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Postharvest Fungal Rots of Sweet Potato in Tropics and Control Measures

Ramesh C. Ray* • **Maniyam Nedunchezhiyan**

Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar – 751 019, India

Corresponding author: * **rc_rayctcri@rediffmail.com**

ABSTRACT

Postharvest rots of sweet potato are mostly caused by fungi. The most important rot causing fungi are *Botryodiplodia theobromae* (Java black rot), *Rhizopus oryzae* (soft rot or Rhizopus rot), *Fusarium* spp. (Fusarium rot), *Ceratocystis fimbriata* (black rot), *Sclerotium rolfsii* (Sclerotium rot), *Macrophomina phaseolina* (charcoal rot), *Cochliobolus lunatus* (*Curvularia lunata*), *Rhizoctonia solani* and *Plenodomus destruens*, in that order. Curing to promote wound healing, fungicide treatment, bio-control, UV-irradiation, and improved storage practices were found to have intermediate impact in controlling these rots. The other viable proposition is to cultivate rot- resistant/tolerant varieties.

Keywords: bio-control, curing, Java black rot, Fusarium rot, Rhizopus rot, Sclerotium rot, sweet potato
Abbreviations: CIP, International Potato Centre; **DCNA**, dichloronitroaniline; **FAO**, Food and Agricultural Organizaton; **PD**, pathological deterioration

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INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is the world's seventh most important food crop after wheat, rice, maize, potato, barley and cassava (FAO 2008). More than 95% of the production is in the developing countries, with approximately 92% in Asia, 5% in Africa and 3% in the rest of the world (Ray and Tomlins 2010). In India, sweet potato is the third most important root and tuber crop after Irish potato and cassava. It is grown in different agro-ecological zones, largely by small-scale farmers, for home consumption and surplus is sold in local markets (Nedunchezhiyan and Ray 2010; Ray *et al.* 2010). Sweet potato is an important secondary crop that plays an important role in household food security in many countries (Mutuura *et al.* 1992; Ray *et al.* 2010; Tomlins *et al.* 2010). It combines many advantageous attributes that give it great potential as food (Woolfe 1992). The yellow-orange cultivars contain variable, but sometimes large, quantities of carotenoids which act as precursors of vitamin A (Ray and Tomlins 2010), and their consumption is considered an important food-based approach to combat vitamin A deficiency.

Despite its many good attributes, the harvested root of sweet potato has a short shelf life of less than four weeks in the tropics (Nedunchezhiyan and Ray 2010). The root is covered by a thin and delicate skin which is easily damaged during harvesting and postharvest handling. The resulting injuries become easy pathways for entry of rot causing microorganisms and moisture loss (Clark 1992). Consequently, postharvest pathological deterioration is a principal limiting factor in the marketing and the wider utilization of sweet potato in the tropics (Ray and Ravi 2005). During a national social-economic survey of sweet potato farmers in the main sweet potato production areas of Kenya, rotting of roots was rated as the seventh most important production constraint of the 17 cited constraints (Mutuura *et al.* 1992).

Microorganisms, mostly fungi may infect sweet potato roots at different stages, including field, harvest and storage stages (**Table 1**). Infection is mainly facilitated by mechanical injuries of the roots and environmental conditions, but the physiological condition of the root may influence infection (Wills *et al.* 1998). In addition, environmental and cultural stresses during growth also directly or indirectly predispose the roots to postharvest microbial infection. The

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Invited Mini-Review

Table 1 Microorganisms associated with sweet potato rots of sweet potato (Ray 2010; modified)

Types of rot	Causative organism	Symptoms	Pre-disposing factors	Avoidance/control measures
Aspergillus rot	*Aspergillus ochraceus*	Infected tissues show black spores on the surface	Wet soil, humid and warm temperature in field and in store	Curing in incubator in polyethylene and in the sun*
Black rot	*Ceratocystis filmbriata*	Sunken circular lesions initially brown and later greenish black. Associated with lesions are minute black bodies (perithecia) with long necks, appeared to naked eye as dark bristles	Wet soil, humid and warm temperature, contamination in seed roots	Crop rotation, careful handling of roots, heat treatment for no more than 24 h and curing at 35°C for 2 to 10 days. Cultivation of resistant varieties.
Java black rot	*Botryodiplodia theobroame*	Infected tissues are at first yellowish brown and fairly firm, later darkening to black. After some weeks, affected roots become mummified and skin is pimpled with minute black bodies (pycnidia)	Wounding during harvesting and handling	Curing and subsequent storage at a temperature between 13-16°C; cultivation of resistant varieties
Fusarium rot	*Fusarium* spp.	Type of decay is variable. End rot is characterized by a dry decay at one or both ends of fleshy roots. Infected tissues shrivel, forming cavities filled with white molds	Wounding during harvest and handling, infected roots used as seed, infestation by weevils	Minimizing injury during harvesting and handling, curing, cultivation of resistant varieties
Charcoal rot	*Macrophomina phascolina*	Infected roots show three zones- the advancing edges of the lesion is pale brown and spongy, intermediate zone is reddish brown and firm and the older part is almost black (micro sclerotia)	Wounding	Minimizing injury during harvesting and handling, and curing
Rhizopus rot	*Rhizopus* spp.	Decay beings at one end and under humid conditions, roots shrivel, become soft and watery and the skin ruptures. The mold spreads causing next of decay.	Wounds during postharvest handling, R.H. (75-85%), high temperature (< 35°C)	Careful handling, curing, cultivation of resistant varieties
Sclerotium rot	*Sclerotium rolfsii*	Circular lesions, sometimes internal tissues becoming water-soaked yet firm later hand and stringly	Wounds during postharvest handling, warm moist conditions (R.H. 75,-85%; temperature <35oC)	Careful handling curing
Spongy rot	*Cochliobolus lunatus* (*Curvularia lunata*)	Infected roots swollen and spongy	Wounding, warm and humid environment	Careful handling, curing
Rhizoctonia rot	*Rhizoctonia solani*	Pale brown spot on skin, tend to shrivel	Wounding, warm and humid environment	Careful handling, curing
Gliomastix rot	*Gliomastix novae-zelandiae*	Lesions appear as brown corky tissue	Wounding, warm and humid environment	Careful handling, curing
Foot rot	*Plenodomus destruens*	Lesions appear as brown corky tissue	Wounding, warm and humid environment	Careful handling, curing

*Sowley and Oduro (2002)

subject has been elaborately discussed by the author in his earlier publications (Ray and Ravi 2005; Ray *et al*. 2010). Nevertheless, an up to date brief account of the various fungal rots of sweet potato is given in this article.

FUNGAL ROTS

There are several fungi which cause severe postharvest loss of sweet potato in field, during storage and transportation. These are discussed in the order of severity and prevalence in sweet potato growing countries.

Major rots

1. Botryodiplodia theobromae

B. theobromae causes Java black rot. The rot is more prevalent in tropical and sub-tropical climates than in temperate climate i.e. Bangladesh (Jenkins 1981, 1982), India (Ray and Misra 1995; Ray and Punithalingam 1996), Philippines (Dalisay *et al*. 1987), Nigeria (Arinze and Smith 1982a, 1982b; Weerasinghe and Naqvi 1985) and the sub-tropical zone of USA (Lo and Clark 1988, Nelson 2008). The rot usually progresses from the ends of the root or from other wound sites and totally decays every infected root. The infected roots are at first yellowish brown and fairly firm, and later darkening to black. After 6- 8 weeks, the affected roots show dark patches externally, within which develops numerous pycnidia and internally the tissues turn yellow and later coal black. Finally, the rotted roots become shrivelled, brittle and mummified (Ray and Punithalingam 1996).

2. Rhizopus spp.

Rhizopus spp. cause soft–rot. The rot is widespread in all sweet potato growing countries (Ray *et al.* 2010). Several species of *Rhizopus* have been reported to cause rotting i.e. *R. stolonifer*, *R. oryzae* and *R. nigricans*. Affected roots are usually decayed totally by a rapidly developing soft and watery rot. Under dry atmosphere, the rotting is restricted but under humid conditions, the roots shrivel and at places, where the skin ruptures there is copious development of coarse white mould bearing characteristics globular spore head (sporangia). The sporangia are at first white but turn black as they mature and the entire mycelium appears grey.

3. Fusarium spp.

Fusarium spp. cause Fusarium root rot in sweet potato and the common species are *F. solani*, *F. oxysporum* and *F. pallidoroseum* (Ray and Ravi 2005).The type of decay is rather variable. End rot caused by *F. oxysporum* and *F. pallidoroseum* is characterized by a dry decay at one or both ends of the fleshy roots, the lesions being brown with dark margins (Clark and Moyer 1988). Infected tissue shrivels, sometimes forming cavities filled with white mould. On the other hand, surface rot caused by *Fusarium* species consists of pale brown circular lesions and the decay remains shallow with white mould but the lesions constitute a disfiguring blemish (Ray and Balagopalan 1997).

4. Ceratocystis fimbriata

C. fimbriata is another important rotting fungi causing 'black rot' of sweet potato. Most references of this rot are from USA (Clark 1992) and Japan (Uritani 1999). The rot is not reported from South-East Asian countries like Bangladesh, India and and Pakisthan. The characteristics of rottage are sunken circular lesions which are initially brown and later greenish black (Ray *et al.* 2010). Associated with lesions are minute black bodies (perithecia) with long necks.

5. Sclerotium rolfsii

S. rolfsii causes two diseases of sweet potato: sclerotial blight which develops on sprouts and mother roots in plant production beds and circular spots (sclerotium rot) which develops on stored roots (Clark 1992). The rot has also been recorded from Bangladesh (Jenkins 1982), Cuba (Gonzalez 1972), Jamaica, Israel, Mozambique (Snowdon 1991).

Minor rots

1. Macrophomina phaseolina

M. phaseolina caused charcoal rot which is wide spread in tropics (Jenkins 1981) but it is less severe in comparison to *B. theobromae*, *R. oryzae* or *C. fimbriata*. Decay of harvested roots usually begins at the point of original attachment to the plant, following 'collar rot', in the field. The 'charcoal' appearance results from thousands of minute bodies (micro-sclerotia) which colonise the interior, but never the surface of the root.

2. Cochliobolus lunatus (Curvularia lunata)

The fungus is reported to cause spongy rot on SP tuber in India (Ray and Misra 1995). The infected roots are swollen and spongy and the inside flesh turns brown to black.

3. Aspergillus ochraceus

It is reported in Ghana (Sowley and Oduro 2002). The symptoms are typical of any aspergillus rot.

4. Rhizoctonia solani

The rot is called Rhizoctonia rot and is reported from India (Ravichandran and Sullia 1983). Pale brown spots develop and affected roots tend to shrivel. Eventually, the entire root surface may be covered win brownish mould.

5. Gliomastix novae-zelandiae

The fungus is reported to cause Gliomastix rot in Egypt (Kararah *et al*. 1981). Lesions appear as irregular brown corky tissues usually slightly depressed. In a humid atmosphere, there is copious growth of black mould win abundant spores (conidia).

6. Plenodomus destruens

The fungus causes 'foot rot' in storage, plant production beds and the field and is reported from USA (Clark and Watson 1983) and Brazil (Rubin *et al*. 1994).

MOST RECENT STUDIES

Research was conducted to determine the effect of soil pH on postharvest deterioration of sweet potato roots using two sweet potato cultivars, Yanshu 1 (CIP 440024) and KSP 20 (CIP 440170), and three soil pH levels, 4.6, 5.8 and 6.1 arranged in randomized complete block design with four replications. Nine-mm circular agar plugs, removed from the edge of actively growing two-day old culture of two postharvest pathogens of sweet potato, *R. oryzae* and *B. theobromae*, were used to inoculate the sweet potato roots. Pathological deterioration (PD) was estimated by measuring the diameter and depth of the developing internal lesion (extent of tissue degradation) on the storage roots, 24 h after inoculation. Results showed that postharvest PD of the storage roots was not significantly ($P > 0.05$) influenced by growing sweet potato in soil at the different pH levels. Growing sweet potato in soil at pH levels within the range for normal plant growth is unlikely to affect postharvest deterioration of the storage roots (Kihurani *et al*. 2008).

The sweet potato roots initially cured for 7 and 14 days were stored in traditional, pit, and clamp storage structures for a maximum of 28 days. For the 7 days-cured sweet potato roots, the bacteria population in the three different storage structures increased by 1.2-2.3 log cfu (colony forming units)/g whereas for the 14 days-cured roots, the bacteria population was 0.1-1.0 log cfu/g within 28 days of storage. The fungal population in the 14 days-cured sweet potato roots was higher than in the 7 days-cured sweet potato roots by 0.6-1.6 log cfu/g for 28 days of storage. For both the 7 and 14 days-cured sweet potato roots, the sweet potato roots stored for 28 days in the three different storage structures had a higher microbial count compared to the sweet potato roots stored for 14 days. *Aspergillus flavus* was the most dominant fungal species occurring in all of the three different storage structures followed by *A. niger*, *Rhizopus stolonifer*, *Trichoderma viride*, *Fusarium oxysporum*, *Penicillium digitatum*, *Cladosporium herbarum*, and *Aspergillus ochraceus*, in that order (Tortoe *et al*. 2010).

CONTROL MEASURES

The following approaches have been made to control fungal rots.

Careful handling

Careful handling of roots, particularly during harvesting and transportation is very important (Ray and Balagopalan 1997). The handling and transport system resulted in up to 20-86% of roots with severe breaks and skinning injury respectively - a survey conducted in Tanzania (Tomlins *et al*. 2000, 2010).

Curing

Curing facilitates toughening of the skin and healing of wounds thereby reducing the risk of postharvest infection and decay (Ray and Balagopalan 1997). Environmental conditions for proper curing have been standardised; 29 ± 1°C, 90-95% relative humidity for 4-7 days (Ray *et al.* 1994). These parameters are more or less ambient in the hot and humid climates of tropical countries (Jenkins 1981; Ray *et al*. 1994, 2010).

Fungal pathogens isolated from rotten sweet potato root tubers were *Aspergillus ochraceus*, *B. theobromae*, *Fusarium moniliforme*, *F. oxysporum* and *R. stolonifer*. The thickness of the wound periderms in tubers cured in an incubator in polyethylene and in the sun were significantly different at 270.5, 232.2 and 17.6 μm, respectively. The thickness of the normal periderm was 312.6 μm. Curing prolonged the period for which sweet potatoes can be stored without rotting. Incubator-cured roots stored for at least 18 weeks (Sowley and Oduro 2002).

Storage techniques

Various cheap but effective storage methods are practised in tropics for arresting microbial spoilage and enhancing shelf life of SP roots. These methods are storage in pits, sand bed, saw dust, earthen pots, heaps in corner of mud house (Jenkins 1981; Ray and Balagopalan 1997).

Methods for sweet potato storage, previously developed at a research station, were tested on-farm by subsistence farmers in Lake Zone, Tanzania. On-farm testing confirmed

that the methods were suitable but indicated that practical and simple improvements were necessary, without which losses in the proportion of market-quality roots from the store could be as high as 79%. These practical improvements were mainly concerned with the position of stores on the farms. The addition of a new step, dehaulming, improved the recovery of market-quality roots by 48% (Tomlins *et al.* 2007). However, although the storage methods were developed in order to improve farmer income, most farmers said they would use the stored roots as a subsistence staple for household food security. Variations among the farmers in their attitudes to storing sweet potato suggest that, when transferring methods from the research station to the farm, it is necessary to target those most able to adopt the approach. Additionally, the farmers considered that local market traders may not be keen to sell stored roots. Therefore, other actors in the value chain, such as market traders and consumers, ought to be included in the process of transferring methods from the research station to the farm.

Drying of orange-fleshed sweet potato was evaluated under African rural conditions. Three locally built dryers (open-air sun, tunnel and shade) were tested using Resisto and MGCL01 varieties in Mozambique. Total carotenoid losses were low in all dryers being 9.2% on average. After drying, sweet potato chips were stored in a traditional way (jute bags inside a mud house). Chip size (thin, thick chip or slice) had a significant effect on drying ($P < 0.05$) but not on storage and variety had an effect on both. Total carotenoid losses during storage were much higher being 83.7% on average, after 4 months, with main individual carotenoids fitting a first-order kinetics degradation. Globally, carotenoid losses on-farm or on-research stations were of similar level (Bechoff *et al.* 2011).

Chemical control

Postharvest application of fungicides is generally avoided to prevent spoilage, as it may imparts residue problem. Some fungicides i.e. dichoronitroaniline (DCNA), benomyl, dichloran, iprodione were found effective in controlling various microbial rots of SP (Afek and Wiseblum 1995) and are primarily used for disinfecting planting materials.

Biocontrol by antagonistic bacteria and yeasts

Biological control, primarily with antagonistic yeasts, has shown promise for control of postharvest diseases of fruits and vegetables. Ray and Das (1998) reported complete growth inhibition *in situ* by three antagonistic yeast species i.e. *Debaryomyces hansenii*, *Pichia anomala* and *Saccharomyces cerevisiae* against Botryodiplodia rot of sweet potato. Control of Rhizopus soft rot by ultraviolet irradiation and yeast *D. hansenii* were compared (Stevens *et al*. 1997). Ultraviolet irradiation alone reduced the incidence of all the storage rots (Stevens *et al*. 1990, 1997, 1999). If *D. hansenii* was used 2-3 days after ultraviolet irradiation, the result was more significant.

Bacillus subtilis isolated from cowdung microflora was found to drastically inhibit the growth of *B. theobromae* and *F. oxysporum*, isolated from rotting microflora of greater yams, *in vitro* and *in vivo* (Swain *et al*. 2008).

Resistant varieties

The studies in Philippines have recognised that sweet potato genotypes vary widely in their susceptibility / resistance to Java black rot (*B. theobromae*) (Acedo *et al*. 1996). Similar observations were recorded for *Botryodiplodia*, *Fusarium* and *Rhizopus* spp. from other tropical countries like Bangladesh, China, India and Peru (Ray *et al*. 2010). However, postharvest rots often occur together as a complex rot involving many microorganisms; it is therefore, necessary to develop genotypes with broad spectrum resistance to major postharvest pathogens (Acedo *et al*. 1996).

FUTURE PROSPECTS

Curing and improved storage practices in sand bed or sawdust are few selected practices, which can prevent microbial attack for significant period. Bio control by antagonistic yeasts can be an alternate approach for arresting microbial rots either singly or in combined treatment with ultraviolet-irradiation. In temperate region, major emphasis is given on storability in selecting breeding lines. The same approach can be adapted in tropical countries like Bangladesh, China, India and Philippines.

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