Economic Losses Experienced by Small-scale Farmers in Malawi due to Cassava Brown Streak Virus Disease

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Introduction

Cassava (*Manihot esculenta* Crantz) is an important root crop in Malawi. It is the second most important food crop after maize (*Zea mays* L.). It is grown throughout the country as a food security crop, snack/cash crop, and as a staple food crop along the shore of Lake Malawi. It is a staple for over 30% of the country's population.

Cassava has the potential to sustain food security and alleviate poverty among the rural communities because it is adapted to many agro-ecological zones in Malawi. Promotion of cassava as a food crop to traditionally non-cassava staple areas has intensified with the drought problems experienced in the early 1980s and 1990s. The area under cassava has grown from 70,000 hectares in 1990 to 200,000 hectares in 2000 (Famine Early Warning System Project data). Cassava is now becoming a more important crop for both food and for cash income to the rural areas. Recently cassava has become the second staple food to some of the non-cassava staple areas. It has also become an important fresh market commodity in the urban areas throughout the country. Table 1 shows that the area under cassava in major growing areas where it is a staple, such as Karonga, Mzuzu, Salima and Machinga, has increased by about 50%, while in non-traditional cassava eating areas near urban centres such as Lilongwe and Kasungu, it has increased by more than 400%.

The average yield for smallholder cassava farmers in Malawi is about 15 t/ha. At the present yields, cassava is providing more than five times as much staple food (per unit area) as maize in Malawi. On the other hand, when cassava is offered for sale on the fresh market, it generates more cash income than the traditional high value cash crops such as tobacco (*Nicotiana tabacum* L.). Compared to 5.2 for cassava in the peri-urban fresh market, the benefit/cost ratios for tobacco are 1.08, for maize 0.90, for soyabeans (*Glycine max* (L.) Merr.) 1.05, and 1.74 for groundnuts (*Arachis hypogaea* L.) (Akoroda and Mwabumba, 2000). When cassava is processed its benefit-cost ratio is still higher at the traditional market than most other crops. A survey in 2001 by the Southern Africa Root Crops Research Network (SARRNET) revealed that the benefit/cost ratio for production of fermented chips was 2.9 and for fermented flour was 3.7. Farmers can therefore grow cassava more efficiently and exploit the market opportunities and combat poverty and food insecurity.

Farmers are not benefiting as much as they might from cassava because they are faced with a number of constraints. These include: (i) inherent low yielding and late maturing local cultivars, (ii) pests and diseases prevalent in the country and (iii) low promotion of good cultural practices. The major pests and diseases of cassava in Malawi are, cassava mosaic virus disease (CMD), cassava bacterial blight (CBB), cassava brown streak virus disease (CBSD), cassava green mite (CGM), cassava mealybug (CM) and termites.

CBSD was first reported in East Africa in the 1930s (Storey, 1936). Nichols (1950) reported that the disease was endemic in all East African coastal cassava-growing areas up to 1000 m asl from Kenya to southern Tanzania and also at lower elevations in Malawi. CBSD has been reported to seriously affect cassava production in the coastal areas of East Africa. A virus belonging to the family *Potyviridae*, genus *Ipomovirus*, causes the disease (Monger *et al.*, 2001). The vector for the transmission of this disease is not yet known. Symptoms of the disease include brown streaks on stems, leaf chlorosis and root necrosis. Stem

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Table 1. Cassava production estimates for 1995/96 and 2000/01 in Malawi

Agriculture Development Division	1995/96 Area (ha)	1995/96 Production (tonnes)[1]	2000/01 Area (ha)	2000/01 Production (tonnes)[1]
Karonga	8,979	141,767	14,183	284,466
Mzuzu	26,588	680,390	38,693	936,098
Kasungu	4,882	46,390	16,636	232,010
Salima	16,564	322,513	26,940	359,295
Lilongwe	5,851	72,947	20,223	276,259
Machinga	21,925	253,513	43,167	567,869
Blantyre	30,136	243,353	40,367	519,442
Shire Valley	1,598	20,957	1,494	22,611
National total	116,523	1,781,830	201,703	3,201,051

1. Famine Early Warning System Network (FEWSNET) 2001 crop estimates (2nd round); production is tonnes of fresh weight.

necrosis develops as brown elongated necrotic lesions on young tissues from which the name 'brown streak' was derived.

The disease impacts on the farmer in two major ways: low yield and poor root quality due mainly to root necrosis. The disease causes low yield because it leads to production of fewer roots, roots of smaller size, and distorted roots due to pitting and constriction. The effects of CBSD on growth and yield of a cassava crop are not fully documented. SARRNET reported an average of 34% loss due to CBSD in Tanzania (SARRNET, 1996). Field experiments to determine the effect of the disease on yield and quality of the roots showed that CBSD can decrease root weight in the most sensitive cultivars by up to 70% in Tanzania (Hillocks *et al.*, 2001). In addition to loss in root yield the disease has an important effect on root quality caused by patches of root necrosis that make the roots unsuitable for home consumption or the market (Bock, 1994; Hillocks *et al.*, 2001). The length of time between the appearance of foliar symptoms and the development of root necrosis is a varietal characteristic. In the most susceptible cultivars, root necrosis may appear within six months of planting cuttings derived from symptomatic mother plants. There are cultivars that exhibit a form of 'tolerance' to CBSD in which foliar symptoms appear but with a delayed development of root necrosis, allowing the full yield potential to be realized (Hillocks *et al.*, 2001). Photographs of CBSD symptoms and root necrosis loss can be seen in the Annex at the end of this paper.

The objective of this study was to determine the economic impact of CBSD on the farmers in Malawi where the disease is prevalent.

Methodology

The study was conducted in three surveys: the CBSD incidence survey (May 2001), the CBSD severity survey (September 2001) and the follow-up survey (February 2002).

The incidence study was a nationwide exploratory survey carried out along the major roads from the northern tip (Chitipa) to southern tip (Nsanje) covering the full length of the country. It covered the road along the shore of Lake Malawi and the mainland roads. Fields were sampled to check for the incidence of the CBSD from area to area. In major cassava growing areas, sampling was done at regular intervals of about 10 km apart while in places where cassava is not commonly grown, sampling depended on the presence of the crop. Sampling was mainly done on a crop that was old enough to start losing old leaves. Three observers traversed a field at regular distances and each counted the number of CBSD-affected plants at regular intervals in the field. Close to 100 fields were visited from all over the country. Data were collected in all locations on the presence of the disease in the field and farmers' knowledge where the disease was present.

A follow up to the incidence survey was conducted to assess the severity of the disease in terms of root necrosis. The survey was carried out in an unstructured form along the shore of Lake Malawi in areas where CBSD was prevalent based on the incidence survey. It was conducted in all four Agriculture Development Divisions (ADDs) where CBSD is prevalent. A sample of 10 fields with foliar CBSD symptoms was studied per zone and 10 diseased plants per field were sampled. A second follow-up survey was conducted in February 2002, at a time when cassava plants, planted by February 2001, were believed to be

over 12 months old. ADDs in three zones, Karonga, Mzuzu and Salima, were selected. A sample of 7 fields was used from each zone and a total of 22 fields were surveyed. At each field, a sample of two plants per cultivar was used, one plant with and one without symptoms of CBSD. In such fields where more than five cultivars were planted, a maximum of four common cultivars was sampled. In the two follow up surveys a total of 418 diseased plants were sampled.

The sampled plants were uprooted to check for root necrosis and constrictions. CBSD data collected included scoring for symptoms on leaf chlorosis and root necrosis (Hillocks *et al.*, 1996), variety of cassava and age of plants. Yield comparisons were made between infected plants and plants without symptoms in the same field. Economic losses were arrived at by assessing the impact of the disease on the uses of leaves, stems and roots. Impact on root use was computed by an approximate percent yield loss using number of roots and size of roots, and further assessing percent necrosis on all the tuberous roots on each plant. This was then computed into a total root loss. Analysis was done using frequencies, averages, and percentages and cross tabulations using the social sciences analysis software SPSS.

Results and Discussion

Presence of CBSD in Malawi

CBSD symptoms vary with cultivar of cassava, environmental factors and age of the plant (Hillocks *et al.*, 1999). The disease is more prominent along the shores of Lake Malawi at low altitudes between 400–1000 m asl. It is present in Karonga, Rumphi, Nkhata Bay, Nkhota Kota, Salima, Dedza, Machinga and Mangochi (Figure 1). Over 40% of the crop in low altitude areas along the shore of Lake Malawi was infected by CBSD with an average severity assessment of class 3 from shoot symptoms.

It was also found that farmers who were using cassava cuttings from research and NGOs had clean fields in the high-pressure areas of the most important diseases. However, in infected fields, neither farmers nor extension workers were aware of this disease. The farmers thought that the symptoms were mainly due to heavy rainfall or water logging. In a few cases farmers thought it was due to old age. It was found that all the most common cultivars, Manyokola, 20:20, Korobeka, Thepula, Beatrice and Gomani, had some CBSD symptoms and 31 of the sampled cultivars had CBSD.

Age of the plants

Most plants in the field during the severity study were less than 12 months old. Table 2 shows by cumulative percent that about 70% of the sample was less than 10 months old. It also shows that relatively severe symptoms (class 3, 4 or 5) are more common in plants that are above 8 months old, demonstrating that CBSD becomes more severe as the plant gets older. The age distribution shows that Nkhota Kota, Mangochi and Karonga had relatively younger crops than Nkhata Bay and Salima. The following list of Rural Development Projects (RDPs) shows the mean crop age in parentheses: Karonga (10.8), Nkhata Bay (12.3), Nkhota Kota (7.7), Salima (15.6) and Mangochi (10.2).

Figure 1 Cassava brown streak prevalent areas of Malawi (also showing areas covered by survey not affected by CBSD)

Table 2. CBSD leaf score of plants in Malawi

Age of plants in months	CBSD leaf score (severity)				Total plants in class	Total plants (%)	Cumulative percentage
	2	3	4	5			
2	3	1	–	–	4	1.0	1.0
5	1	5	4	–	10	2.4	3.3
6	–	6	1	–	7	1.7	5.0
7	5	5	–	–	10	2.4	7.4
8	37	23	3	1	64	15.3	22.7
9	33	42	2	–	77	18.4	41.1
10	35	62	18	1	116	27.8	68.9
11	3	12	1	1	17	4.1	73.0
12	–	2	2	–	4	1.0	73.9
13	1	–	–	–	1	0.2	74.2
14	2	7	1	–	10	2.4	76.6
17	1	1	1	7	10	2.4	78.9
19	5	38	8	3	54	12.9	91.9
21	9	10	5	–	24	5.7	97.6
30	–	5	4	1	10	2.4	100.0
Total	135	219	50	14	418	100.0	

CBSD leaf severity symptoms

In the CBSD-prevalent areas, it was found that CBSD is more widespread in Karonga than the rest of the survey areas while it was least widespread in Nkhota Kota. About 70% of the crop has CBSD in Karonga against a mean of 45% (Table 3). The mean of the leaf scores was 2.9 showing that CBSD severity is moderate. More severe leaf symptoms were found in Karonga, Nkhata Bay and Nkhota Kota RDPs than in Salima and Mangochi.

CBSD root severity symptoms

The results in Table 4 show that about 34% of the plants had root necrosis and that there was higher necrosis in Nkhata Bay and Salima, which had older crops than the other locations. Where low root necrosis was observed, i.e. in Karonga and Mangochi, less than 25% of the plants with leaf symptoms had root necrosis. Further analysis was done to assess the association between leaf score and root necrosis. Cross-tabulations of leaf score by root score show that more plants that had lower leaf symptoms expression of class 2 had no apparent root symptoms. These may have been plants that had just started showing leaf symptoms, i.e. due to young crop age and early stage of infection. Plants with a score of 3, 4 or 5 for leaf symptoms had more serious root necrosis (Table 5).

Table 3. CBSD leaf score for sites in Malawi

CBSD leaf score	Survey sites					
	Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	Total
1 No apparent symptoms	0	0	0	0	0	0
2 Slight foliar mosaic, no stem lesions	33	32	4	29	37	135
3 Foliar mosaic, mild stem lesions, no dieback	68	50	13	34	54	219
4 Foliar mosaic and pronounced stem lesions, no dieback	16	12	4	9	9	50
5 Defoliation with stem lesions and pronounced dieback	1	11	–	2	–	14
Total	118	105	21	74	100	418
Average incidence (%)	70	55	15	50	40	46
Mean leaf score	2.87	3.02	3.00	2.78	2.72	2.86

Table 4. CBSD root necrosis (%) at survey sites in Malawi

CBSD root necrosis score	Survey sites					Total
	Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	
Not apparent	79.7	55.2	61.9	51.4	75.0	66.5
Less than 5% of root necrotic	10.2	28.6	33.3	29.7	20.0	21.8
5–10% root necrotic	6.8	2.9	4.8	10.8	4.0	5.7
10–25% of root necrotic, mild root constriction	1.7	2.9	–	1.4	–	1.4
25% of the root necrotic and severe root constriction	1.7	10.5	–	6.8	1.0	4.5
Total	100	100	100	100	100	100
Sample size (N)	118	105	21	74	100	418
Mean	1.36	1.85	1.43	1.82	1.32	1.56

Economic loss due to CBSD

Farmers were asked about the effect of disease on plant uses such as roots or leaves. The impact of CBSD on yield was also assessed by comparing yield from plants with symptoms to those without symptoms.

Leaves: Farmers normally use young leaves as a green vegetable. However, it was found that most farmers did not separate healthy from infected plants. They used leaves of plants with CBSD as well as those without it because they did not recognize the disease. They were not aware that CBSD had any effect like early leaf defoliation, or change of taste of the leaves. Farmers therefore said that CBSD had no effect on leaf use.

Stems: Most farmers only use the stems for planting (cuttings) and a few for fuel wood. Just like the leaves, farmers said they were not experiencing any loss in amount of stems because even the infected stems were being used for planting since they did not recognize the disease. In the main cassava-growing areas it was found that stems do not have much monetary value since farmers mostly share them for free and the seed market is not well developed. Some farmers who sold some planting material also used infected cuttings in their own fields. Thus, the loss in planting material is transferred to yield since farmers do not select planting material. It was noted in some fields however, that the crop was stunted and sometimes had such very pronounced dieback due to CBSD that the stems were not fit for planting. Such farmers had heavy yield losses. It was also found that planting material was a constraint only in terms of availability and not cleanliness. For cleanliness, farmers select through stem symptoms and in most cases just against mealybug but not other pests or diseases.

Roots: The most important impact of CBSD to the farmers is on roots. Losses were well expressed by necrosis and constriction of the roots. However, most plants showed necrosis on only a few roots. It was found that necrosis was present more on old plants than on younger plants. It was also observed that fewer roots were produced by affected plants. Also, some affected plants had smaller roots than plants without

Table 5. CBSD leaf score by CBSD root necrosis score

CBSD leaf score	CBSD root necrosis score (%)					Total (%)
	1	2	3	4	5	
2 Slight foliar mosaic, no stem lesions	43.9	14.3	–	–	–	32.3
3 Foliar mosaic, mild stem lesions, no dieback	50.4	70.3	37.5	33.3	21.1	52.4
4 Foliar mosaic and pronounced stem lesions, no dieback	5.4	15.4	62.5	33.3	21.1	12.0
5 Defoliation with stem lesions and pronounced dieback	0.4	–	–	33.3	57.9	3.3
Total	100	100	100	100	100	100

Table 6. Impact of CBSD on root harvest in Malawi

Loss from CBSD plants compared to clean plants (%)	Survey site (plants surveyed)					Total plants
	Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	
0	36	32	6	32	60	166
5	11	6	4	3	8	32
10	17	7	3	2	6	35
15	10	11	2	2	1	26
20	10	7	1	3	2	23
30	9	13	4	9	4	39
40	4	8	–	7	8	27
45	–	–	–	1	–	1
50	6	2	–	3	6	17
60	2	2	1	3	1	9
75	5	7	–	3	3	18
80	3	2	–	2	–	7
90	3	6	–	1	–	10
95	1	–	–	–	–	1
100	1	2	–	3	1	7
Total	118	105	21	74	100	418
Mean loss	21.2	26.3	13.3	24.7	12.8	20.7

CBSD symptoms. In some cases yield loss was mainly due to constriction and pitting such that some roots were totally useless. Comparison of infected and uninfected plants in various survey locations showed that Karonga, Nkhata Bay and Salima had higher losses than Nkhota Kota and Mangochi. Root loss was about 20% over the three locations (Table 6).

When farmers were asked to estimate yield losses due to necrosis from CBSD after being shown the symptoms, they estimated yield losses from 0% to 60%. It was noted that the number of farmers that estimated high yield loss was quite significant; 20% of the farmers said they lose over 40% of their yield, and the average loss reported was 24.3%. Farmers based their losses on recall of the proportion of necrotic roots that are found at harvest. Women were more aware of the symptoms than men since they are involved in the peeling and the subsequent processing. They could easily make an estimate of the proportion of necrotic roots on a basket full of cassava harvest. High root loss was reported by farmers in Karonga, Nkhata Bay and Salima, which matched the field observations (Table 7).

The farmers said that they sometimes eat some necrotic roots if necrosis is light but throw them away if necrosis is heavy. They said that extensively damaged roots have a bad taste whether processed or unprocessed and hence are thrown away. For flour

Table 7. Yield loss (%) due to CBSD as estimated by farmers at the various survey sites in Malawi

Reported yield loss (%)	Survey site					Total (%)
	Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	
0	–	1	–	1	–	3.4
5	–	1	–	3	2	10.3
10	3	1	2	2	2	17.2
15	1	–	–	1	2	6.9
20	2	1	–	1	1	8.6
25	4	3	–	–	1	13.8
30	6	3	–	–	1	17.2
40	3	1	1	–	–	8.6
50	2	2	–	1	1	10.3
60	1	–	–	1	–	3.4
Mean loss	29.3	26.2	20.0	18.0	18.5	24.3

the lightly affected parts are in most cases used but the extensively damaged roots may be cut off or otherwise thrown away entirely. Under the fermentation process, the affected parts do not soften but remain as brown, hard, corky particles and hence can easily be separated for subsequent flour-making processes. Flour from heavily necrotic roots is discolored and has a bitter taste that makes it unpalatable.

As seen in Tables 6 and 7, the mean loss in production ranges from 20–25% depending on the method of estimation. This range of loss at a 40% average incidence translates to 137,000–172,000 t in cassava per year due to CBSD (Table 8). This loss in monetary terms, using the cassava price for the year 2001 (MK 3.00/kg), ranges from MK 400 million to MK 500 million, which is about US$ 6 million to US$ 7 million each year. When farmers run out of food, they buy maize grain or cassava flour from other farmers at more than 10 times the farm value of cassava, i.e. a further degradation of the farmers' resources.

Farmers' practices that influence trends in CBSD

Where CBSD is severe, such as in Karonga, farmers complained that it was sometimes necessary to harvest early to avoid root necrosis. During the survey it was observed that most farmers had started to harvest young crops and very few had crops that were more than 12 months old. Farmers said that they get fewer necrotic roots in young plants. Another reason for early harvesting in these areas was the lack of food. Since farmers have little knowledge about the disease, they keep on recycling the infected planting material. When asked about the symptoms present in most fields, farmers attributed them to loss of soil fertility, heavy rains and waterlogging. It was also noted that apart from early harvesting some farmers practice selective harvesting, in which they harvest plants that seem to have larger roots, hence they remove healthy plants first. Such farmers postpone harvesting diseased plants to a later date in order to get well filled roots. Harvesting healthier plants first means leaving diseased plants in the field and these then become the pool for next season's planting material. This puts the farmer in a cycle of decreasing yield as the disease builds up. The above two systems of harvesting have different effects on susceptible and tolerant cultivars, i.e. farmers who plant susceptible cultivars may be harvesting a young crop in subsequent harvests while those growing a tolerant cultivar may be selectively harvesting healthy plants while building up the disease in the remaining crop.

Conclusion

Since farmers and extension workers do not recognize CBSD, the disease continues to spread as farmers continue to share and use infected cuttings for planting in their fields. The intensity of the disease is also increasing because farmers are adopting practices that exacerbate the situation as yields begin to be adversely affected by the disease.

Yield losses by farmers were quite high, at an average loss of 24%. Since yield loss depends on the severity of the disease, higher losses will be reported as the disease continues to spread and its average severity increases. Since some plants give 100% yield loss, especially at 12 months or more after planting, farmers stand to lose a significant proportion of their food reserve through ground storage. This disease has serious food security implications for the population along

Table 8. Value of CBSD yield losses in areas along the shore of Lake Malawi

Location	Production 2001 (tonnes)[1]	18.9% loss (tonnes)	25% loss (tonnes)
Karonga RDP[2]	234,832	18,787	23,483
Nkhata Bay RDP	743,055	59,444	74,306
Nkhota Kota RDP	342,078	27,366	34,208
Salima RDP	96,022	7,682	9,602
Namwera RDP	63,112	5,049	6,311
Kawinga RDP	133,023	10,642	13,302
Balaka RDP	23,015	1,841	2,302
Mangochi RDP	76,106	6,088	7,611
Total (tonnes)	1,711,243	136,899	171,125
Total value in MK		410,697,000	514,375,000
Total value in US$		5,475,960	6,845,000

1. Famine Early Warning System Network (FEWSNET) data
2. RDP = Rural Development Project

the shore of Lake Malawi and urgent attention is required, as a significant proportion of this population (20%) has reported high yield losses (>40%).

Recommendations

1. The cassava research organizations should mount urgent awareness campaigns of the disease and its management for both extension agents and farmers.

2. The cassava research organizations should establish effective collaboration with the extension system on matters of proper cassava husbandry to effectively and efficiently control the disease.

3. The cassava research organizations should carry out local collection exercises for cultivars that show CBSD disease resistance in the high disease pressure areas

4. There is an urgent need for cassava research and extension organizations to multiply cultivars (e.g. Beatrice in Nkhota Kota) and promising clones (e.g. CH92/077 and CH92/112) that have shown multiple disease resistance and that are widely accepted by farmers for distribution in the heavily affected areas.

5. The cassava research and extension organizations in collaboration with entrepreneurs need to develop and strengthen sustainable seed multiplication and distribution systems as a way of assuring the provision of clean planting material.

Summary

Cassava is an important root crop in Malawi. It is a staple food for about 30% of the population. Production of cassava has increased in the past 10 years from about 0.6 million tonnes in 1992 to 3.2 million tonnes in 2001. However, diseases and pests affect cassava production in Malawi with the major ones being CBSD, CMD, CBB, CGM, CM and termites.

CBSD has been reported to seriously affect cassava production in the coastal areas of eastern Africa (Kenya, Tanzania and Mozambique) and the areas along the shore of Lake Malawi. The symptoms of the disease are brown streaks on stems, leaf chlorosis, root necrosis and root pitting or constriction. The symptoms vary with cultivars, age of the plant and the environment. The major economic impact of the disease to the farmers is low root yield, as the number and size of roots is reduced and root quality is decreased due to necrosis.

Surveys were conducted in 2001/02 in Malawi and data were collected on cultivar of cassava, age of plant, CBSD leaf chlorosis, CBSD root necrosis, proportion of necrotic roots on total yield, yields of diseased plant versus apparently healthy plants in the same field, and the effects of CBSD on uses of leaves, stems and roots.

CBSD is widespread in the low altitude areas along the shore of Lake Malawi and about 40% of the crop in these areas is affected. It is more prevalent in the northern areas along the shore of Lake Malawi from Nkhata Bay to Karonga than those areas south of Nkhata Bay. CBSD, however, is not well known to either farmers or extension workers. They ascribe symptoms of the disease to heavy rainfall and water logging. It was found that the disease is spreading in farmers' fields through harvesting practices. Farmers select plants with filled roots for harvest and thus remove the healthier plants first. The more affected plants may remain in the field until the rainy season and they become the seed stock.

The disease is causing from 18% to 25% yield loss where it is prevalent. This loss translates to about MK 400 million to MK 500 million or US$ 5 million to US$ 7 million annually based on farm-gate prices.

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CBSD Symptoms and Root Necrosis Loss

Brown streaks on the cassava stems

Early CBSD leaf symptoms of serious attack on a young plant

Mild CBSD root necrosis

Severe CBSD root necrosis

Comparing stuntedness and root yield of CBSD plant (left) with a healthy plant of the same cultivar and age (Photo Mr Chirambo, Timbiri, Nkhata Bay)

Heavy yield loss due to CBSD root constriction

100% loss from CBSD necrosis

Heavily necrotic roots that did not soften during fermentation but remained corky

Slightly necrotic roots still left for flour processing