J. Mycopathol. Res. **43**(2) : *147-158 (2005)*

MINI REVIEW

Microbial spoilage of stored sweet potato (*Ipomoea batatas*) roots in the tropics and control measures

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In the tropics, research on post harvest aspects of sweet potato has been limited—especially, in the field of microbiology. Several microorganisms (mostly fungi) have been found to induce spoilage in stored sweet potato. The most important among them are *Botryodiplodia theobromae* (causing Java black rot), *Rhizopus oryzae* (causing soft rot or Rhizopus rot), *Fusarium* spp. (causing Fusarium rot) and to some extent *Ceratocystis fimbriata* (causing Black rot). The other less frequently occurring spoilage microorganisms are *Sclerotium rolfsii, Macrophomina phaseolina, Cochliobolus lunatus (Curvularia lunata), Rhizoctonia solani, Plenodomus destruens* etc.. Physiological and biochemical changes i.e. starch, total sugar, organic acids (ascorbic and oxalic), polyphenols, ethylene and phytoalexins associated with post harvest spoilage of sweet potato have been discussed. Other approaches such as fungicide treatment, bio-control, UV-irradiation, hydro warming, and storage in sand and saw dust were found to have intermediate impact in controlling spoilage and enhancing shelf life of roots. New thrust area in controlling microbial spoilage could be to develop varieties having multi-spectrum resistance to major post harvest rot pathogens.

Key words : Curing, ethylene, microbial spoilage, phytoalexin, polyphenols, resistant varieties

INTRODUCTION

There are many kinds of tuberous root crops in the tropics, some of which are utilised as staple food. Sweet potato (*Ipomoea batatas* (L) Lam., Family-Convolvulaceae) is one such important root crop which is widely grown throughout the tropics and in warm temperate regions of the world between latitudes 40°N and S of the equator, and between sea levels and 2300 m altitude (Bourke, 1982). The world sweet potato (SP) production has been estimated to be 124,339,000 t of which 92% is in Asia (FAO, 1999). The starchy fleshy storage roots of SP serve as a staple food, animal feed (Posas, 1989 ; Wolfe, 1992) and to some extent as raw material for production of starch, organic acids and industrial alcohol (Wolfe, 1992). The roots contain about 50-80% starch and 4-15% sugar on a dry weight basis and 7-28% starch on fresh weight basis (Li *et al.*, 1994 ; Pati, 2001). Fresh roots are also a source of vitamin C (ascorbic acid), provitamin A, vitamin B (thiamine) and iron, but poor in protein and fats (Woolfe, 1992). Roots of yellow-orange fleshed cultivars contain high amount of carotenes and a few cultivars are rich in anthocyanins (Yamakawa, 1997).

Sp roots like any other vegetables of the tropics are subjected to several forms of post harvest wastages during storage and transportation from farmers' field to market. These are physical damage, weight loss, sprouting, weevil infestation and most important of all is the microbial spoilage (Jenkins 1981, 1982 ; Wagner *et al.*, 1983 ; Clark, 1997 ; Ray and Balagopalan, 1997). However, much scientific research on post-harvest aspects of this crop remains to be performed—including the field of microbiology. There are two major factors which contribute to under appreciation of spoilage of SP. One is that in many tropical regions, sweet potatoes have not been stored after harvest, but instead harvested only as they are needed. With increasing

urbanisation in many countries, this luxury may become less feasible (Horton *et al.*, 1989). If so, post harvest spoilage of SP will become as important or even more important in tropical areas as they already are in temperate growing regions. The other reason why SP spoilage study has been underestimated is the lack of scientific manpower and effort. This review will focus on spoilage of stored SP induced primarily by microorganisms, physiological and biochemical changes and appropriate control measures to prevent/arrest spoilage.

MICROBIAL SPOILAGE

Several fungi and bacterium (*Erwinia chrysanthemii*) have been reported to cause spoilage of stored SP roots. Most of these spoilage microorganisms have been found to be inhabitants on the surface of the root (Ray and Byju, 2003). General accounts of the biology of these spoilage microorganisms and disease symptoms have been published (Clark and Moyer, 1988 ; Snowdon, 1991 ; Clark, 1992 ; Clark *et al.*, 1992). An updated information (upto November 2004) reviewing on these aspects under tropical climates is summarised below.

Fungal Diseases

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 (Talukdar, 1974 ; Jenkins, 1981, 1982), India (Ray *et al.*, 1991 ; Ray and Balagopalan, 1994, 1997 ; Ray and Misra, 1995 ; Ray and Punithalingam, 1996), Philippines (Palomar *et. al.*, 1980 ; Dalisay *et al.*, 1987), Nigeria (Arene and Nwankiti, 1978 ; Arinze and Smith, 1982a, 1982b ; Weerasinghe and Naqvi, 1985) and the sub-tropical zone of USA (Lo and Clark, 1988). There are many synonyms of *B. theobromae* i.e. *Lasiodiplodia theobromae* (Pat.) Griff and Moubl. (Cadenas and Icochea, 1994), *L. tubericola* (E&E), *Diplodia gossypina* Cooke (Lo and Clark, 1988) and *D. tubericola* (E&E) (Dalisay *et al.*, 1987). Punithalingam (1980) summarised the pertinent literature and described the fungus as *Botryodiplodia theobromae* Pat. as the information about the fungus has been filed for several years mainly under the name. The rot usually progresses from the ends of the root or from other wound sites and totally decays every infected root. The infected tissues 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 Misra, 1995 ; Ray and Punithalingam, 1996 ; Ray and Balagopalan, 1997).

Wounding is the most important pre-disposing factor for *Botryodiplodia* infection (Ray and Punithalingam, 1996). Other pre-disposing factors are temperature (Jenkins, 1981 ; Ray and Punithalingam, 1996 ; Pati *et al.*, 2001), chilling (Clark, 1992), ethylene (Randle and Woodson, 1986), moisture (Zhao and Jia, 1985) or over-pilling (Winaro, 1982).

Rhizopus spp.

Rhizopus spp. cause soft-rot. The rot is widespread in all SP growing countries of temperate (Clark, 1992 ; Clark and Moyer, 1988) as well as in tropical climate (Jenkins 1981, 1982 ; Thankapan, 1994 ; Ray *et al.*, 1994, 1996, 1997). Several species of *Rhizopus* have been reported to cause spoilage viz. *R. stolonifer* (Clark and Moyer, 1988 ; Clark *et al.*, 1992 ; Thankapan, 1994), *R. oryzae* (Talukdar, 1974 ; Jenkins, 1981 ; Sinha and Prasad, 1986 ; Ray and Misra, 1995) and *R. nigricans* (Afek *et al.*, 1999). 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 root shrivel and at places, where the skin ruptures, there is copious development of coarse white mould bearing characteristics globular spore head (sporangia) (Snowdon, 1991 ; Ray *et al.*, 1997). The sporangia are at first white but turn black as they mature and the entire mycelium appear grey. Further colonisation of the entire rot can occur within a few days and the mould spread to adjacent tubers in a storage pile causing 'nest of decay' (Ray and Balagopalan, 1997 ; Ray *et al.*, 1997) Unlike *B.*

theobromae, the fungus is ubiquitous and infects the roots through wounds especially in which tissue is crushed or bruised. Sweet potatoes are more susceptible to Rhizopus soft rot following curing if they are rewounded (McClure, 1959 ; Clerk, 1992 ; Ray *et al.*,1997).

Wounds predispose the roots to be attacked (Ray and Balagopalan, 1997) and the root tip is especially susceptible to invasion because the natural presence of dead tissue is advantageous to the fungus (Srivastava and Walker, 1959). The other predisposing factors for *Rhizopus* infection in SP are relative humidity (R.H.) (75-85%) (Ray *et al.*, 1997), chilling (McClure, 1959), sunlight (Jenkins, 1981) and overpiling (Winaro, 1982).

***Fusarium* spp.**

Fusarium spp. cause Fusarium root rot in SP and the common species found in rotted SP are *F. solani* (Liu *et al.*, 1982 ; Campbell and Collins, 1987, 1988 ; Chen *et al.*, 1990 ; Clark, 1992), *F. oxysporum* (Snowdon, 1991 ; Clark, 1992 ; Ray *et al.*, 1994) and *F. pallidoroseum.* (Ray and Misra, 1995). *F. oxysporum* and *F. solani* have been recorded on SP in the USA (Nielsen and Moyer, 1979 ; Clark *et al.*, 1986 ; Campbell and Collins, 1987, 1988), China (Hu and Zhou, 1982 ; Liu *et al.*, 1986) and Israel (Afek and Wiseblum, 1995 ; Afek *et al.*, 1999) while *F. pallidoroseum* is reported from India (Ray and Misra, 1995).

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 (Nielsen and Moyer, 1979 ; Ray and Balagopalan, 1997).

The pre-disposing factors for *Fusarium* infection are drought stress (Clark, 1992), mechanical injury (Lineberger and Stikeleather, 1998), insect infestations (Agona *et al.*, 1998) or pre-harvest temperature (Ahn *et al.*, 1980).

Ceratocystis fimbriata

Next to *B. theobromae* and *Rhizopus* spp., *C. fimbriata* is the important spoilage fungus of SP causing the rot called 'black rot'. Most references of this rot are from USA (Daines, 1971 ; Clark and Moyer, 1988 ; Clark, 1992) and Japan (Hyodo and Uritani, 1984 ; Kojima, 1993 ; Uritani, 1998, 1999), although the disease has virtually been eliminated by use of thiabendazole fungicides on seed roots and by cutting transplants above the soil line (Clark, 1992). Nevertheless, it is still considered as important in other tropical and sub-tropical climates such as Papua New Guinea, Haiti and Peru (Woolfe, 1992). The rot is not reproted from South-East Asian countries like Bangladesh, India and Pakisthan. The characteristics of spoilage are sunken circular lesions which are initially brown and later greenish black (Snowdon, 1991). Associated with lesions are minute black bodies (perithecia) with long necks.

Pre-disposing factors for *C. fimbriata* infection are mechanical wounding, ethylene etc. (Hirano *et al.*, 1991 ; Hyodo, 1991 ; Kojima, 1993 ; Okumara *et al.*, 1999).

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, 1989 ; 1992). The rot has also been recorded from Bangladesh (Jenkins 1981, 1982), Cuba (Gonzalez, 1972), Jamaica, Israel, Mozambique (Snowdon, 1991).

Various types of decay have been described. Lesions may be circular undergoing no further enlargement after harvest (Clark, 1989). On the other hand, rotting may be invasive with major portion of internal tissues becoming water-soaked and yet firm, later hard and stringy (Snowdon, 1991). In a humid atmosphere, there may be copious white mould growth, followed by production of sclerotia (Gonzalez, 1972).

Other fungal species

Macrophomina phaseolina

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

Cochliobolus lunatus (Curvularia lunata)

The fungus is reported to cause spongy rot on SP tuber in India (Borborua, 1990 ; Ray and Misra, 1995). The infected roots are swollen and spongy and the inside flesh turns brown to black.

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 with brownish mould.

Gliomastix novae-zelandiae

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

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).

Bacterial Disease

***Erwinia* sp.**

Erwinia chrysanthemi causes root rot of SP in tropical (Ray and Misra, 1995) as well as in temperate climate (Schaad and Brenner, 1977 ; Duarte and Clark, 1992). Other soft rot Erwinias (e.g. *E. carotovora*) which are common on potato, have not been found on SP and also does not induce soft rot following artificial inoculations. Erwinia soft rot is similar to Rhizopus soft rot but primarily distinguished from the later by the absence of mycelia.

BIOCHEMICAL CHANGES

Microbial spoilage of SP roots is manifested in many physiological and biochemical changes i.e. starch, total sugars, organic acids, enzymes, phenols, ethylene, phytoalexins etc.

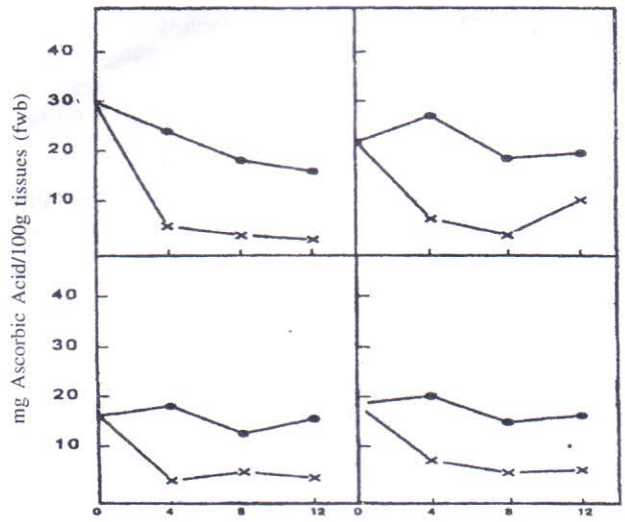
Starch, total sugars and organic acids

One of the first parameter noticed following microbial spoilage of SP is decline in starch and ascorbic acid contents (Thompson, 1979 ; Thornton and Workman, 1987 ; Pati, 2001 ; Ray and Pati, 2001). The decline in starch content is either associated with concomitant increase (Acedo *et al.*, 1996) or negligible variation (Ray and Pati, 2001) in total sugar. Like wise, the ascorbic acid contents of four SP varietites was reported to decrease further following infection by *B. theobromae* or *R. oryzae* (Fig. 1) Thompson, 1979 ; Ray and Pati, 2001).

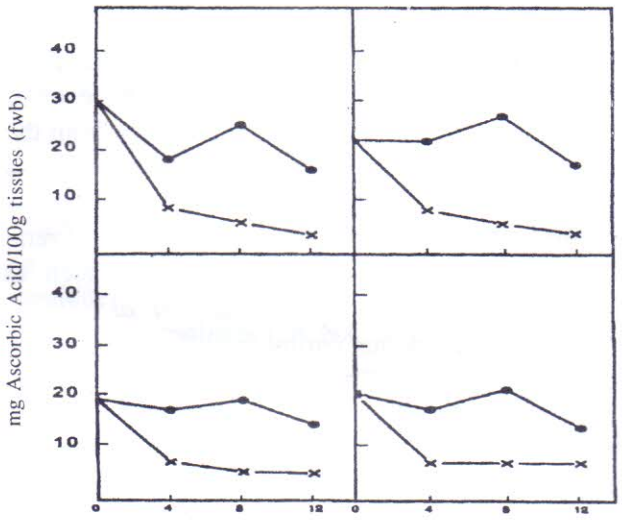
Oxalic acid concentration was reported to increase significantly in microbial infected SP tissues (Faboya *et al.*, 1983). The increase in oxalic acid is suggested to aid pathogen penetration by sequestering Ca or Mg in the middle lamella of cell walls, thereby increasing susceptibility of pectates to hydrolysis by cell wall degrading enzymes i.e. cellulases and pectinases. Oxalic acid may also lower the pH of the root tissues to a level suitable for pathogenic enzyme degradative activity.

Proline and carotenoids

There is no significant change in proline content between healthy and fungus (*Rhizopus* or *Botryodiplodia*) – infected SP roots (Ray and Pati, 2001), although proline accumulation is considered



(a) Infection by *B. theobromae*



(b) Infection by *R. oryzae*

Fig. 1 : Changes in ascorbic acid content in sweet potato roots following infection by fungi (•...•, uninfected ; x...x, infected with the fungus). (a) Infected by *B. theobromae*, and (b) Infection by *R. oryzae* (Ray and Pati, 2001).

as a measure of stress imposed on plant or plant parts due to adverse environments such as drought (Boggess *et al.*, 1962), temperature or microbial infection (Mohanty and Sridhar, 1982). On the contrary, roots infected with *R. stolonifer* contain only 24 mg carotenoids. $100g^{-1}$ (fwb)as compared with 50 mg. $100g^{-1}$ in uninfected SP roots (Thompson, 1979).

Enzyme activities

In response to wounding of SP by spoilage fungi, many enzymes are induced. The enzymes first activated belong to those in the phenyl propanoid pathway i.e. phenylanaline ammonia–lyase (PAL) and trans-cinnamic acid 4-hydroxylase (Uritani, 1998). Peroxidase and polyphenol oxidase activities are reported to subsequently increased (Arinze and Smith, 1982a). Likewise, most of the rotting fungi i.e. *B. theobroamae* and *R. oryzae* produce cellulolytic and pectolytic enzymes in microbial cultures and infected tissues (Arinze *et al.*, 1975, 1976 ; Arinze and Smit, 1982a ; Ray, 2003) that facilitated pathogen entry into SP roots (Arinze *et al.*, 1975).

Polyphenol production

There are many reports that phenol concentration increases several folds in SP roots following microbial infections (Uritani, 1998, 1999). Arinze and Smith (1979) reported that *B. theobromae* (SP isolate) produced polygalacturonase isoenzymes in SP roots. Total phenol content was generally higher in and around the lesions of SP infected by *B. theobramae, Botrytis cineria,* or *Rhizopus oryzae* (Thompson, 1979 ; Arinze and Smith, 1982a ; Ray, 1997 ; Mohapatra *et al.*, 2001). The chemistry and biochemical interpretation of phytoalexin *vis-à-vis* pathogen infection has been reviewed by several workers (Edwards and Kessmann, 1992 ; Uritani *et al.*, 1994 ; Uritani, 1999).

Total phenols and o-dihydroxy phenols increased in SP roots infected with *R. stolonifer* (Thompson, 1979). Woolfe (1992) reviewed that the majority of phenolics in SP are esters formed between quinic acid and caffeic acid. These phenolic esters are o-dihydroxy phenols, chlorogenic acid, isochlorogenic acids and related compounds (Mohapatra *et al.*, 2001 ; Thompson, 1981). The optimum phenol production by either *B. theobromae* or *R. oryzae* is obtained at pH 5.0–6.0 and temperature of 29 ± 1° (Mohapatra *et al.*, 2001). The proposed biosynthetic pathway by which chlorogenic acid and isochlorogenic acid may form in injured SP roots has been outlined (Villages and Kojima, 1986). Polyphenols can act as antibiotics. Both chlorogenic acid and isochlorogenic acid are found slightly inhibitory to the strains of *C. fimbriata* (Uritani, 1978) and *B. theobromae* (Mohapatra *et al.*, 2000).

Ethylene formation

Ethylene evolves in plants in response to attack by microorganisms as well as wound stress (Boller, 1991 ; Hyodo, 1991). Ethylene production in SP roots greatly increases in response to infection by fungi like *C. fimbriata* (Hyodo and Uritani, 1984 ; Okumura *et al.*, 1999) and *B. theobromae* (Pati, 2001). Further, the rate of ethylene production increases correspondingly with the extent of fungal penetration by using three strains of *C. fimbriata* differing in pathogenicity to SP (Hyodo *et al.*, 1969 ; Hirano *et al.*, 1991 ; Shima *et al.*, 1996, 1997). It is concluded that ethylene production is induced in SP root by an injury stimulus brought about by a consequence of fungal invasion, and mechanical wounding does not play any role in this system (Kozima, 1993 ; Okumura *et al.*, 1997).

Proteins and phytoalexins

In response to infection by *C. fimbriata,* high molecular weight proteins are converted into low molecular proteins (Li and Oba, 1985). Phytoalexins are not present in fresh SP, but they are produced by microbial infection (Arinze and Smith, 1980 ; Clark *et al.*, 1981 ; Fujita and Yoshizawa, 1989 ; Uritani, 1999) or weevil infestation (Padmaja and Rajamma, 1982). In SP, about 30 furanoterpenoid compounds are identified (Wilson and Burka, 1979 ; Schneider *et al.*, 1984). Ipomeamarone is the main component and recognised as the first example of a phytoalexin. These compounds are investigated primarily to determine if they are responsible for toxicoses in animals fed with 'mouldy' SP (Peckham *et al.*, 1972). Further, SP genotypes vary considerably in synthesising phytoalexins following microbial attack (Clark *et al.*, 1981 ; Jenkins, 1982). Further studies are warranted to determine if furanoterpenoids have a role in cultivar resistance to postharvest microbial rots.

CONTROL MEASURES

SP spoilage microorganisms have two means of entering the storage roots through wounds caused during harvest/weevil or insect infestations or through infected vines (used as propagating materials). The following approaches have been made to control microbial spoilage.

Careful handling

Any measure that reduces wounding the roots will help reduce spoilage (Miyazaki and Ino, 1991). Careful handling of roots, particularly during harvesting and transportation is very important (Aidoo, 1993 ; Jenkins, 1982 ; Stikeleather and Harrell, 1990 ; Shima *et al.*, 1996 ; Ray and Balagopalan, 1997). The handling and transport system resulted in up to 20-86 % of roots with severe breaks and skinning injury–a survey conducted in Tanzania (Tomlins *et al.*, 2000).

Curing

Despite best attention during post harvest handling of SP, some woundings inevitable occur, even if only as a result of attachment of the roots from the vines. For successful storage and marketing, it is necessary to subject the harvested roots to a preliminary process of curing which has several beneficial effects (Walter *et al.*, 1989) such as sweetness and palatability (Wang *et al.*, 1998). Most important is that curing facilitates toughening of the skin and healing of wounds thereby reducing the risk of post harvest infection and decay (Ray and Balagopalan, 1997). Environmental conditions for proper curing have been standardised ; 29 ± 1°C, 90-95% relative humidity (R.H.) for 4-7 days (Picha, 1986 ; Kays *et al.*, 1992 : 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 ; Ray Balagopalan, 1997).

Recommended curing and storage practices are difficult to follow in many developing countries of the tropics because they involve high initial costs for construction of suitable facilities. A simple technique for curing of SP was innovated at Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar, India by covering the freshly harvested roots with a polythene sheet raised 6"–8" above the roots spread open in a well ventilated place (Ray and Balagopalan, 1997). The polythene cover is removed during night. The

system could generate R. H. (85-90%) without any free water and temperature (28-30°C) during harvesting season in India (Sep-Nov/Feb-April) which are very ideal conditions for curing. By adopting this simple technology, the shelf life of SP increased 60 per cent over uncured roots and fungal infection is drastically reduced (> 10%). Curing induces suberization of exposed parenchyma cells and development of a wound periderm (Afek *et al.*, 1998). Following curing, storage at temperature of 14 ± 1°C and R. H. of 90% is generally recommended (Kays *et al.*, 1992). Other low cost curing processes such as storing SP in moisten saw dust, plastic green house have been developed (Nwinyi, 1987 ; Watanabe *et al.*, 1992 ; Afek and Wiseblum, 1995 ; Lineberger and Stikeleather, 1998) but additional research in these areas is needed for a meaningful conclusion.

Chemical control

Since the roots are directly used as food or feed commodity in many countries (Woolfe, 1992), post harvest 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 ; Afek *et al.*, 1998, 1999 ; Clark, 1992) and are primarily used for disinfecting planting materials.

Hot water treatment

Hot water treatment is found some what effective for control of microbial decay of SP (Scriven *et al.*, 1988). Dipping the roots at 90° C for 2 s, 80° C for 2, 4 or 20 s, 70° C for 10 s or 40° C for 120 s substantially delayes the time to initial rot without affecting the weight loss or respiration.

Biocontrol

Biological control, primarily with antagonistic yeasts, has shown promise for control of post harvest diseases of fruits and vegetables (Droby *et al.*, 1991 ; Schisler *et al.*, 1995). Ray and Das (1998) report complete growth inhibition *in situ* by three antagonistic yeast species i.e. *Debaryomyces hansenii, Pichia anomala* and *Saccharomyces cerevisiae* against Botryodiplodia rot of SP. Control of Rhizopus soft rot by ultraviolet irradiation and yeast *D. hansenii* are compared (Stevens *et al.*, 1997). Ultraviolet irradiation alone reduces the incidence of all the storage rots (Stevens *et al.*, 1990, 1997, 1999). If *D. hansenii* is used 2-3 days after ultraviolet irradiation, the result is more significant. It is suggested that ultraviolet irradiation and biological control agent could be used together as an alternative to chemical control of storage rot in SP. However, more numbers of studies are necessary to rationalise any significant conclusion on biocontrol of SP. Like wise, the use of natural fungicides with low mammalian toxicity should be investigated for use on SP. Other means of post harvest rots reported are gamma irradiation (Lu *et al.*, 1989).

Resistant varieties

In temperate region, major emphasis is given on 'storability' and post harvest rot resistance in selecting breeding lines (Campbell and Collins, 1987 ; Clark, 1992). The same approach can be adopted in tropical countries too (Chen *et al.*, 1990 ; Li *et al.*, 1994 ; Feng *et al.*, 1995). The studies in Philippines have recognised that SP genotypes vary widely in their susceptibility / resistance to Java black rot (*B. theobromae*) (Palomar *et al.*, 1980 ; Dalisay *et al.*, 1987 ; Acedo *et al.*, 1996). Similar observations are recorded for *Botryodiplodia, Fusarium* and *Rhizopus* spp. from other tropical countries like Bangladesh (Jenkins, 1981), China (Chen *et al.*, 1990 ; Sheng *et al.*, 1981), India (Ray and Naskar, 2000) and Peru (Cadenas and Icochea, 1994). However post harvest rots often occur together as a complex rot involving many microorganisms ; it is therefore, necessary to develop genotypes with broad spectrum resistance to major post harvest pathogens. Recently, Harrison *et al.* (2001) observe that sweet potato periderm components (resin glycosides) inhibit *in vitro* growth of root rotting fungi i.e. *B. theobromae, F. solani, F. oxysporum* and *R. stolonifer,* but a relationship between such components and disease resistance could not be established. With the advantage of genetic engineering and

biotechnology, it is now possible to incorporate resistant genes from bacteria and other biotic sources into SP genome. Improving SP by breeding new cultivars is difficult in part because of its hexaploid nature, and the complexity of compatibility groups. Many SP genotypes have combinations of numerous desirable characteristics but are deficient in resistance to certain pathogens. The potential for transgenic technology to further improve the products of traditional breeding by overcoming such critical deficiencies is highly attractive. A few approaches are being tested now, such as transformation with genes for lytic peptides that selectively lyse bacteria or with genes for enzymes such as chitinases and endoglucanases that degrade fungal call walls (Prakash, 1994). These technologies have to yet been evaluated sufficiently to estimate their practical potential.

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 ; Nwinyi, 1987 ; Ray *et al.*, 1994 ; Ray and Balagopalan, 1997).

CONCLUSION

To summarise the results, post harvest microbial rots like Botryodiplodia rot, Rhizopus rot and Fusarium rot are the most important for SP in tropics. Physical injury and infection through mother plants are found as two most significant pre disposing factors for rot to spread. Curing, hydro warming and storage in sand bed or sawdust are few selected practices, which can prevent microbial attack for significant period. Biocontrol by antagonistic yeasts can be an alternate approach for arresting microbial rots eitther 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 adopted in tropical countries like China, India and Philippines. Further, post harvest microbial rots often occur together as a complex rot ; it is necessary therefore, to develop genotypes with broad spectrum resistance to major post harvest pathogens.

REFERENCES

Acedo, A. L. Jr., Data, E. S. and Quevedo, M. A. 1996. Genotypic variations in quality and shelf life of fresh roots Philippines sweet potato grown in two planting seasons. *J. Sci. Food Agric.*, **72** : 209-212.

Aidoo, K. E. 1993. Post harvest storage and preservation of topical crops. *Intern. Biodeter. Biodegrad.*, **32** : 161-173.

Afek, U., Orenstein, J. and Nuriel, E. 1998. Increased quality and prolonged storage of sweet potatoes in Israel. *Phytoparastica,* **26** : 307-312.

Afek, U., Orenstein, J. and Nuriel, E. 1999. Fogging disinfectants inside storage rooms against pathogens of potatoes and sweet potatoes. *Crop Protec.*, **18** : 111-114.

Afek, U., and Wiseblum, A. 1995. Prolonged storage of sweet potato using a combined treatment of curing and iprodione (Rovral) disinfection. *Hassadeh,* **75** : 42-47.

Agona, J. A., Nahdy, M. S., Giga, D. P. and Rees, D. 1998. The effect of salting sweet potato chips prior to drying on infestation by *Araecerus fasciculatus. Trop. Agric.* **75** : 84088.

Ahn, K., Collins, W. W. and Pharr, D. M. 1980. Influence of pre-harvest temperature and flooding on sweet potato roots in storage. *Hort. Sci.* **15** : 261-263.

Arene O. B. and Nwankiti A. O. 1978. Sweet potato diseases in Nigeria. *PANS*, **24** : 294-305 illus.

Arinze, A. E., Naqvi, S. H. Z. and Ekundayo, J. A. 1975. Storage rot of sweet potato (*Ipomoea batats* L.) and the effect of fungicides on extracellular cellulolytic and pectolytic enzymes of the causal organisms. *Intern. Biodeterior. Bull.* **17** : 41-43.

Arinze, A. E., Naqvi, S. H. Z. and Ekundayo, J. A. 1976. Production of cellulolytic and pectic enzymes by *Lasiodiplodia theobromae* on sweet potato (*Ipomoea batats*) tubers. *Intern. Biodeterior. Bull.* **18** : 15-18.

Arinze, A. E. and Smith, I. M. 1979. Production of a polygalacturonase complex by *Botryodiplodia theobromae* and its involvement in the rot of sweet potato. *Physiol. Plant Pathol.*, **14** : 141-152.

Arinze, A. E. and Smith, I. M. 1980. Antifungal furanoterpenoids of sweet potato in relation to pathogenic and non-pathogenic fungi. *Physiol. Plant Pathol.*, **17** : 144-155.

Arinze, A. E. and Smith, I. M. 1982a. Distribution of polygalacturonase, total phenolic substance, polyphenol oxidases and peroxidases in rot zones of sweet potato. *Plant Pathol.*, **31** : 119-122.

Arinze, A. E. and Smith, I. M. 1982b. Effect of storage conditions on the resistance of sweet potato tissues to rotting by *Botryodiplodia theobromae* (Pat.) and other fungi. *J. Stored Prod. Res.*, **18** : 37-41.

Boggess, S. F., Aspinall, D. and Paleg, L. G. 1962. Stress metabolism. IX. The significance of end-production inhi-

bition of proline biosynthesis and of compartmenta-tion in relation to stress-induced proline accumulation. *Austr. J. Plant Physiol.*, **3** : 513-525.

Boller, T. 1991. Ethylene in pathogenesis and disease resistance. In : *The Plant Hormone Ethylene* Mattoo, A. K. and Suttle, J. C. (eds.), CRC Press, Boca Raton, Fl., pp. 293-314.

Borborua, A. 1990. New host records of fungi from India. Indian *J. Mycol. Plant Pathol.* **20** : 201

Bourke, R. M. 1982. Sweet potato in Papua New Guinea, In : *Sweet potato* Villareal, R. L. and Griggs, T.D. (eds.), Proc. 1st Intern. Symp. Asian Veg. Res. Dev. Center, Taiwan, China, pp. 45-57.

Cadenas, C. G. and Icochea, T. 1994. Behaviour of 196 clones of *Ipomoea batatas* (L) Lam. to Java black rot (*Lasiodiplodia theobromae* Pat.) *Fitopatol.*, **29** : 197-201.

Campbell, T. M. and Collins, W. W. 1987. *Fusarium solani* root rot resistance in sweet potatoes. *J. Am. Soc. Hort. Sci.* **112** : 386-389.

Campbell, T. M. and Collins, W. W. (1988). Effects of *Fusarium solani* root rot and pre-sprouting treatments of ''Jewel'' sweet potato plant production. *Can. J. Plant Pathol.*, **10** : 240-245.

Chen, L. F., Xu, Y. G. and Fang, Z. D. 1990. Identification of isolates causing root rot of sweet potato and tests on resistance of varieties of sweet potato to root rot. *Jiangsu J. Agric. Sci.*, **6** : 27-32.

Clark, C. A. 1989. Influence of volatiles from healthy and decaying sweet potato storage roots on sclerotial germination and hyphal growth of *Sclerotium rolfsii*. *Can. J. Bot.*, **67** : 53-57.

Clark, C. A. 1992. Post harvest disease of sweet potatoes and their control. *Post Harvest News and Information*, **3** : 75N-79N.

Clark, C. A. 1997. Prospects and problems of managing sweet potato diseases. *Proc. Intern. Workshop on Sweet potato Production System toward the 21st Century*, Miyakonojo, Miyazaki, Japan, pp. 323-333.

Clark, C. A., Dukes, P. D. and Moyer, J. W. 1992. Diseases. In : *Fifty Years of Cooperative Sweetpotato Research 1939-1989* Jones. A. and Bouwkamp, J. C. (eds.). Southern Co-operative Ser. Bull. No. 369, pp. 88-105.

Clark, C. A., Lawrence, A. and Martin, F. A. 1981. Accumulation of furanoterpenoids in sweet potato tissues following inoculation with different pathogens. *Phytopathol.*, **71** : 708-711.

Clark, C. A. and Mathew, S. W. 1987. Histopathology of sweet potato root infection by *Streptomyces ipomoea*. *Phytopathol.*, **77** : 1418-1423.

Clark, C. A. and Moyer, J. W. 1988. *Compendium of Sweet potato Diseases.* St. Paul., Minnesota, USA, The Am. Phytopathol. Soc.

Clark, C. A., Randle, W. M. and Pace, C. S. 1986. Reactions of sweet potato selections to Fusarium root rot and stem canker caused by *Fusarium solani*. *Plant Dis.*, **70** : 869-871.

Clark, C. A. and Watson, B. 1983. Susceptibility of weed species of Convolvulaceae to root-infecting pathogens of sweet potato. *Plant Dis.*, **67** : 907-909.

Daines, R. H. 1971. The control of black rot of sweet potatoes by the use of fungicide dips at various temperatures. *Phytopathol.*, **61** : 1145-1146.

Dalisay, R. F., Divinigracia, G. G. and Mendoza, E. M. T. 1987. Screening sweet potato roots for resistance to Java black rot caused by *Diplodia tubericola*. *Philippine J. Crop. Sci.*, **12** : 33-37.

Droby, S., Chalutz, E. and Wilson, C. L. 1991. Antagonistic micro-organisms as biological control agents of post harvest diseases of fruits and vegetables. *Post Harvest News and information.*, **2** : 169-173.

Duarte, V. and Clark, C. A. 1992. Presence on sweet potato through the growing season of *Erwinia chrysanthemi*, cause of stem and root rot. *Plant Dis.*, **76** : 67-71.

Edwards, R. and Kessman, H. 1992. Isoflavonoid phytoalexins and their biosysnthetic enzymes In : *Molecular Plant Pathology : A Practical Approach*, Vol. II., Gull, S. J. Mcpherson, M. J. and Bowles, D. J. (eds.) Oxford University Press, New York, pp. 45-62.

Faboya, O. O. P., Ikotun, T. and Fatoki, O. S. 1983. Production of oxalic acid by some fungi infected sweet potato tubers. *Z. Allg. Mikrobiol.*, **23** : 621-624.

FAO 1999. Production year Book. Vol. 48, FAO, Stat. Sec. 125, Food and Agric. Organisation, United Nations, Rome.

Feng. Q., Yun, R. S., Li, W. and Guang, C. 1995. Sampling methods in test for resistance of sweet potato to black rot *Ceratocystis fimbriata*. *Acta Agron. Sin.*, **21** : 540-543.

Fujita, M. and Yoshizawa, T. 1989. Induction of phyloalexins by various mycotoxins and metabolism of mycotoxins in sweet potato root tissues. *J. Food Hyg. Soc., Jpn.*, **30** : 501-505.

Gonzalez Avila, M. 1972. Algunos estudios sobrv *Sclerotium rolfsii* en Cuba. *Revista de Agric., Cuba* **5** : 37-44.

Harrison, H. F., Peterson, J. K., Clark, C. A. and Snook, M. E. 2001. Sweet potato periderm components inhibit *in vitro* growth of root rotting fungi. *Hort Sci.* **36**(5) : 927-930.

Hirano, T., Uritani, I. and Hyodo, H. 1991. Further investigations on ethylene production in sweet potato root tissues infected by *Ceratocystis fimbriata*. *Nippon Shokuhin Kogyo Gakkaishi* **38** : 249-259.

Horton, D., Prain, G. and Gregory, P. 1989. High level investment returns for global sweet potato research and development. *CIP Circular.*, **17** : 1-11.

Hu, C. and Zhow, L. 1982. The causal organism of root rot of sweet potato (InChinese ; English Summary). *Acta Phytopathol. Sin.*, **12** : 47-52.

Hyodo, H. 1991. Stress/wound ethylene, In : *The Plant Hormone Ethylene* Mattoo, A. K. and Suffle, J. C. (eds.), CRC Press, Boca Raton, Fl., pp. 43-63.

Hydo, H. and Uritani, I. 1984. Ethylene production in sweet potato root tissues infected by *Ceratocystis fimbriata*. *Plant Cell Physiol.*, **25** : 1147-1152.

Hyodo, H., Uritani, I. and Akai, S. 1969. Production of

furanoterpenoids and other compounds in sweet potato root tissues in response to infection by various isolates of *Ceratocystis fimbriata, Phytopath. Z.*, **65** : 332-340.

Jenkins, P. D. 1981. Differences in the susceptibility of sweet potatoes *(Ipomoea batatas)* to infection by storage fungi in Bangladesh *Phytopath. Z.*, **102** : 247-256.

Jenkins, P. D. 1982. Losses in sweet potatoes (*Ipomoea batatas*) stored under traditional conditions in Bangladesh. *Trop. Sci.*, **24** : 17-28.

Kararah, M. A., El-Shehedi, A. A., El-Tobshy, Z. M. and Abdel-Gafoure, S. E. 1981. Pathological and histological studies on *Gliomastix novae-zelandiae* infecting sweet potato in A. R. Egypt. *Agric. Res. Rev.*, **59** : 219-240.

Kays, S. J., Bhagsari, A. S. and Picha, D. H. 1992. Physiology and Chemistry. In : *Fifty Years of Co-operative Sweet potato Research 1939-1989* Jones, A. and Bouwkamp. J. C. (eds.), Southern Co-operative Ser. Bull. No., 369, pp. 44-70.

Kojima, M. 1993. Phytoalexins and other biochemical factors associated with infection by *Ceratocystis fimbriata.* In : *Ceratocystis and Ophiostoma : Taxonomy, Ecology and Pathogenicity.* Wingtield, M. J., Seifert, K. A. and Webber, J. F. (eds) APS Press, St. Paul, pp. 243-251.

Li. H. S. and Oba, K. 1985. Major soluble proteins of sweet potato roots and changes in proteins after cutting, infection or storages. *Agric. Biol. Chem.*, **49** : 737-344.

Li, L., LIAO, C. W. and Chin, L. 1994. Variability in test and physico-chemical properties and its breeding implications in sweet potato (*Ipomoea batatas*) *J. Agric. Assoc., China, New Ser.*, **165** : 19-31

Lineberger, B. and Stikeleather, L. F. 1998. Low cost bulk storage system for sweet potatoes using earth-coupled thermal buffering. In : *Am. Soc. Agric. Engineers Annu. Intern. Meeting, Orlando, Fl, USA, 12-16th* July, p. 6.

Liu. Q., Ye, D. and Xu, Z. 1982. On the root rot of sweet potato. *Acta Phytopathol. Sin.*, **12** : 21-28.

Lo, J.-Y. and Clark, C. A. 1988. Sources of inoculum and infection courts of *Diplodia gossypina* on sweet potato. *Phytopathol.*, **78** : 1442-1446.

Lu, J. Y., Miller, P. and Loretan, P, A. 1989. Gamma radiation dose rate and sweet potato quality. *J. Food Qual.*, **12** : 369-376.

McClure, T. T. 1959. Rhizopus decay of sweet potatoes as affected by chilling, re-curing and hydro-warming after storage. *Phytopathol.*, **49** : 359-361.

Miyazaki, T. and Ino, M. 1991. Effect of root quality and storage conditions on internal brown spot symptoms in stored sweet potato. *Bull. Chiba Prefectural Agric. Expt. Stn. No.* **32** : 65-72.

Mohanty, S. K. and Sridhar, R. 1982. Physiology of rice tungro virus disease : Proline accumulation due to infection. *Physiol. Plant.*, **56** : 89-93.

Mohapatra, N. P., Pati, S. P. and Ray, R. C. 2000. In vitro inhibition of *Botryodiplodia theobromae* Pat. causing Java black rot in sweet potato by phenolic compounds. *Ann. Plant Protec. Sci.* **8** : 84-86.

Mohapatra, N. P., Pati, S. P. and Ray, R. C. 2001. Spoilage os sweet potato tubers in tropics. V. Java black rot by *Botryodiplodia theobromae* Pat. : Phenol accumulation in culture and tubers during spoilage. *J. Mycopathol. Res.*, **39** : 21-27.

Nielsen, L. W. and Moyer, J. W. 1979. A Fusarium root rot of sweet potatoes. *Plant Dis. Rep.*, **63** : 400-404.

Nwinyi, S.C.O. 1987. Sweet potato : A potential industrial and staple food crop of Nigeria. *Outlook on Agric.*, **16** : 178-181.

Okumara, K. , Hyodo, H., Kato, M., Ikoma, Y. and Yano, M. 1999. Ethylene biosynthesis in sweet potato root tissues infected by black rot fungus (*Ceratocystis fimbriata*). *Post Harvest Biol. Tech.*, **70** : 117-125.

Palomar, M. K., Solis, A. D. and Bandala, H. S. 1980. Sweet potato tuber rot disease in the Philippines. *Ann. Trop. Res.*, **2** : 11-121.

Pati, S. P. 2001. *Post harvest spoilage of sweet potato.* Ph.D Thesis, Utkal University, Orissa, India, 138 pp.

Pati, S. P., Maheswari, S. K. and Ray, R. C. 2001. Effect of culture media, temperature, pH, carbon and nitrogen sources on growth of *Botryodiplodia theobromae* causing Java balck rot of sweet potato tubers. *J. Mycopathol. Res.*, **39** : 15-19.

Padmaja, G. and Rajamma, P. 1982. Biochemical changes due to weevil (*Cylas formicarius* Fab.) feeding on sweet potato. *J. Food Sci. Technol., India.*, **19** : 162-163.

Peckham, J. C., Mitchell, F. E., Jones, O. H. JR. and Doupnik, B. JR. 1972. A typical interstitial pneumonia in cattle fed on mouldy sweed potatoes. *J. Am. Vet. Med. Assoc.*, **160** : 169-172.

Picha, D. H. 1986. Weight loss in sweet potatoes during curing and storage : contribution of the transpiration and respiration. *J. Am. Soc. Hort. Sci.*, **111** : 889-892.

Posas, O. B. 1989. Sweet potato as animal feed. *Radix*, **11** : 1-8.

Prakash, C. S. 1994. Sweet potato biotechnology ; Progresses and Potential. *Biotechnol. Develop. Monitor* No. 18 : 18-19.

Punithalingam, E. 1980. Plant diseases attributed to *Botryodiplodia theobromae* Pat. *Bibilotheca Mycologica*, **71** : 1-123.

Randle, W. M. and Woodson, W. R. 1986. The effect of storage and wounding on ethylene production by sweet potato (*Ipomoea batatas*). *Hort. Sci.*, **21** : 1018-1019.

Ravichandran, V. and Sullia, S. B. 1983. Pathogenic fungi from sweet potato. *Curr. Sci.* **52** : 1031.

Ray, R. C. 1997. Spoilage of sweet potato tubers in tropics. IV. Phenolaccumulation by *Rhizopus oryzae* L. in culture and in tubers during spoilage. *J. Root Crops.*, **24** : 99-104.

Ray, R. C. 2003. Biochemistry of post harvest spoilage of sweet potato (*Ipomoea batatas* L.) 3. Pectolytic anzymes production in cultures and fungi-infected sweet potato tubers. *J. Mycopathol. Res.* **41** : 123-126.

Ray, R. C. and Balagopalan, C. 1994. Post harvest rottage of sweet potato. In : *Tropical Tuber Crops : Food Secutiry and Nutrition* Balagopalan, C. (ed.) Oxford & IBH Publishing Pvt. Ltd., New Delhi, pp. 74-79.

Ray, R. C. and Balagopalan, C. 1997. Post harvest rottage of sweet potato. *Tech. Bull. Ser. 23,* Cen. Tuber Crops Res. Inst., Trivandrum, India, 31pp.

Ray R. C., Bhat. P. S., Kumar, P. P. and Nedunzhiyan. M. 1991. Sweet potato in Orissa. In : *Sweet potato in South Asia : Post-harvest handling storage, processing and uses* Scott, G. (ed.) CIP-CTCRI, Trivandrum, India, pp. 23-25.

Ray. R. C. and Byju, G. 2003. Root surface mycoflora of sweet potato (*Ipomoea batatas* L.) and post harvest rot of the tubers. *Adv. Hort. Sci.* **17** : 176-180.

Ray. R. C. and Das, B. B. 1998. Yeasts as possible microbial antagonists of post harvest spoilage of tuber crops. *J. Root. Crops.* **24** : 99-104.

Ray. R. C. and Misra, R. S. 1995. Spoilage of sweet potato tubers in tropics. III. Soft rot by *Rhizopus oryzae* L. *Adv. Hort. Sci.* **11** : 103-107.

Ray. R. C. and Misra, R. S. and Balagopalan, C. 1996. Fungi associated with storage decay of sweet potatoes in India. In : *Trpiccal Tuber Crops : Problems, Prospects and Future Strategies* Kurup. G. T. (ed.) Oxford & IBH Publishing House Pvt. Ltd., New Delhi, pp. 491-501.

Ray. R. C. and Naskar, S. K. 2000. Screening sweet potato tubers for resistance to Java black rot by *Botryodiplodia theobromae. Proc. 3rd Intern. Symp.,* 5-8 Jan, Tropical Tuber Crops, Trivandrum, India.

Ray. R. C. and Pati, S. P. 2001. Biochemistry of post harvest spoilage of sweet potato (*Ipomoea batatas* L.) 1. Changes in starch, total sugar, proline and ascorbic acid contents. *Ann. Trop. Res.* **23**(2) : 34-48.

Ray. R. C. and Punithalingam, E. 1996. Spoilage of sweet potato tubers in tropics II. Java black rot by *Botryodiplodia theobromae* Pat : Growth studies and mode of infection. *Adv. Hort. Sci.* **10** : 151-157.

Ray. R. C., Roychowdhury, S. and Balagopalan, C. 1994. Minimising weight loss and mocrobial rotting of sweet potato (*Ipomoea batatas*) in storage under tropical ambient conditions. *Adv. Hort. Sci.,* **8** : 159-164.

Rubin, R. Da, S., Loris, A. A. R. and Duarte, V. 1994. Control severity under field conditions and reaction of sweet potato (*Ipomoea batatas*) of foot rot (*Plenodomus destruens*). *Fitopatol. Bras.,* **19** : 39-43.

Schaad, N. W. and Brenner, D. 1977. A bacterial wilt and root rot of sweet potato caused by *Erwinia chrysanthemi. Phytopathol. Z.,* **67** : 302-308.

Schisler, D. A., Kurtzman, C. P., Bothast R. J. and Slininger, P. J. 1995. Evaluation of yeasts of biological control of Fusarium dry rot of potato. *Am. Potato J.,* **72** : 339-353.

Schneider, J. A., Lee, J., Naya, Y., Nakanishi, K., Oba, K. and Uritani, I. 1984. The fate of the phytoalexins impomeamarone : furanoterpenes and butenolides from *Ceratocystis fimbriata* – infected sweet potatoes. *Phytochem.,* **23** : 759-764.

Scriven, F. M., Ndunguru, G. T. and Wills, R. B. H. 1988. Hot water dips for the control of pathogenic decay in sweet potatoes. *Scient. Hort.,* **35** : 1-5.

Sheng, J., Yuan, B. and Zhu, C. 1981. Xushu 18 : A new high yield sweet potato variety with Fusarium root rot resitance (In Chinese ; English summary). *Chung-Kuo Nung Yeh K'o Hsueh Sci. Agric. Sin.,* **2** : 41-45.

Shima, Y., Nagahama, T., Suganuma, T. and Kitahara, K. 1996. Effect of storage conditions of deterioration of mechanically injured sweet potato tuberous roots especially on induction of ipomeamarone. *Jpn. J. Trop. Agric.,* **40** : 204-212.

Shima, Y., Nagahama, T., Suganuma, T. and Kitahara, K. 1997. Endogenous furanoterpenoid inducing factors found in mechanically injured sweet potato roots. - *Nippon Nogei -Kagaku Kaishi.,* **71** : 1261-1272.

Sinha, D. C. and Prasad, R. K. 1986. Rhizopus rot of sweet potato in India. *Indian Phytopathol.,* **39** : 89-90.

Snowdon, A. L. 1991. *A Colour Atlas of Post Harvest Diseases and Disorders of Fruits and Vegetables.* Wolfe Scientific Ltd., Aylesbury, England, pp. 364-383.

Srivastava, D. N. and Walker, J. C. 1959. Mechanisms of infection of sweet potato roots of *Rhizopus stolonifer, Phytopathol.,* **49** : 400-406.

Stevens, C., Khan, V. A., Tang, A. Y. and Lu, J. Y. 1990. The effect of ultraviolet radiation on mould rots and nutrients of stored sweet potatoes. *J. Food Protect.,* **53** : 223-226.

Stevens, C., Khan, V. A., Lu, J. Y., Wilson, C. L., Pussey, P. L., Igwegbe, E. C. K., Kabwe, K., Mafolo, Y., Liu, J., Chalutz, E. and Droby, S. 1997. Integration of ultra violet (UV-C) light with yeast treatment for control of post harvest storage rots of fruits and vegetables. *Biol. Cont.,* **10** : 95-103.

Stevens, C., Khan, V. A., Ly, J. Y. Wilson, C. L., Chalutz, E. Drobey, S., Kabwe, M. K., Haung, Z., Adeyeye, O., Pusey, L. P. and Tang, A. Y. A. 1999. Induced resitance of sweet potato to Fusarium root rot by UV-C hormesis. *Crop. Protec.,* **18** : 463-470.

Stikeleather, L. F. and Harrell, K. P. 1990. Sweet potato damage as measured by weight loss. *Am. Soc. Agric. Engineers,* No. 19-1614, pp. 11.

Talukdar, M. J. 1974. Plant diseases in Bangladesh, *Bangladesh J. Agric. Res.,* **1** : 61-86.

Thankapan, M. 1994. Fungal diseases of sweet potatoes. In : *Advances in Horticulture,* Vol. 8. *Tuber Crops* Chadha, K. L. and Nayar, G. G. (eds) Malhotra Publishing House, New Delhi, pp. 388-396.

Thompson, D. P. 1979. Phenols, carotenes and ascorbic acid in sweet potato roots infected with *Rhizopus stolonifer. Can. J. Plant Sci.,* **59** : 1177-1179.

Thompson, D. P. 1981. Chlorogenic acid and other phenolic compounds in fourten sweet potato cultivars. *J. Food Sci.,* **46** : 738-740.

Thornton, M. K. and Workman, M. 1987. Changes in ascorbic acid content of black spot-resistant and susceptible potatoes following bruishing. *Hort. Sci.,* **22** : 455-456.

Tomlins, K. I., Ndunguru, G. T., Rwiza, E. and Westby, A. 2000. Post harvest handling, transport and quality of sweet potato in Tanzania. *J. Hort. Sci. Biotech.,* 75 : 586-590.

Uritani, I. 1978. Biochemistry of host response to infection. In : *Progress in Phytochemistry* Reinhold, L., Harborne, J.

B. and Swain, T. (eds.) Pergamon Press, Oxford, pp. 29-63.

Uritani, I. 1998. Biochemical comparison in storage : Stress responses between sweet potato and cassava. *Trop. Agric. (Trinidad),* **75** : 177-182.

Uritani, I. 1999. Biochemistry of post harvest metabolism and deterioration of some tropical tuberous crops. *Bot. Bull. Acad. Sin.*, **40** : 177-183.

Uritani, I., Garcia, V. V. and Mendosa, E. M. S. (eds.) 1994. *Post harvest Biochemistry of Plant Food materials in the Tropics.* Jpn. Scientific Soc. Press, Tokyo, 257 pp..

Villages, R. J. A. and Kojima, M. 1986. Purification and characterisation of hydroxy cinnamoyl D-glucose : quinate hydroxy cinnamoyl transferase in the roots of sweet potato (*Ipomoea batatas* Lam.). *J. Biol. Chem.* **261** : 8729-8733.

Wagner, A. B., Burns, E. E. and Paterson, D. R. 1983. The effect of storage systems on sweet potato quality. *Hort. Sci.,* **18** : 336-337.

Weerasinghe, B. and Naqvi, S. H. Z. 1985. Some comparative physiological studies on selected isolates of *Botryodiplodia theobromae* Pat. causing storage rot of yams, cassava and sweet potato in Nigeria. *Intern. Biodeterior. Bull.,* **21** : 225-228.

Walter, W. M. J. R., Hammlett, L. K. and Ciesberecht, F. G. 1989.Wound healing and weight loss of sweet potatoes harvested ast several soil temperatures. *J. Am. Soc. Hort. Sci.,* **114** : 94-100.

Wang, Y., Horvat, R. J., White, R. A. and Kays, S. J. 1998. Influence of post harvest curing treatment on the synthesis of the volatile flavour components in sweet potato. *Acta Hort.* **64** : 207-212.

Watanabe, K., Yamazaki, I., Nakazaki, K. and Yoneyama, S. 1992. Curing system using a plastic green house for prevention of storage rots of sweet potato. *Proc. Kanto-Tosan Plant Protec. Soc.* **39** : 53-55.

Wilson, B. J. and Burka, L. T. 1979. Toxicity of novel sesquiterpenoids from the stressed sweet potato (*Ipomoea batatas*). *Food Cosmet. Toxicol.,* **17** : 353-355.

Winaro, F. G. 1982. Sweet potato processing and by product utlisation in the tropics, In : *Sweet potato.* Villareal, R. L. and Griggs, T. D. (eds.) Proc. 1st Intern. Symp Asian Veg. Res. Dev. Centre, Taiwan, China, pp. 373-384.

Woolfe, J. A 1992. *Swet potato – an untapped food resource.* Cumb. Univ Press, Cambridge – New York, 643 pp.

Yamakawa, O. 1997. Development of new cultivation and utilisation system for sweet potato toward the 21st century. *Proc. Intern. Workshop on Sweet potato production system toward the 21st century,* Miyakonojo, Miyazaki, Japan, pp. 1-8.

Zhao, Z. and Jia, F. 1985. *Storage and simple processing of sweet potato (In chinese ; English summary).* The publishing House of Agric., China.

(Accepted for publication April 12, 2005)