583
W-287 (Ruddy)	L/1	0.833	
W-308	M/14		0.908
W-317	N/6	0.508	0.483
W-325	O/16		0.383
W-341	P/17	0.567	
W-345	Q/18	0.375	
White Regal	R/9	0.742	0.417
	mean	0.658	0.460
	cult effect	***	***
	p value	0.001	<0.001
	LSD	0.261	0.265

For both experiments 12 replicate roots were assessed for each cultivar. The trial design was a complete randomised block.

LI measured at high humidity by cultivar for set B in first and second season

Cultivar name	Label/no.	First season	Second season.
97K-11 (W364)	A/2	0.998	1.000
Beaux	B/15	0.656	0.975
PI538354	C/4	0.930	1.000
PI595856	D/10	0.939	0.975
PI595873	E/5	0.936	1.000
Picadito	F/3	0.872	1.000
Regal (culls)	G/13	0.967	1.000
SC1149-19	H/11	0.901	1.000
Sumor	I/7	0.856	1.000
Tanzania	J/8	0.943	0.975
Tinia	K/12	0.896	1.000
W-287 (Ruddy)	L/1	0.762	0.800
W-308	M/14	0.978	1.000
W-317	N/6	0.878	1.000
W-325	O/16	0.839	0.975
W-341	P/17	0.996	1.000
W-345	Q/18	0.872	1.000
White Regal	R/9	0.928	1.000
	mean	0.897	0.983
	cult effect	***	***
	p value	<0.001	<0.001
	LSD	0.091	0.071

For each cultivar 6-9 roots were assessed for the first season and 4 roots were assessed for the second season.

DM by cultivar for set B in first and second season

Cultivar name	Label/no.	First season	Second season
97K-11 (W364)	A/2	27.89	30.69
Beaux	B/15	19.15	19.39
PI538354	C/4	26.23	25.71
PI595856	D/10	26.16	28.05
PI595873	E/5	27.41	26.72
Picadito	F/3	29.41	30.65
Regal (culls)	G/13	20.92	22.37
SC1149-19	H/11	23.72	24.48
Sumor	I/7	28.75	27.45
Tanzania	J/8	30.63	29.85
Tinia	K/12	26.78	27.06
W-287 (Ruddy)	L/1	15.93	19.57
W-308	M/14	21.33	23.23
W-317	N/6	21.26	25.10
W-325	O/16	19.59	19.88
W-341	P/17	25.53	25.57
W-345	Q/18	26.57	28.70
White Regal	R/9	22.63	24.09
	mean	23.74	25.48
	cult effect	***	***
	p value	<0.001	<0.001
	LSD	4.539*	3.88

For each cultivar at least 3 roots were assessed for season 1 and 4 roots were assessed for season 2.

LI for individual screening experiments for set C first season

Cultivar	no.	Expt 1	Expt 2
Beau Regard		0.717	0.883
Budagala		0.083	0.308
Hernandez		0.258	0.317
Iboja		0.075	0.111
Jewel		0.642	0.775
Kemb 10		0.417	0.383
KSP20		0.358	0.608
L86-33		0.725	0.731
Mwanamonde		0.108	0.133
Sinia		0.742	0.730
SPN/0		0.508	0.417
Zapallo		0.775	0.958
	mean	0.451	0.530
	cult effect	***	***
	p value	<0.001	<0.001
	LSD	0.212	0.208

For both experiments 12 roots were assessed per cultivar. The trial design was a complete randomised block.

Combined analysis of Experiments 1 and 2 indicate small statistical difference between screenings ($p=0.017$), but no cultivar x experiment interaction.

LI for individual screening experiments for set C second season

Cultivar	no.	Expt 1	Expt 2
Beauregard		0.950	0.783
Bilagala		0.283	0.300
Budagala		0.167	0.025
Hernandez		0.050	0.067
Iboja		0.033	0.033
Jewel		0.717	0.900
Kagole		0.067	0.083
Kemb 10		0.117	0.033
KSP 20		0.075	0.083
L-86-33		0.650	0.317
Mwanamonde		0.000	0.017
Polista		0.050	0.150
Sinia		0.783	0.433
Sinia B		0.717	0.333
SPK004		0.000	0.017
SPN/0		0.250	0.167
Yanshu 1		0.717	1.000
Zapall0		0.875	0.675
	mean	0.352	0.283
	cult effect	***	***
	p value	<0.001	<0.001
	LSD	0.282	0.261

6 roots were assessed per cultivar for each experiment. (12 in a few cases). LSDs are given for 6 reps
Combined analysis of experiments 1 and 2 gives a difference between experiments significant to 0.004, but cultivar x experiment interaction not significant.

LI measured at high humidity by cultivar for set C in first and second season

Cultivar name	label	First season	Second season
Beau Regard		0.488	0.450
Bilagala			0.725
Budagala		0.925	0.956
Hernandez		0.650	0.562
Iboja		1.000	1.000
Jewel		0.725	0.825
Kagole			0.963
Kemb 10		0.988	0.950
KSP20		0.950	0.963
L86-33		0.625	0.663
Mwanamonde		1.000	1.000
Polista			1.000
Sinia		0.963	0.900
Sinia B			0.975
SPK004			0.925
SPN/0		0.863	0.825
Yanshu 1			1.000
Zapallo		0.988	0.969
	mean	0.847	0.886
	cult effect	***	***
	p value	<0.001	<0.001
	LSD	0.172	0.158

For each cultivar 8 roots were assessed for each season.

DM by cultivar for US cultivars in first and second season

Cultivar name	label	First season	Second season
Beau Regard		18.15	20.35
Bilagala			35.89
Budagala		29.83	30.44
Hernandez		22.19	22.47
Iboja		36.20	33.78
Jewel		21.31	21.30
Kagole			31.63
Kemb 10		30.46	32.44
KSP20		27.72	28.03
L86-33		16.29	18.91
Mwanamonde		32.88	31.45
Polista			37.01
Sinia		34.29	34.27
Sinia B			35.24
SPN/0		31.97	33.90
Yanshu 1			29.44
Zapallo		20.28	22.36
	mean	26.80	29.30
	cult effect	***	***
	p value	<0.001	<0.001
	LSD	4.44	3.05

For each cultivar at least 3 roots were assessed for season 1 and for season 2.