"POSTHARVEST DISEASES OF FRUITS IN NAIROBI MARKETS AND THEIR CONTROL"

BY

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IN MEMORY OF

MY MOTHER CHRISTINAH WAMBUGA

D E C L A R A T I O N

a. I, Serah Wadom Mwanycky, declare that this thesis is my original work and has not been presented for a degree in any University.

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b. This thesis has been submitted for examination with our approval as University supervisors.

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A B S T R A C T

Disease survey in the Nairobi fruit markets revealed the prevalence of the following pathogens associated with fruit diseases: Aspergillus niger, Botryodiplodia theobromae, Colletotrichum gloeosporioides, Colletotrichum musae, Fusarium roseum, Penicillium digitatum, Penicillium expansum, Pezicula sp., Rhizopus stolonifer, Thielaviopsis paradoxa and Pseudomonas mangiferae-indicae. It was possible to grow the fungi on malt extract agar, potato dextrose agar, corn meal agar and czapek-dox-agar. However, potato dextrose agar supported the best growth and sporulation.

Injury to fruit surface was found to be prerequisite avenue for attack by these pathogens. Some of these pathogens were able to attack through the stem end, blossom end or through intact surface of the fruit.

Fruit losses due to spoilage varied considerably in the five markets depending on the prevailing storage and handling conditions. Losses in monetary value were estimated at Kshs. 17,558.36 per annum in the five markets surveyed.

Spores of various pathogens germinated at a temperature range of 20 - 25^{o}C. Mycelial growth and disease development were favoured by a temperature range of 20 - 35^{o} as well as at 10^{o}C in some cases.

Spores germinated at a relative humidity of 90 - 100 per cent, compared to disease development which needed 70 - 100 per cent. Most of the postharvest pathogens germinated at a wide range of pH (4.5 - 6.5) with an optimum between pH 5.5 and 6.5.

Some organic fungicides and a few mild disinfectants were effective against fruit diseases. Captan was the most effective organic fungicide inhibiting spore germination, while benlate was rated the best for inhibition of mycelial growth. However, calcium hypochlorite, being cheaper, was found to be economical to use in extending the shelf life of fruits. It was found uneconomical to treat apples, tangerines and pineapples with chemicals as they have a fairly long shelf life.

1. INTRODUCTION

Kenya is an agricultural country with the majority of people depending mainly on farming for their livelihood. The farmers grow a wide range of crops including tropical and temperate fruits such as bananas, mangoes, pawpaws, avocadoes, pineapples, apples, pears, plums, strawbarries and various citrus fruits. Many of these fruits are of comparable quality to those of major fruit producing countries (Stoughton, 1967).

Oranges, tangerines, mandarines, grapefuit and lemons are cultivated in many parts of Kenya and the markets are always well supplied. Development of an export trade for these fruits is limited because, in most areas where they are cultivated, high temperatures coupled with other factors hinder development of high quality in fruits, except for grapefruit (Stoughton, 1967). Consequently, oranges and lemons are locally used for commercial production of juice and the rest of the citrus fruits are sold in rural and urban markets for home use.

Pineapple is one of the most important of the horticultural crops in Kenya. Most of it is grown on large-scale farms in Thika District and is commercially processed by Kenya Canners Ltd.

Mangoes are rarely grown on a plantation scale. Although, the varieties grown in Kenya are good enough for export, there is room for improvement in quality, cultivation and packaging.

Bananas are normally found intercropped with maize, sweet potatoes, beans and other crops and are widespread in distribution. Pawpaws are grown in the Coastal areas as well as Eastern Province. Apples, pears and plums are high altitude crops, restricted to the Kenya highlands. The major apple growing area is Trans Nzoia District near Kitale. Pears and plums are mainly grown in Limuru Division in Kiambu District.

Some of the fruits produced in Kenya are exported abroad. From 1968-1972, fruits accounted for approximately forty percent of the horticultural exports (Anon, 1971, 1972). Pineapples alone accounted for over thirty per cent of the horticultural exports in 1972 (Anon 1972). In 1978, fruit exports were £3,043,000 by value (Anon 1978). Fruits are therefore, earning a lot of foreign exchange for the country.

Although the potential for horticultural production in Kenya is very great, the present production of fruits per unit area is not at all meeting the requirements for the local and foreign

markets due to untimely attack by pests and diseases. These are taking heavy toll each year in the field as well as in storage. Kenya is therefore, faced with the challenge to increase her fruit production to meet this demand and this can only be achieved if diseases and pests are timely controlled.

Postharvest diseases of fruits may be caused by both non-pathogenic and pathogenic causes (US Dept. Agric., 1953). The former may be caused by fluctuations in environmental factors, which may result in suboxidation, accumulation of aromatic esters, unfavourable temperature and humidity and chemical injury (Stackman and Harrar, 1957). The latter may be induced by pathogenic organisms like bacteria and fungi. This is because, mature fruits are highly susceptible to invasion by pathogenic microorganisms. They are also rich in moisture and nutriment and are no longer protected by intrinsic factors which confir resistance during development on the plant. In addition, many fruits become easily injured as they approach maturity and therefore, are more vulncrable to attack by pathogens which enter through wounds.

Fruit losses due to microbial decay are therefore, enormous in various countries including Kenya. Singh (1960), recorded a loss of 20 - 33 per cent for mangoes in Jamaica. Smoot (1969), noted

a total loss of 40 - 50 per cent for orange in Florida (USA). Ramsey (1938), estimated a loss of 40 - 50 per cent for pineapple in Cuba. In 1967, annual losses of fresh fruits and vegetables from deterioration during shipment and retail marketing were estimated at about 200 million dollars in USA (Eckert and Sommer, 1967).

So far, there is limited information on postharvest diseases of fruits in Kenya, although they constitute a major problem in fruit preservation in tropical Africa. Because of the economic importance of this problem and urgency in solving it to save foreign exchange earnings from fruit export, basic investigations were undertaken in order to provide the knowledge needed to prolong the storage period of fruits. The scope of the present study includes:-

(1) Survey and identification of the causal agents of postharvest diseases in fruit markets in Nairobi.

(2) Association of disease symptoms with various disease causing agents.

(3) Laboratory study on disease development.

and (4) Search for disease control measures.

Investigations were confined to apples, bananas, citrus fruits, mangoes, pawpaws, pears, pineapples and plums; chosen in accordance with a

tropical and subtropical fruit classification of Mortensen and Bullard (1968) as follows:-

Class I - Fruits of wide commercial importance.

Class II - Fruits of limited commercial importance.

Class III - Fruits grown for local markets.

2. REVIEW OF LITERATURE

Postharvest diseases of fruits can be divided into two categories: infectious and non-infectious diseases. Non-infectious diseases are caused by physiological disorders or adverse environmental conditions during growth in the orchards or during harvest, in storage and marketing (U.S. Dept. Agric., 1953). Infectious diseases are caused by either fungi or bacteria. The fungal diseases are caused by contaminations and infections that occur in orchads during the growing season or due to infection through incidental injuries during harvesting, processing, packing and transportation of produce (Stackman and Harrar, 1957; U.S. Dept. of Agric., 1953).

The amount of damage and loss from diseases varies greatly with the commodity, the kind of disease, the growing and handling conditions. More than 100 fungal diseases are known to cause decay and blemishes in commercial shipment of fruits (U.S. Dept. of Agric., 1953).

Etiology and Control of Storage Diseases of Different Fruits.

(a) Apples (Malus sylivestris)

The major storage pathogens of this fruit are the species of Botrytis, Penicillium, Phoma,

Stremphylium and Pezicula.

Blue mould rot in apple is caused by Penicillium expansum. The fungus enters the fruits through, skin abrasion or lenticels. The fruit decay first appears as soft watery, light-brown or yellow spots, which vary in size and may occur on any part of the fruit. Eventually, the infected area becomes blue as a result of abundant sporulation of the fungus.

Control of Penicillium expansum and Botrytis cinerea is by 600 ppm benlate, 600 ppm thiabendazole and 600 ppm thiophanate (Valdebento and Pinto, 1973; Spalding, 1972; Maas and MacSwann, 1970).

Lenticular rot is caused by Pezicula alba and Pezicula malicorticis. Infection generally occurs through lenticels. Thus, the decay is usually centred around lenticels. It is moderately firm, cream or tan-coloured, slightly sunken and round with brown borders. The surface of the rotten place is often covered with creamy-white spore masses. The diseases develop slowly in the fruit and do not become apparent until after the fruit has been stored for several months.

Captan at 0.2 percent and zineb at 0.3 per cent applied in the field can control these diseases (Borecka, 1968). Thiabendazole and benomyl at

300 ppm can give good control after harvest (Edney, 1970; Bompeix and Morgat, 1969).

(b) Bananas (Musa paradisiaca)

Black rot of bananas is caused by Thielaviopsis paradoxa (De Seynes) Von Hohn, the perfect ascomycetous stage of which is Ceratocystis paradoxa (Moreau) Dade. The fungus enters the bunches through the tips and butts of stalk. When the fruit is harvested infection of the green fruit is characterized by small black areas at the end of the fruit near the point of attachment to the cushion. When the infected green fruit is kept for ripening, high temperatures and relative humidities become conducive to black rot development. As the fruits turn yellow with ripening, the infected areas first turn brown and then black. The pulp is usually not invaded.

Severe infection may cause 10 - 25 per cent of the fruits to drop from the bunches during ripening and marketing (U.S. Dept. Agric. 1953; Wardlaw, 1961).

Srivastava and Tandon (1970) recorded a fruit rot caused by Botryodiplodia theobromae Pat. Infection occurs through the stem end or cushion. Symptoms of this disease start as water-soaked discolourations and proceed irregularly. The rotting of the pulp is faster than that of the rind. Under moist conditions, white or light-grey cottony mycelium covers the infected tissue. Pycnidial formation takes place rather late.

Banana anthracnose is caused by Colletotrichum musae. This fungus is capable of direct penetration. The fungus causes irregular brown sunken lesions over the surface of the fruit in storage.

Anthracnose and stem end rot caused by Botryodiplodia theobromae have been controlled by 400-1000 ppm thiabendazole (Allen, 1970) and 100-500 ppm benomyl (Frossard, 1969). These can also be controlled by hot water treatment (Burden, 1968). Thiophanate-methyl (NF 44) was also found to be effective (Frossard et al, 1973).

(c) Citrus Fruits (Oranges, Lemons and Tangerines)

The commonest moulds are green mould (Penicillium digitatum) and blue mould (Penicillium italicum). These fungi attack fruits through wounds after harvest. Infection begins as a water-soaked soft lesion, which later turns white as if covered with powder dust, as the fungus grows. As disease progresses, the infected area becomes green or blue depending on the species infecting, when the fungus sporulates.

Borax at 5 - 8 per cent concentrations and sodium carbonate at 3 - 5 per cent at 38-48^{o}C temperature, controlled both moulds (Allen, 1962; Eckert and Sommer, 1967). Also 500-1000 ppm benomyl controlled Penicillium, Diplodia and

Phomopsis decays of citrus fruits (Gutter, 1970, 1975; Brown and McCornack, 1970; Vanderweyen and Trogoff, 1969, 1973).

Stem end rot is caused by Botryodiplodia theobromae Pat. Infection occurs through the stem end or skin injury. The disease is characterized by softening of the rind and underlying pulp. In the advanced stages, the affected rind turns brown and in many cases infection reaches the blossom end.

Srivastava and Tandon (1969), found captan to be effective against Botryodiplodia theobromae from citrus and mango at 0.5 per cent and 1.0 per cent, respectively. Diatomaceous earth was used to vary the concentrations.

(d) Mangoes (Mangifera indica)

Botryodiplodia theobromae causes stem end rot of mangoes and 1 per cent captan can control the disease (Srivastava and Tandon, 1969).

Steyn et al (1975), isolated Pseudomonas mangiferae-indicae from black spots on mango fruit. Sarkar (1974), observed the black spots to occur at lenticels and concluded that they were the infection foci. Palaniswani et al (1975), found that this disease spread by contact.

Colletotrichum gloeosporioides (Penz.) Sacc. causing mango anthracnose is capable of direct penetration (Eckert, 1975). Infected mangoes appear brown and hardened.

Hot water treatment at 54°C for five minutes controlled mango anthracnose (Spalding and Reeder, 1972). Control can also be obtained with thiabendazole at 1000 ppm (Jacobs et al, 1973) and benomyl at 500 ppm (Sohi et al, 1975).

(e) Pawpaw (Carica papaya)

Fruit rot is caused by Rhizopus stolonifer. The organism can attack intact surface of ripe fruit although infection usually occurs through wounds. The symptoms of the disease are irregular, water-soaked lesions which enlarge and become covered by young (white) and old (dark brown) sporangiophores of the causal organism. The fruit then collapses within 4 to 5 days and produces a watery juice. The rotten fruits emit a foul odour.

The best temperature for disease development was found to be 30°C and no disease developed at 10°C (Tandon and Mishra, 1969).

Brodrick et. al. (1975), recommended hot water dips at 50°C for 5 minutes, followed by benomyl at room temperature for the control of Rhizopus stolonifer Colletotrichum gloeosporioides and Aschochyta sp. on pawpaw.

Colletotrichum gloeosporioides causing pawpaw anthracnose penetrates the fruit through injuries or natural openings (Eckert, 1975) unlike that of orange and mango. Generally, infection occurs at temperatures of 25-30°C when there is a high moisture content.

Control can be obtained with hot water treatment at 45-49°C and dithane M 45 (Tsai, 1971).

(f) Pears (Pyrus prunifolia)

Grey mould infection occurs often at the stem end, but may occur through skin breaks on any part of the fruit. It is caused by Botrytis cinerea. Spread of the disease is effected by the fungus growing from one fruit to another and can penetrate ordinary paper wrappers.

Rapid development of the disease occurs at temperatures between 20-25°C and the fungus will continue to produce usual decay at the usual cold storage temperature of 4°C.

Spread of the disease can be prevented by use of copper treated wrappers in boxes (U.S. Dept. Agric., 1953).

(g) Pineapples (Ananas comosus Merr.)

Fruit rot is caused by Botryodiplodia ananassae. Bhargava (1971), found that spore germination was best between 25°C and 30°C and it decreased with any increase or decrease in temperature. Maximum germination occurred between pH 5.5 and 6.5 and decreased with increased acidity or alkalinity.

(h) Plums (Prunus salicina)

Monilia fructicola causes brown rots in plums, peaches, apricots and cherries in transit, storage and marketing.

Brown rot first appears as small, circular, light-brown spots, which enlarge and bring about extensive decay in 24 hours at high temperatures and high relative humidities. Yellowish-grey masses of fungus develop on the surface.

Spray or dusts containing sulphur are used to control brown rot in the field and low temperatures are used in storage (U.S. Dept. Agric., 1953).

3. MATERIALS AND METHODS

A. Disease Survey

A survey on fruit diseases was carried out in the following main fruit markets in Nairobi: City Market; Retail Market; Westlands Fresh Vegetable Company; Westands In Greengrocers; and Westlands Greengrocers. The following questionnaire was prepared and distributed to fruit dealers who were required to answer specific questions:

Name of the dealer.....

Type of business.....

Market.....

Date.....

1. How much fruit do you buy?.....
2. When do you buy the fruits?.....
3. Where do you buy the fruit from?.....
4. Which part of the world do these fruits come from?.....
5. How is the fruit stored at the place you buy?.....
6. Do you have any storage facilities for the fruits?.....
7. How long do you store the fruits?.....
8. How much of the fruit do you manage to sell out of the stock which you buy?.....

9. What losses do you incur as a fruit seller?

.....

10. Do you have any complaints as to the quality of the fruits that you buy?.....

11. What solutions do you have as to the problems that you are facing?.....

12. Any other comments.....

Ten samples of each fruit were collected from each of these markets once a fortnight, and the samples taken to the laboratory for various studies.

Total fruit losses by weight were determined per annum and the losses in monetary terms calculated by using the formula: No. of kg x cost per kg.

B. Symptomatology

Typical symptoms of collected diseased samples were described. The symptoms were compared with those caused when healthy fruits were inoculated with the isolated organisms.

C. Identification of the Causal Agents

(a) Direct observation.

This was done by the use of hand lens and a binocular microscope for any fungal structures, such as spores, spore producing structures, outgrowth or eruption, which were then scraped, mounted in a drop of lactophenol cotton blue or

water on a slide and examined under the microscope.

(b) Sectioning.

Five sections of diseased material were cut with a sharp razor and examined under the microscope for any typical fungal structures. Identification of fungi was made by referring to books by Alexoupoulos (1952), Barnett and Barry (1972), Von Arx (1974) and Funder (1968). The samples were then sent to Commonwealth Mycological Institute for confirmation.

D. Pathogenicity Tests.-

Discs of infected fruit peel and pulp about 2 mm in size were disinfected with a 1:10 solution of sodium hypochlorite for 10 minutes, dried and then transferred aseptically on potato dextrose agar. A few of them were dipped and left to ooze in sterile distilled water for a few minutes. The ooze was then streaked aseptically on nutrient agar. The petri dishes were incubated at room temperature ($20^{o}C$). The pathogenicity of the organisms was confirmed by using Koch's postulates and by the injection infiltration method (Kiraly et al, 1970). Fruits were inoculated with the isolated fungi at the stem end, blossom end, intact surface and damaged surface. For bacteria, leaves of Nicotiana tabacuum were used for inoculations.

E. Physiological Studies.

Preparation of media

(i) Solid media[a]

The media were prepared by suspending the ingrediants in cold or boiled distilled water as the case may be, dissolving and sterilizing in the autoclave at 15 pound pressure for 15 minutes in case of malt extract agar, potato dextrose agar and corn meal agar and at 10 pounds pressure for 20 minutes in case of czapek-dox-agar. Pouring of media was done aseptically in 90 mm diameter petri-dishes, previously sterilized in the oven at 180°C for an hour and then allowed to cool.

(ii) Liquid media[b]

Two liquid media: Richard's solution and Czapek's solution were prepared. After dissolving the ingredients in distilled water, the media were dispensed in 50 ml quantities into flasks measuring 100, 150 and 250 ml, plugged with cotton wool and sterilized in the autoclave at 15 pounds pressure for 15 minutes.

Single spore isolations

A sparse spore-suspension was made in a universal bottle using sterile distilled water. A

(a) See appendix for the constituents.

(b) See appendix for the ingredients.

loopful of the suspension was streaked on a thin plate of 20 per cent water agar and incubated at 24°C. After 18 hours, germinating spores were located on the agar with the aid of an ordinary microscope. A single spore was selected and without moving the petri-dish the objective lens were lifted. While supporting the petri-dish by the left hand without changing its position, a cut was made around the flicker of light set on the agar from the microscope, with a straight, wire transfer needle. The block of agar, supposedly to carry the germinating spore was aseptically transferred onto potato dextrose agar and incubated at room temperature (20°C) as suggested in the CMI Plant Pathologist's Pocketbook (1972), with slight modifications because of the limited facilities.

The media prepared and the single-spore cultures were used for the following studies:-

(a) Effect of temperature on growth of fungi.

Discs of cultures 4 mm in diameter were cut from the edge of three-day old cultures and transferred to the centre of potato dextrose agar dishes. Four dishes were set per isolate per treatment and incubated at 4, 10, 25, 35°C and room temperature (20°C).

Radial growth of mycelia was determined with

a ruler every day for 8 days. Sporulation was also noted.

(b) Growth on solid media.

The effect of potato dextrose agar, malt extract agar, corn meal agar and czapek-dox-agar were observed on the radial growth of mycelia. The set up was as explained here, but the dishes were incubated at the optimum temperature for growth of each fungus. The radial growth was also determined in the same way.

(c) Growth on liquid media.

Fungal discs 4 mm in diameter were transferred into the flasks containing media and incubated at the optimum temperature for growth of each fungus. Twelve flasks were set for each fungus and sampled at 7-day interval for 21 days.

The mycelia were harvested on filter papers of known weights and dry weights were taken after drying in the oven at 60^{o}C till constant weights were obtained. The final constant weights were noted and the fungal weights obtained by substracting the filter paper weights from the total.

F. Disease development.

(a) Factors influencing Spore germination.

Spores of various fungi were spread on slides

in sterile distilled water and used for various investigations.

(i) Temperature.

Four slides were incubated at 4, 10, 25, 35°C and room temperature (20°C). A concentration of 15 - 35 spores was examined per microscopic field.

Data on spore germination was taken at 2 - 3 hour intervals up to 24 hours.

(ii) Relative humidity.

The relative humidities of 70, 80, 90 and 95 per cent were prepared by varying sulphuric acid concentrations in desicators. The volumetric method of Solomon (1951), was used for this experiment. Four slides with spores were incubated in desicators per treatment. One hundred per cent relative humidity was also used.

Data on spore germination was taken at every 2 - 3 hours for 24 hours.

(iii) pH.

Hydrogen ion concentration of 4.5, 5.0, 5.5, 6.0 and 6.5 were used for spore germination.

Spore suspensions were prepared in the above mentioned way. A drop of the spore suspension was placed on slides and kept in moist chambers at room temperature and data on spore germination taken after 24 hours.

(b) Factors influencing spoilage.

(i) Temperature.

Fresh fruits were disinfected in 1:10 sodium hypochlorite solution for 10 minutes and then inoculated with fungi by scalped injury. The fruits were then placed at 4, 10, 25, 35°C and room temperature (20°C).

Observations were made daily on the deterioration of fruits.

(ii) Relative humidity.

Inoculations were done in the same way as mentioned above, but the fruits were kept in desicators at 70, 80, 90, 95 and 100 per cent relative humidity.

Observations on spoilage were made daily for 14 days.

G. Disease Control.

Evaluation of fungicides:

Five fungicides were evaluated for their effectiveness on spore germination and mycelial growth. They were benomyl /50% methyl 1-(butylcarbamoyl) - 2-benzimidazole carbamate/; captan (65% N-trichloromethyl Thio - 4 - cyclohexane-1, 2-dicarboximide); zineb (80% zinc

ethylene-1, 2 bisdithiocarbamate); blitox (50% metallic copper); and dithane M-45 (80% co-ordination product of zinc ion manganese ethylene).

(a) Inhibition of spore germination.

The concentration of fungicides used was 500 ppm. The fungicides were also tried at 10, 50, 125, 750, 1000 and 1500 ppm. Slides in quadrilate replicates containing a drop of each fungicide and spore suspension were incubated at room temperature ($20^{\circ}C$) for 24 hours. Spores in sterile water on slides were kept as controls.

About 100 spores were observed in each replication and germination percentage was calculated. The percentage inhibition was calculated by using the formula given below:

$$100-\left(\frac{\text{Percentage germination in treatment}}{\text{Percentage germination in control}} \times 100\right)$$

(b) Inhibition of mycelial growth.

The fungicides were incorporated in sterilized potato dextrose agar to make final concentrations of 100, 200 and 500 ppm, before pouring.

Discs of inoculum about 4mm in diameter were cut from the edge of three day old growing cultures, then transfered on petri-dishes which were incubated at $22^{\circ}C$. Four petri-dishes were set per treatment. The controls were set on potato dextrose agar without incorporating the fungicides.

The diameters of the colonies were determined after three days. Inhibition of growth was taken as a measure of effectiveness of fungicides.

(c) The value of chemicals in fruit storage.

Six fresh fruits of each type were dipped in 0.1, 0.2 and 0.4 per cent solutions of borax, sodium hypochlorite, calcium hypochlorite (35% chlorine), sodium carbonate, captan and benomyl for 2 minutes. In the case of the controls, the fruits were dipped in distilled water for two minutes. The treated fruits were air-dried. Some were wrapped in polythene bags and kept at room temperature (20°C) in the laboratory and others were kept on clean trays under similar conditions.

Observations were made daily for 21 days for any signs of disease.

4. RESULTS

A. DISTRIBUTION AND EXTENT OF POSTHARVEST DISEASES OF FRUITS

A disease survey was carried out in 1978 and 1979 in five fruit markets of Nairobi. Fruit losses were directly proportional to the percentage of rot in the markets(Fig.1A)

Penicillium expansum and Pezicula sp. were observed to cause spoilage in apples. The former causes blue mould rot and the latter lenticular rot. Both diseases were found in the three Westlands markets surveyed, causing about nineteen per cent losses of apples. However, Penicillium expansum was more prevalent in the city market and caused 12 per cent fruit loss.

Botryodiploidia theobromae, Thielaviopsis paradoxa, Fusarium roseum, Colletotrichum musae and Rhizopus stolonifer caused stem end rot, black rot, anthracnose and fruit rot, respectively. All these diseases were noted mostly in the Retail market. Stem end rot and crown rot were the commonest, resulting in 23 per cent fruit loss. Anthracnose and fruit rot were observed more commonly in the City market, the latter being more prevalent and causing a loss of 12 per cent. They were also recorded in Westlands markets where they were causing about 10 per cent loss.

Table 1A: Weekly fruit losses in the surveyed Nairobi markets

Fruit	Average Weekly fruit losses in the markets[a]		
	Retail market	City Market	Westlands Market
Apples	Not sold in this market	12	19
Bananas	23	12	10
Lemons	50	50	20
Mangoes	12	13	12
Oranges	18	31	17
Pawpaws	15	44	32
Pears	--	--	--
Pineapples	12	25	8
Tangerines	25	20	15

a = Average of ten samples, each of a hundred fruits over a period of twenty weeks.

The pathogens of citrus fruits recorded were, Penicillium digitatum, Botryodiplodia theobromae and Colletotrichum gloeosporioides. These were responsible for causing green mould rot, stem end rot and anthracnose, respectively. All these diseases were common especially in the Retail market. The first two were noted to cause a loss of 18 per cent of oranges and 25 per cent of tangerines, while green mould alone caused a loss of 50 per cent of lemons. In the City market, green mould and anthracnose were observed as common diseases, where they were responsible for causing 31 per cent, 50 per cent, and 20 per cent losses of oranges, lemons and tangerines, respectively. Stem end rot and green mould also noted in the Westlands markets, resulted in 20 per cent loss of lemons, 15 percent loss of tangerines and 17 per cent of oranges.

Anthracnose, stem end rot, fruit rot and black spots of mangoes caused by Colletotrichum gloeosporioides, Botryodiplodia theobromae, Rhizopus stolonifer and Pseudomonas mangiferae - indicae, respectively were recorded in all the markets surveyed. Fruit rot was an uncommon disease and noted only in Westlands markets. Bacterial black spot and anthracnose were the most prevalent diseases of mango, resulting in approximately

12 per cent and 23 per cent losses.

The most common disease of pawpaw recorded were anthracnose, Rhizopus rot and fruit rot incited by Colletotrichum gloesporioides, Rhizopus stolonifer and Aspergillus niger respectively. These were observed mostly in Westlands markets. Rhizopus rot alone was responsible for causing 15 per cent loss in the Retail market, 44 per cent in the City market and about 32 per cent in the Westlands markets, respectively.

Only a single disease of pineapple, black rot caused by Thielaviopsis paradoxa was present in all markets. It was noted to cause 12 per cent fruit loss in the retail, 26 per cent in the City and 8 per cent in Westlands markets.

It is revealed from the above studies that the amount of damage and losses from postharvest fruit diseases varied greatly with the kinds of fruits, diseases and the storage conditions of the markets. All the fresh fruits brought into these markets, get spoilt quickly due to difective storage facilities.

B. Postharvest fruit losses in monetary terms.

Losses of fruits in terms of money were assessed by taking the number of rotten fruits out of the healthy ones per 100 fruits.

The incidence of apple rots was found to be 15 fruits out of 100 per week. The loss per annum

was $\frac{15}{6} \times \frac{366}{7}$ kg = 130.71 kg. Because the average cost of apples was Kshs. 25.00 per kg., the total loss in monetary value was found to be Kshs. 3,267.86 per annum.

This was calculated for other fruits on the same basis.

Incidence of banana rots was 14 fruits out of 100 per week. Total loss being 732 fruits per annum. On average a dozen fruits cost Kshs. 8.00. The total loss in monetary value was found to be Kshs. 488.00.

Incidence of lemon rots was 40 fruits out of 100 per week. Total fruit loss was 2,091 fruits per annum and on average 3 fruits cost Kshs. 1.00. The total loss in monetary value was Kshs. 697.00.

Incidence of orange rots was 21 fruits out of 100 per week. Total loss was 183.00 kg. per annum and total loss in monetary value was Kshs. 1,464.00 on the average oranges cost Kshs. 8.00 per kg.

Incidence of tangerine rots was 18 fruits out of 100 per week. Total loss was 117.64 kg. per annum. On average tangerines cost Kshs. 10.00 per kg. Thus total loss in monetary value was Kshs. 1,176.40.

Incidence of mango rots was 16 fruits out of 100 per week. Total loss was 209.14 kg. per annum. On average a kg of mango cost Kshs. 6.00. Therefore, total loss in monetary value was Kshs. 1,254.86.

Incidence of pawpaw rots was 32 fruits out of 100 per week. Total loss was estimated at 1,673.14 kg. per annum. Pawpaw cost Kshs. 3.00 per kg. The total loss in monetary value was Kshs. 5,019.43.

Incidence of pineapple rots was 16 fruits out of 100 per week. Total loss was 837 fruits per annum and each fruit cost Kshs. 5.00 on average. Total loss in monetary value was estimated at Kshs. 4,185.00.

Total loss in monetary value per individual market was therefore estimated at Kshs. 17,552.55 and for the five markets Kshs. 87,762.75 per annum.

C. ISOLATIONS

Organisms isolated from infected fruit samples on potato dextrose agar and their growth characteristics are given on Table - 1.

Table 1. Isolated organisms from collected fruit samples and their growth characteristics

Fruit	Isolate	Characteristics
Apples	*Penicillium expansum*	Mycelium white on culture, sporulates within 2 - 3 days, turning blue. Spores global in shape.
	Pezicula sp.	Mycelium grey at first, spores hyaline and oval in shape at first and darken with age.
	Alternaria sp.	Mycelium grows fast, showing concentric rings; spores have both vertical and horizontal septa.

Fruit	Isolate	Characteristics
Banana	Botryodiplodia theobromae	Mycelium grey, fluffy in growth. Mushroom-like pycnidia develop on the surface of the culture within 5 - 6 days. Dark, ovoid, aseptate spores ooze out. As the culture ages, pycnidia appear as open morning glory flowers, containing darker, single-septate spores, which no longer ooze.
	Fusarium roseum	Mycelium pinkish, fluffy in growth, spores septate with pointed ends.
	Colletotrichum musae	Mycelium white at first, turning pink within 4 - 5 days when acervuli develop and pink spores ooze out. Later acervuli turn brown with age and

		produce oval spores
	Rhizopus stolonifer	Mycelium grows fast on medium, sporulates within 2 - 3 days. The sporangia are white at first and then darken with age.
	Thielaviopsis paradoxa	Mycelium white at first quickily turning grey and then black within 5 - 6 days. Conidia of two kinds: endoconidia formed within cannon-shaped fertile hyphae, rectangular and hyaline and the second type produced acrogenously in short chains on short hyaline conidiophores.
Citrus Fruit	Penicillim digitatum	Mycelium white, turns green due to sporulation in 2 - 3 days; spores ovoid to global in shape and vary in size with age.

Fruit	Isolate	Characteristics
	Colletotrichum gloeosporioides	As described above for Colletotrichum musae.
	Fusarium sp.	Same as above.
	Botryodiplodia theobromae	As mentioned above.
Mangoes	Pestalotia sp.	Mycelium white; develops black pycnidia later, from which dark conidia with two appendages ooze out.
	Colletotrichum gloeosporioides	As described above.
	Botryodiplodia theobromae	As mentioned above.
	Rhizopus stolonifer	As described above.
	pseudomonas	Produces round yellow

Fruit	Isolate	Characteristics
	Pseudomonas mangiferae-indicae	colonies on nutrient agar at 25°C within 24 - 48 hours. The colonies are butyrous in consistency and dome-shaped.
Pawpaws	Aspergillus niger	Mycelium white at first and spores produced on straight vertical conidiophores which bear phialides on which conidia produced in chains. Later, appears black due to black globose spores.
	Stremphylium sp.	Mycelium grey in colour, grows fairly fast. Sporulates within 2 - 3 days. The spores are ovoid and have horizontal and vertical septa, which are uniformly distributed over the surface and appear to have obvious sectoring.

Fruit	Isolate	Characteristics
	Rhizopus stolonifer	As mentioned above.
	Colletotrichum gloeosporioides	As described above.
Pears	Not identifiable at first but later identified as *Phycomyces blacksleans*	Mycelium white, thick and failed to sporulate. Efforts to induce sporulation were unsuccessful.
Pineapples	*Penicillium* sp.	Mycelium white at first, turns green after sporulation.
	Thielaviopsis paradoxa	As described above.

D. PATHOGENICITY

Pathogenicities with the isolated organisms were done by using Koch's postulates or injection infiltration method using leaves of *Nicotiana tabacuum* in case of *Pseudomonas mangiferae - indicae*, which gave a hypersensitive reaction within 24 - 48 hours.

The isolates proved pathogenic on various healthy fruits tested and the inoculation methods which caused infection and disease development are given in Table - 2.

All the inoculation methods proved ideal for initiating the development of postharvest diseases in fruits. The scalpel injury method proved as the best among all the methods used, followed by the stem end then blossom end and intact surface, which were not different. In all the methods, the incubation period varied from 2 - 3 days, except in *Pezicula* sp., *Aspergillus niger*, *Penicillium expansum*, *Colletotrichum gloeosporioides* and *Pseudomonas mangiferae-indicae* which required about 6 - 7 days.

Table 2. Pathogenic organisms and their modes of infection.

Fruit	Pathogen	Inoculation methods*			
		Stem end	Blossom end	Intact surface	Scalpel injured surface
Apple	Penicillium expansum	+	-	-	+
	Pezicula sp.	-	-	-	+
Bananas	Thielaviopsis paradoxa	+	+	+	+
	Rhizopus stolonifer	-	-	-	+
	Botryodiplodia theobromae	+	+	+	+
	Colletotrichum musae	+	+	+	+
	Fusarium roseum	-	-	-	+
Citrus fruit	Penicillium digitatum	-	-	-	+
	Botryodiplodia theobromae	+	+	+	+
	Colletotrichum gloeosporioides	+	+	+	+
Mangoes	Colletotrichum gloeosporioides	+	+	+	+
	Rhizopus stolonifer	-	-	-	+
	Botryodiplodia theobromae	+	+	+	+
	Pseudomonas mangiferae-indicae	+	+	+	+
Pawpaws	Colletotrichum gloeosporioides	-	-	-	+
	Rhizopus stolonifer	+	+	+	+
	Aspergillus niger	-	-	-	+
Pineapples	Thielaviopsis paradoxa	+	+	+	+

* Average of three fruits in each of the four different inoculation methods.

+ Infection with subsequent disease development.

- No infection.

E. SYMPTOMATOLOGY

The disease symptoms of inoculated healthy fruits are described below:-

Apples

Blue mould is caused by Penicillim expansum. Initial symptoms appear as a water-soaked lesion around the point of infection. The infected tissue becomes soft, turns brown and later the rotten pulp turns brown. Few days later, a white growth of the fungus appears and within 5 - 7 days, depending on conditions, a large number of spores are produced. The surface of the fruit becomes bluish in colour (Fig. 1A). The disease was first described by Ramsey and Smith (1953).

Lenticular rot is incited by Pezicula sp. The symptoms of this disease appear similar to the blue mould described above, but it is moderately firm, differing significantly in advanced stages. A water-soaked lesion develops at the point of infection, usually centred around lenticels, which then becomes brown. As the disease advances, the inner part of the lesion becomes cream to light brown in colour surrounded by a dark brown margin, superficially appearing as a bull's eye (Fig. 1B). The rot was referred to as bull's eye rot by Ramsey and Smith, 1953. The same rot in the past was described to be caused by Gloeosporium

Fig. IA. An advanced stage of apple blue mould rot.

Fig. IB. Apple lenticular rot, 4 - 5 days after inoculation.

perennans (Pezicula malicorticis) and Gloeosporium album (Pezicula alba). The former was noted as the more pathogenic (Elke and Konstantinova, 1975). Spore formation appears late, giving the fruit a black appearance.

Bananas

Black rot of bananas is caused by Thielaviopsis paradoxa. The disease first appears in the market when the bananas are placed in wooden boxes to ripen. The infected areas first become brown with water-soaked borders and later turn black as the fungus sporulates (Fig. 2A). The pulp usually remains unaffected. The disease was described first as caused by Endoconidiophora paradoxa, the perfect stage of which was Ceratocystis paradoxa (U.S. Dept. Agric. 1953). Wardlaw (1961), named this as one of the blackhead diseases.

Fruit rot inicited by Rhizopus stolonifer, appears as irregular, water-soaked leasions, usually covered with a white mycelium. Later, the fungus produces sporangia which are white at first and then turn dark brown. The entire surface of the fruit becomes affected quickily and collapses within a few days, producing a watery-ooze and emitting a foul smell (Fig. 2B).

Banana stem end rot is caused by Botryodiplodia theobromae. The initial symptom of the disease appears as brownish discolouration at the stem end, which

Fig. 2A. Banana black rot. Advanced stages of the disease with the fruits collapsing.

Fig. 2B. Banana fruit rot, 3 - 4 days after inoculation.

proceeds irregularly. Few days later depending on conditions, the fruit becomes covered with grey cottony mycelium. Pycnidial formation takes place rather late when the rotten fruit assumes a brown to black colour. The fruit produces a watery ooze after a few days of infection (Fig. 2C).

Banana anthracnose which is incited by Colletotrichum musae is manifested by dark-brown sunken lesions on the surface of the fruit. Soon after, the lesions become covered with pink spores which on maturity become brown in colour. The rot does not progress very rapidly at first, but later covers the entire surface and the fruit loses its shape, later degenerates (Fig. 2D).

Crown rot is caused by Fusarium roseum. The infected surface becomes black and soft. Later, a pink fungal growth develops on the fruit, which degenerates and produces a watery ooze (Fig. 2E).

Citrus fruit

Stem end rot caused by Botryodiplodia theobromae first appears as brown lesion at the point of infection, followed by a fluffy growth of a white mycelium over the infected area. The rot spreads fairly regularly, but the fruit does not lose shape (Fig. 3A and 3B). Pycnidial formation occurs much later and the fruit acquires a darker appearance and produces a watery ooze.

Fig. 2C. Banana stem end rot. Advanced stages of the disease with the production of watery ooze.

Fig. 2D. Banana anthracnose, 4 - 5 days after inoculation.

Fig. 2E. Early stages of banana crown rot with pink fungal growth just showing up.

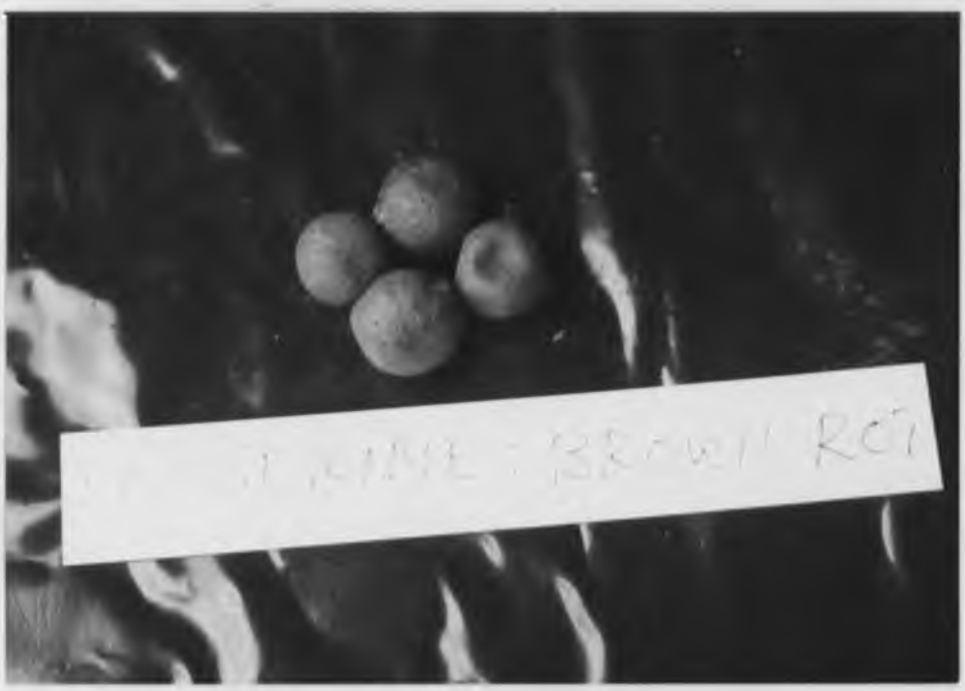

Fig. 3A. Tangerine stem end rot, 5 - 6 days after inoculation.

Fig. 3B. Dark pycnidia of orange stem end rot pathogen on the fruit surface during advanced stages of the disease.

Green mould of citrus fruits which is caused by Penicillium digitatum starts as a water-soaked lesion which develops at the point of infection. After 24 hours, a white growth of the fungus appears on the surface. The infected area becomes soft and within 2 - 3 days, the fungus sporulates abundantly. Later, the fruit acquires a greenish appearance when a large number of spores are produced (Fig. 3C, 3D and 3E).

Citrus anthracnose is caused by Colletotrichum gloeosporioides. The infected tissue becomes hard brown. The pulp also hardens and becomes brown. The disease does not progress very fast and usually hardening does not cover the entire fruit. (Fig. 3F and 3G).

Mangoes

Anthracnose is incited by Colletotrichum gloeosporioides. The infection occurs as sunken, brown and hard lesions, which are irregular in shape and spread fairly irregularly. The fruiting bodies of the fungus develop much later on the surface of the fruit. (Fig. 4A).

Stem end rot is caused by Botryodiplodia theobromae. The disease symptoms are similar to those of citrus stem end rot. (Fig. 4B).

Fruit rot is caused by Rhizopus stolonifer and the disease symptoms are similar to those for banana fruit rot (Fig. 4C).

Fig. 3C. Tangerine green mould 3 - 4 days after inoculation.

Fig. 3D. Lemon green mould, 2 days after inoculation.

Fig. 3E. Orange green mould, 3 to 4 days after inoculation.

Fig. 3F. Tangerine anthracnose, 5 to 6 days after inoculation.

Fig. 3G. Advanced stages of orange anthracnose when most of the fruit surface is infected.

Fig. 4A. Mango anthracnose, 3 to 4 days after inoculation.

Fig. 4B. Mango stem end rot, 5 days after inoculation.

Fig. 4C. Mango fruit rot, 3 - 4 days after inoculation.

Bacterial black spots that are incited by Pseudomonas mangiferae-indicae first appear as black spots on the surface of the fruit which progress regularly. When many such spots cover the fruit, it acquires a black appearance. (Fig. 4D).

Pawpaw

Anthracnose which is caused by Colletotrichum gloeosporioides has similar symptoms to those mentioned for mango anthracnose. (Fig. 5A).

Rhizopus stolonifer causes pawpaw rot with symptoms similar to those described for fruit rot of banana. (Fig. 5B).

Fruit rot incited by Aspergillus niger appears soft and later becomes covered with the black heads of the fungus. The infected fruit degenerates in a few days (Fig. 5C).

Pineapple

Black rot of pineapples is caused by Thielaviopsis paradoxa. The infected area becomes covered with fluffy growth of the fungus mycelium. Within 5 - 7 days, depending on conditions, the infected fruit produces a watery-ooze. The fruit however, does not lose its shape, unless crushed. (Fig. 6A).

Fig. 4D. Mango bacterial black spots,
4 - 5 days after inoculation.

Fig. 5A. Pawpaw anthracnose, 5 - 6 days after infection.

Fig. 5B. Pawpaw rot caused by Rhizopus stolonifer, 2 to 3 days after infection.

Fig. 5C. Early stages of pawpaw rot caused by Aspergillus niger.

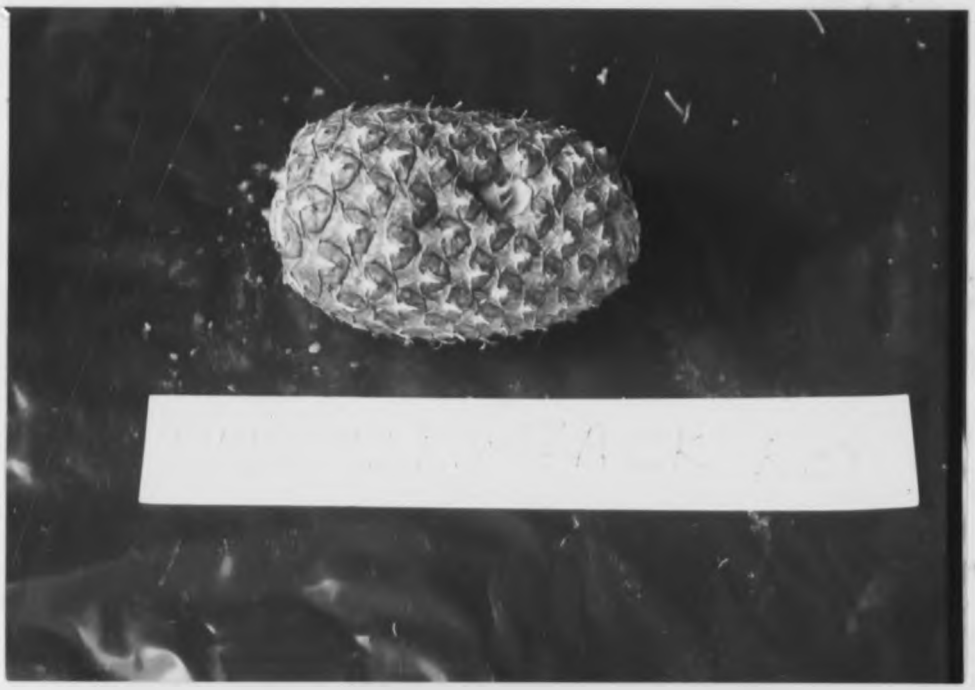

Fig. 6A. Black rot of pineapples, 2 days after infection.

F. PHYSIOLOGICAL STUDIES

(a) Effect of temperature on growth of fungi isolated from infected fruits.

Fungi were grown on potato dextrose agar and kept at temperatures 4 to 35°C. The radial growth of these fungi at different intervals of time are given below:-

Aspergillus niger

The fungus grew at a wide range of temperature (20 - 35)°C. the optimum being at 35°C. The maximum growth of 90 mm and abundant sporulation were noted at 35°C within 48 hours. Sporulation also occurred at 20 and 25°C within 96 hours with a radial growth of 36.5 and 42.5 mm, respectively. No growth and sporulation were observed at 4°C and 10°C (Fig. 1).

Botryodiplodia theobromae

Growth of this fungus was noted at 10 - 35°C. At 35°C, a maximum growth of 90 mm was obtained within 48 hours. Sporulation did not occur within eight days at 35°C, but was noted at room temperature within 6 to 7 days, with a radial growth of 90 mm (Fig. 2).

Colletotrichum gloeosporioides

The optimum temperature was 35°C, which was also favourable for sporulation observed within 48 hours. Sporulation also occured after 48 hours at 25°C and 96 hours at room temperature. No growth

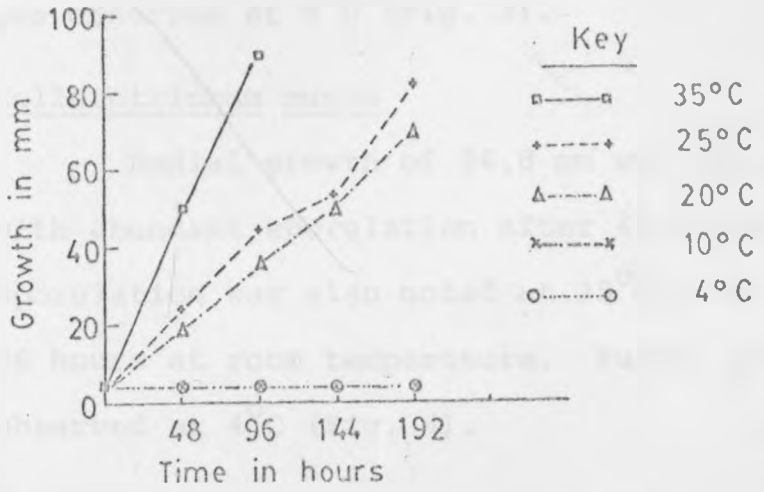

Fig.1. Radial growth of Aspergillus niger on potato dextrose agar at different temperatures.

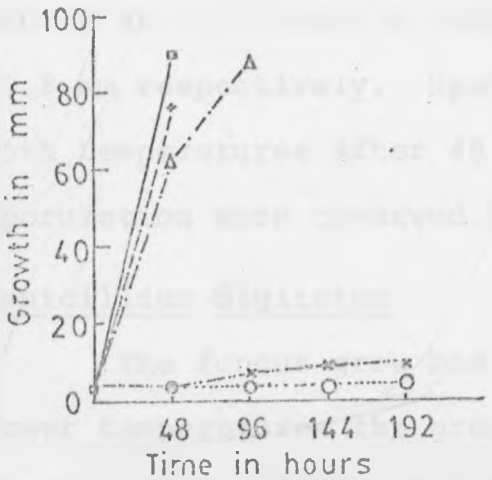

Fig.2. Radial growth of Botryodiplodia theobromae on potato dextrose agar at different temperatures

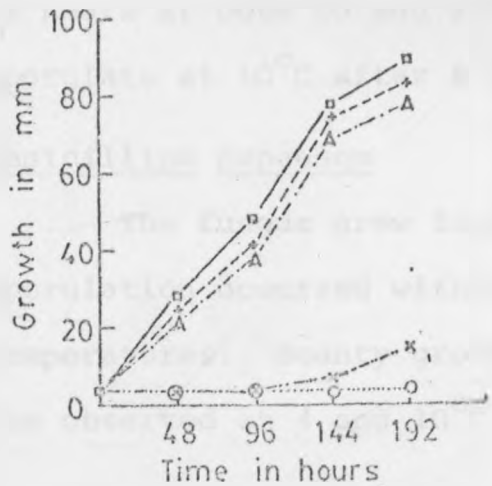

Fig.3. Radial growth of Colletotrichum gloeosporioides on potato dextrose agar at different temperatures

was observed at 4°C (Fig. 3).

Colletotrichum musae

Radial growth of 56.8 mm was observed at 35°C with abundant sporulation after 48 hours. Sporulation was also noted at 25°C after 48 hours and 96 hours at room temperature. Fungal growth was not observed at 4°C (Fig. 4).

Fusarium roseum

The fungus grew best at room temperature (20)°C and 25°C with a radial growth of 75.0 and 60.8 mm respectively. Sporulation was observed at both temperatures after 48 hours. No growth and sporulation were observed at 10°C or 35°C (Fig. 5).

Penicillium digitatum

The fungus grew best at 25°C. At higher or lower temperatures the growth rate decreased considerably. Thus, at 4 and 35°C no growth was observed. Although sporulation occurred after 96 hours at both 20 and 25°C, the fungus did not sporulate at 10°C after 8 days incubation (Fig. 6).

Penicillium expansum

The fungus grew faster at 20 and 25°C. Sporulation occurred within 48 hours at both temperatures. Scanty growth with no sporulation was observed at 4 and 10°C. Growth rate

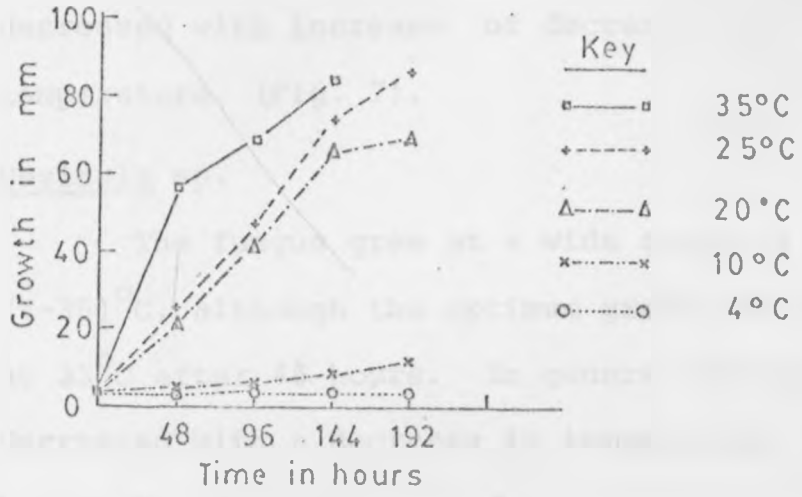

Fig. 4. Radial growth of Colletotrichum musae on potato dextrose agar at different temperatures

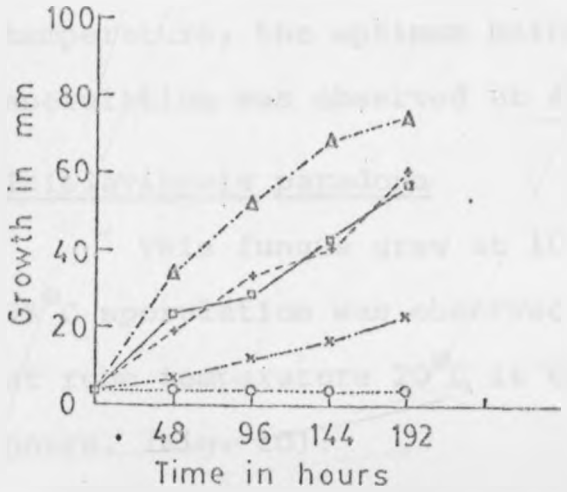

Fig. 5. Radial growth of Fusarium roseum on potato dextrose agar at different temperatures

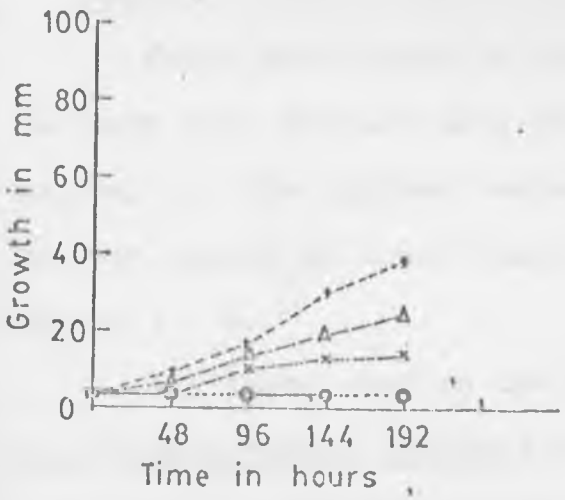

Fig. 6. Radial growth of Penicillium digitatum on potato dextrose agar at different temperatures

decreased with increase or decrease in temperature. (Fig. 7).

Pezicula sp.

The fungus grew at a wide range of temperature (4-35)^{o}C, although the optimum growth was observed at 35^{o}C after 48 hours. In general the growth decreased with a decrease in temperature. (Fig. 8).

Rhizopus stolonifer

The fungus grew over a wide range of temperature, the optimum being 25^{o}C. No growth and sporulation was observed at 4^{o}C. (Fig. 9).

Thielaviopsis paradoxa

This fungus grew at 10 to 35^{o}C. At 25 and 35^{o}C sporulation was observed after 48 hours, while at room temperature 20^{o}C it occurred after 96 hours. (Fig. 10).

(b) Growth of fungi isolated from fruits on solid media.

Fungi were grown on corn meal agar, czapek-dox-agar, malt extract agar and potato dextrose agar and kept at the optimum temperature for the fungus. Average growth of these fungi in mm is given in Tables 3 - 8.

All fungi grew on the four media. Apart from Thielaviopsis paradoxa which grew best on malt extract agar, Rhizopus stolonifer, which grew well on

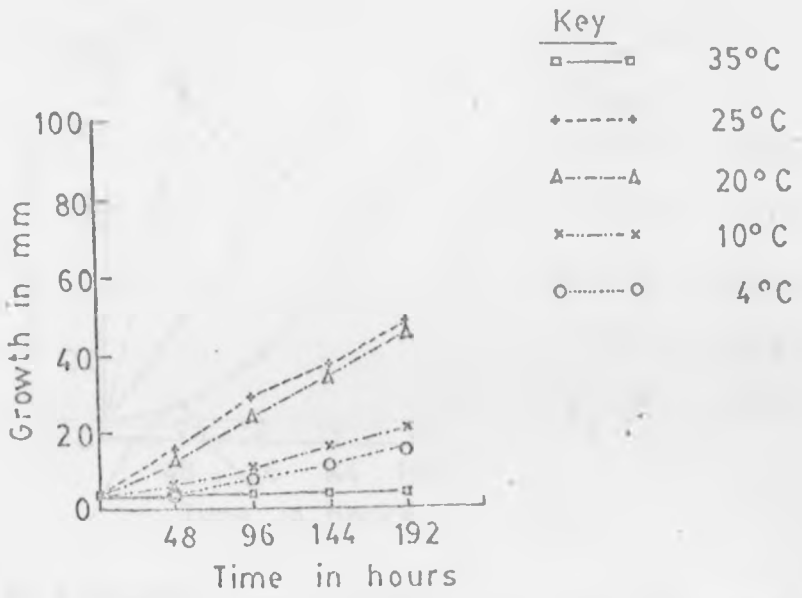

Fig. 7. Radial growth of Penicillium expansum on potato dextrose agar at different temperatures.

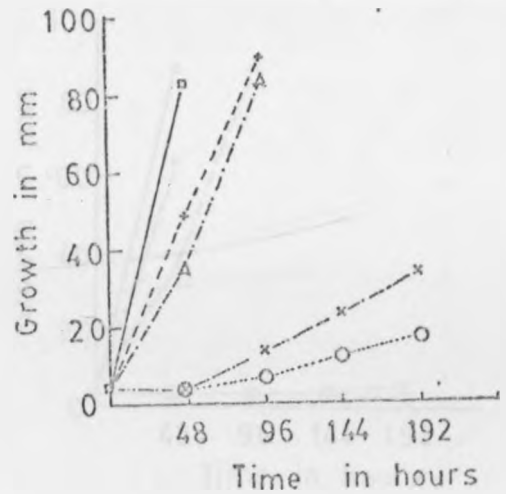

Fig. 8. Radial growth of Pezicula sp. on potato dextrose agar at different temperatures

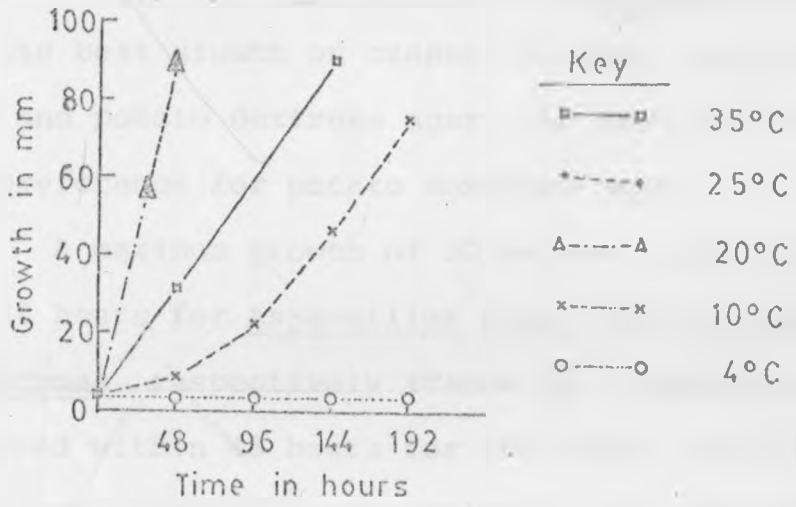

Fig. 9. Radial growth of Rhizopus stolonifer on potato dextrose agar at different temperatures

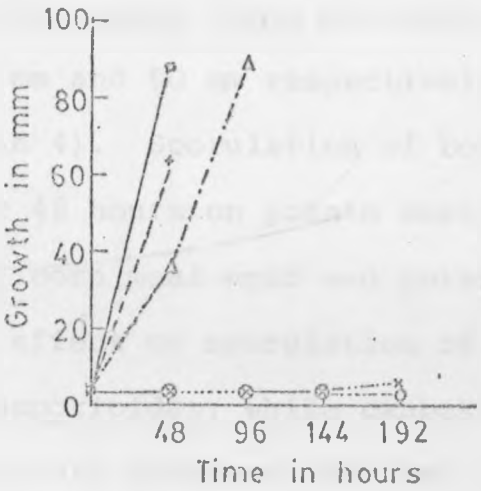

Fig.10. Radial growth of Thielaviopsis paradoxa on potato dextrose agar at different temperatures

corn meal agar, malt extract agar and potato dextrose agar and Botryodiplodia theobromae which had its best growth on czapek-dox-agar, malt extract agar and potato dextrose agar, the rest of the fungi had preference for potato dextrose agar.

A maximum growth of 90 mm was noted after 96 and 48 hours for Aspergillus niger and Botryodiplodia theobromae, respectively (Table 3). Sporulation occurred within 48 hours for the former on all the media and virtually no sporulation was observed on all the media for the latter after 196 hours.

Colletotrichum gloeosporioides and Colletotrichum musae attained a maximum growth of 89.3 mm and 90 mm respectively after 192 hours (Table 4). Sporulation of both fungi was observed after 48 hours on potato dextrose agar. Malt extract agar, corn meal agar and potato dextrose agar had the same effect on sporulation of Colletotrichum gloeosporioides, while czapek-dox-agar, corn meal agar and potato dextrose agar had similar effect on sporulation of Colletotrichum musae.

A maximum growth of 90 mm was noted on potato dextrose agar after 96 hours for Pezicula sp., while Thielaviopsis paradoxa attained a maximum growth of 90 mm after 48 hours on malt extract agar. (Table 5). Sporulation was only noted on malt extract agar after 192 hours for the former and after 48 hours on potato dextrose agar and malt extract

Table 3. Radial growth in mm of Aspergillus niger and Botryodiplodia theobromae in solid media at 35°C.

Medium	Average radial growth in mm after hours[a]							
	48		96		144		196	
	X	Y	X	Y	X	Y	X	Y
Corn meal agar	31.3	75.8	45.5	90.0	65.8	90.0	85.8	90.0
Czapek-dox agar	33.3	90.0	47.5	90.0	65.5	90.0	82.3	90.0
Malt extract agar	41.8	90.0	90.0	90.0	90.0	90.0	90.0	90.0
Potato dextrose agar	51.8	90.0	90.0	90.0	90.0	90.0	90.0	90.0

a = Average of four petri dishes per treatment

X = Aspergillus niger

Y = Botryodiplodia theobromae

No further statistical analysis was carried out due to insufficient data.

Table 4. Radial growth in mm of Colletotrichum gloeosporiodides and Colletotrichum musae on solid media at 35°C.

Medium	Average radial growth in mm after hours[a]							
	48		96		144		192	
	X	Y	X	Y	X	Y	X	X
Corn meal agar	16.8	35.0	22.5	41.8	29.5	56.5	35.8	64.8
Czapek-dox-agar	34.5	45.8	49.0	56.8	73.0	63.0	85.5	85.0
Malt extract agar	29.3	57.5	38.0	68.3	61.0	80.3	84.5	87.5
Potato dextrose agar	27.8	56.8	49.3	69.5	59.3	84.5	89.3	90.0

a = Average of four petri dishes per treatment

X = Colletotrichum gloeosporioides

Y = Colletotrichum musae

No further statistical analysis was carried out due to insufficent data

Table 5. Radial growth in mm of Pezicula sp. and Thielaviopsis paradoxa on solid media at 35°C.

Medium	Average radial growth in mm after hours[a]							
	48		96		144		192	
	X	Y	X	Y	X	Y	X	Y
Corn meal agar	44.0	60.8	54.3	63.0	64.2	64.8	74.0	67.8
Czapek-dox agar	22.5	82.8	49.5	88.5	68.0	90.0	78.5	90.0
Malt extract agar	40.0	90.0	69.5	90.0	70.8	90.0	74.8	90.0
Potato dextrose agar	83.8	88.3	90.0	90.0	90.0	90.0	90.0	90.0

a = Average of four petri dishes per treatment

X = Pezicula sp.

Y = Thielaviopsis paradoxa

No further statistical analysis was carried out due to insufficient data.

agar for the latter.

Corn meal agar, malt extract agar and potato dextrose agar had the same effect on the growth of Rhizopus stolonifer, which attained a maximum growth of 90 mm within 48 hours (Table 6). Sporulation was also favoured by both these media on which it was noted after 48 hours as compared to 96 hours on czapek-dox-agar and no sporulation on corn meal agar after 192 hours. Growth on czapek-dox-agar occurred in patches.

Growth of Penicillium digitatum and Penicillium expansum was 38.3 and 47.5 mm on potato dextrose agar after 192 hours (Table 7). Sporulation was observed on the four media, occurring after 96 hours on malt extract agar and potato dextrose agar for the former, while for the latter it was observed after 48 and 96 hours on malt extract agar and potato dextrose agar, respectively and no sporulation on czapek-dox- agar or corn meal agar.

A maximum growth of 75mm was noted after 192 hours on potato dextrose agar for Fusarium roseum (Table 8). Sporulation was noted on potato dextrose and czapek-dox-agar after 48 hours and after 96 hours on corn meal and malt extract agar.

Table 6. Radial growth in mm of Rhizopus stolonifer on solid media at 35°C.

Medium	Average radial growth in mm after hours[a]			
	48	96	144	192
Corn meal agar	90.0	90.0	90.0	90.0
Czapek-dox-agar	79.5	90.0	90.0	90.0
Malt extract agar	90.0	90.0	90.0	90.0
Potato dextrose agar	90.0	90.0	90.0	90.0

a = Average of four petri dishes per treatment.

No further statistical analysis was carried out because of insufficient data.

Table 7. Radial growth in mm of Penicillium digitatum and Penicillium expansum on solid media at 25°C.

Medium	Average radial growth in mm after hours[a]							
	48		96		144		192	
	X	Y	X	Y	X	Y	X	Y
Corn meal agar	7.0	10.5	14.3	15.0	15.5	16.3	21.5	18.3
Czapek-dox-agar	4.0	9.5	8.3	23.0	18.8	34.5	22.3	43.3
Malt extract agar	9.5	10.0	20.3	21.5	21.3	22.0	32.0	23.5
Potato dextrose agar	9.0	13.0	16.3	29.3	30.0	37.5	38.3	47.5

a = Average of four petri dishes per treatment

X = Penicillium digitatum

Y = Penicillium expansum

No further statistical analysis was carried out because of insufficient data.

Table 8. Radial growth in mm of Fusarium roseum on solid media at room temperature 20°C.

Medium	Average radial growth in mm after hours[a]			
	48	96	144	192
Corn meal agar	14.0	23.7	34.0	43.7
Czapek-dox-agar	28.0	61.3	68.0	72.5
Malt extract agar	6.0	10.7	18.0	27.0
Potato dextrose agar	34.0	52.3	69.8	75.0

a = Average of four petri dishes per treatment

No further statistical analysis was carried out because of insufficient data.

C. Growth of fungi isolated from fruits on liquid media.

The optimum temperature of each fungus was used. The results are given on tables 9 to 11.

Growth of all the fungi was observed in both media. However, the fungi on Table 9 and *Fusarium roseum* (Table 11), had their optimum growth in Richard's solution, while those on Table 10, had their optimum growth in Czapek's solution.

The initial growth of the fungi on Table 10 is greater in Richard's solution and that of *Fusarium roseum* (Table 11) is greater in Czapek's solution.

Table 9. Dry weight of mycelia of six different fungi in two liquid media at 35°C.

Fungus	Medium	Dry weight of mycelium in mg after days[b]		
		7	14	21
Aspergillus	Czapek's solution	250.0	700.0	750.0
niger	Richard's solution	510.0	1008.0	1100.0
Botryodiplodia	Czapek's solution	80.0	210.0	250.0
theobromae	Richard's solution	90.0	160.0	260.0
Colletotrichum	Czapek's solution	40.0	60.0	130.0
glocosporioides	Richard's solution	170.0	450.0	520.0
Colletotrichum	Czapek's solution	120.0	200.0	230.0
musae	Richard's solution	230.0	690.0	710.0
Pezicula sp.	Czapek's solution	40.0	120.0	150.0
	Richard's solution	100.0	250.0	330.0
Thielaviopsis	Czapek's solution	50.0	60.0	120.0
paradoxa	Richard's solution	80.0	170.0	220.0

b = Average of four flasks in each treatment.

Table 10. Dry weight of mycelia of three fungi in two liquid media at 25°C.

Fungus	Medium	Dry weight of mycelium in mg after days[b]		
		7	14	21
Penicillium digitatum	Czapek's solution	90.0	150.0	370.0
	Richard's solution	180.0	250.0	350.0
Penicillium expansum	Czapek's solution	250.0	310.0	580.0
	Richard's solution	380.0	440.0	460.0
Rhizopus stolonifer	Czapek's solution	180.0	340.0	430.0
	Richard's solution	220.0	270.0	320.0

b = Average of four flasks in each treatment.

Table 11. Dry weight of mycelium of Fusarium roseum in two liquid media at room temperature 20°C

Medium	Dry weight of mycelium in mg after days[b]		
	7	14	21
Czapek's solution	40.0	70.0	180.0
Richard's solution	25.0	510.0	560.0

b = Average of four flasks in each treatment.

G. DISEASE DEVELOPMENT

The factors influencing spore germination and disease development, like relative humidity, temperature and pH were considered in this investigation.

(a) Factors influencing spore germination.

All the fungi isolated from various fruits preferred a relative humidity of 90 and above for germination. Maximum germination of spores was observed in 100 per cent relative humidity for Colletotrichum musae, Fusarium roseum and Thielaviopsis paradoxa. Rhizopus stolonifer required (90-100) per cent relative humidity for germination, whereas Penicillium expansum, Penicillium digitatum, Colletotrichum gloeosporioides, Botryodiplodia theobromae and Aspergillus niger needed (95-100) per cent relative humidity.

Armolik and Dickson (1956); Bonner (1948) and Groom and Panisset (1933) have shown that the genera Aspergillus and Penicillium germinate at relative humidities near 80 per cent. The differences in results could be attributed to the techniques used in spore germination experiments and also the fungal species. However, the suggestion that a large group of fungi including Fusarium sp. and Colletotrichum sp. germinate at humidities of 90 - 95 per cent (Chowdhury, 1937), is in agreement with these findings.

Percentage germination of these fungi decreased with decrease in relative humidity and in some fungi like Rhizopus stolonifer, Botryodiplodia theobromae and Penicillium expansum, the minimum time required for germination increased with decrease in relative humidity. However, with Colletotrichum gloeosporioides, Aspergillus niger and Penicillium digitatum such effect was not observed (Table 12).

The figures in Table 13 reveal that the spores of Colletotrichum gloeosporioides, colletotrichum musae, Fusarium roseum and Pezicula sp. preferred a pH of 6.5 for maximum germination, whereas Aspergillus niger, Penicillium digitatum, Penicillium expansum and Thielaviopsis paradoxa all need a pH of 5.5 for maximum germination. Rhizopus stolonifer gave maximum germination of pH 6.0. The spores of Botryodiplodia theobromae did not germinate at all at any of these pH ranges. This may be due to some inhibitory factor in the buffer solution used for germination. However, this fungus germinated well in distilled water at pH 7.0.

It has been suggested that spores of most fungi germinate best at pH 4.5 and 6.5 with limits at about pH 3 and pH 8 (Cochrane, 1958) whereas this also applies to Colletotrichum musae and Penicillium expansum, it does not apply to most of the fungi considered.

Table 12. Effect of relative humidity on percentage germination of spores of 10 fungi isolated from fruits at 25°C.

Fungus	Relative humidity	Per cent germination after hours[c]											
		2	4	6	8	10	12	14	16	18	20	22	24
Aspergillus niger	100	4.76	17.35	34.89	58.14	68.13	84.76	96.03	97.74	98.63	98.63	98.63	98.63
	95	5.13	21.78	39.14	60.81	74.89	94.76	97.63	97.63	97.63	97.63	97.63	97.63
Botryodiplodia theobromae	100	9.38	27.81	43.75	58.35	69.38	78.75	83.75	95.31	96.83	97.09	97.09	97.09
	95	0	0	8.33	14.71	26.81	31.43	38.33	45.00	70.00	78.33	78.33	78.33
Colletotrichum gloeosporioides	100	0	0	0	0	10.45	31.35	45.98	67.16	67.16	67.16	67.16	67.16
	95	0	0	0	0	2.30	29.86	32.30	63.52	63.52	63.52	63.52	63.52
Colletotrichum musae	100	0	0	0	0	4.30	6.13	24.73	33.33	39.78	41.94	48.39	52.69
Fusarium roseum	100	0	0	0	0	0	0	9.59	41.13	52.09	78.05	81.25	86.30
Penicillium digitatum	100	0	0	0	0	0	7.45	13.65	20.08	32.67	48.94	69.15	73.40
	95	0	0	0	0	0	2.70	10.04	17.17	22.60	28.65	29.73	31.35
Penicillium expansum	100	0	0	0	0	0	[illegible]	9.53	13.43	28.97	36.43	40.01	48.57
	95	0	0	0	0	0	0	6.09	10.13	25.67	31.55	38.71	43.70
Pezicula sp.	100	0	0	0	0	6.06	39.39	67.70	79.05	82.35	90.14	90.14	90.14
Rhizopus stolonifer	100	13.04	46.78	63.45	89.58	94.79	95.83	98.11	98.11	98.11	98.11	98.11	98.11
	95	8.35	17.15	35.04	43.84	47.95	50.68	53.28	53.28	53.28	53.28	53.28	53.28
	90	0	0	0	0	2.28	6.34	12.25	15.19	15.19	15.19	15.19	15.19
Thielaviopsis paradoxa	100	4.56	8.34	10.48	92.74	92.74	92.74	92.74	92.74	92.74	92.74	92.74	92.74

c = Average of four slides; 15-35 spores per slide.

No further statistical analysis could be conducted due to lack of adequate data.

Table 13. Effect of pH on percentage germination of spore of 10 fungi at room temperature 20°C.

pH	Per cent germination of spores after 24 hours[c]									
	Aspergillius niger	Botryodiplodia theobromae	Colletotrichum gloeosporioi-des	Colletotrichum musae	Fusanium roseum	Penicillium digitatum	Penicillium expnasum	Pezicula sp.	Rhizopus stoloni-fer	Thielavi-opsis paradoxa
6.5	0	0	26.67	20.00	28.81	0	17.14	7.32	4.55	0
6.0	2.86	0	15.79	13.24	21.78	0	50.00	0	15.31	0
5.5	5.83	0	12.50	8.18	8.22	2.86	68.84	0	2.86	5.71
5.0	0	0	11.11	6.40	9.09	0	54.29	0	0	5.26
4.5	0	0	0	6.35	0	0	54.29	0	0	0

c = Average of four slides; 15 - 35 spores per slide.

No further statistical analysis could be conducted due to lack of adequate data.

All the fungi needed 20 - 35°C temperature, except Penicillium digitatum that required 25°C and room temperature (20)°C for the germination of spores. Although the spores of Colletotrichum musae and Rhizopus stolonifer germinated at 10°C, no germination was recorded at 4°C for any of the fungi. For the fungi studied here, the optimum temperature for germination in most of the fungi lay between 20 and 25°C. Increase or decrease in temperature from the optimum led to a decrease in percentage germination. Togash (1949), also found that the optimum temperature for spore germination was generally between 20 and 30°C. Spores germination at temperatures too low for growth has been reported in Rhizopus sp. (Weimer and Hartar, 1923). This is not the case with the findings of the present investigation, because the lowest temperature for both spore germination and growth for Rhizopus stolonifer was found to be 10°C. Harvey et al. (1972), also found that this fungus will not grow nor will the spores germinate at temperatures below 7.5°C.

Botryodiplodia theobromae, Colletotrichum musae, Penicillium digitatum, Penicillium expansum, Pezicula sp., Rhizopus stolonifer and Thielaviopsis paradoxa had their minimum time required before germination increased with either a decrease or increase in temperature. However, this

did not have such effect on Aspergillus niger, Fusarium roseum or Colletotrichum gloeosporioides. (Table 14).

All the fungi needed 20 - 35°C of temperature, except Penicillium digitatum that required 25°C and room temperature (20°C) for spore germination. Although the spores of Colletotrichum musae and Rhizopus stolonifer germinated at 10°C, no germination was recorded at 4°C for any of the fungi.

The optimum temperature for germination of the fungi was found to lie between 20 and 25°C. Increase or decrease in temperature from the optimum led to a decrease in percentage of germination.

Botryodiplodia theobromae, Colletotrichum musae, Penicillium digitatum, Penicillium expansum, Pezicula sp., Rhizopus stolonifer and Thielaviopsis paradoxa had the minimum time required before germination increased with either a decrease or increase in temperature. However, such increase or decrease did not have such an effect on Aspergillus niger, Fusarium roseum or Colletotrichum gloeosporioides.

(b) Effect of temperature and relative humidity on spoilage of fruits by postharvest pathogens.

Fruits inoculated with pathogens were incubated at different temperatures and relative humidities. Observations on fruit spoilage were

Table 14. Effect of temperature on percentage germination of spores of 10 fungi.

Fungus	Temperature °C	Per cent germination after hours[c]											
		2	4	6	8	10	12	14	16	18	20	22	24
Aspergillus niger	35	10.53	23.51	38.34	49.75	60.05	70.53	85.09	85.09	85.09	92.11	92.11	92.11
	25	9.40	28.42	40.01	58.35	67.07	79.40	96.58	96.58	96.58	96.58	96.58	96.58
	Rm(20)	8.26	25.33	39.98	54.41	65.68	78.26	93.58	93.58	93.58	93.58	93.58	93.58
Botryodiplodia theobromae	35	0	0	0	0	0	0	0	10.00	13.53	16.17	25.48	33.33.
	25	0	13.11	29.51	29.51	50.82	52.14	55.56	57.38	57.38	57.38	57.38	57.38
	Rm(20)	0	17.65	41.18	47.06	51.37	56.88	64.06	64.06	64.06	64.06	64.06	64.06
Colletotrichum gloeosporioides	35	0	0	0	0	7.56	14.29	42.86	42.86	42.86	42.86	42.86	42.86
	25	0	0	0	0	6.00	10.00	47.81	90.00	90.00	90.00	90.00	90.00
	Rm(20)	0	0	0	0	6.90	17.24	50.46	91.38	91.38	91.38	91.38	91.38
Colletotrichum musae	35	0	0	0	0	2.97	3.96	6.93	6.93	6.93	6.93	6.93	6.93
	25	0	11.54	21.15	45.34	50.09	63.53	80.77	80.77	80.77	80.77	80.77	80.77
	Rm(20)	0	4.81	14.42	22.12	25.75	37.03	44.23	44.23	44.23	44.23	44.23	44.23
	10	0	0	0	0	0	0	2.86	2.86	2.86	2.86	2.86	2.86
Fusarium roseum	35	0	0	0	0	0	2.33	4.11	6.45	7.75	22.34	35.89	40.31
	25	0	0	0	0	0	11.59	16.81	20.33	26.09	46.38	50.48	56.52
	Rm(20)	0	0	0	0	0	8.24	11.45	17.36	22.35	44.71	43.89	52.94
Penicillium digitatum	25	0	0	0	0	11.93	13.76	23.89	39.03	47.33	51.38	55.05	61.47
	Rm(20)	0	0	0	0	0	4.55	10.35	15.53	21.82	36.36	57.27	65.45
Penicillium expansum	35	0	0	0	0	0	0	0	0	0	0	0	4.29
	25	0	0	0	0	0	0	0	0	2.86	7.28	11.39	14.29
	RM(20)	0	0	0	0	0	0	0	0	0	2.45	4.55	6.40
Pezicula sp.	35	0	0	0	0	0	8.11	8.11	8.11	8.11	8.11	8.11	8.11
	25	0	0	0	0	12.05	67.47	78.15	90.36	90.36	90.36	90.36	90.36
	Rm(20)	0	0	0	0	7.59	70.89	76.24	88.61	88.61	88.61	88.61	88.61
Rhizopus stolonifer	35	0	0	0	0	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23
	25	15.18	38.09	56.15	82.35	82.35	91.76	94.12	94.12	94.12	94.12	94.12	94.12
	Rm(20)	2.86	9.08	18.21	25.00	81.00	92.00	92.00	92.00	92.00	92.00	92.00	92.00
	10	0	0	0	0	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
Thielaviopsis paradoxa	35	0	0	0	0	0	0	2.86	2.86	2.86	2.86	2.86	2.86
	25	6.97	15.37	29.81	35.40	98.26	98.26	98.26	98.26	98.26	98.26	98.26	98.26
	Rm(20)	9.79	24.45	33.51	48.10	93.67	93.67	93.67	93.67	93.67	93.67	93.67	93.67

c = Average of four slides; 15 - 35 spores per slide.

No further statistical analysis could be conducted due to lack of adequate data.

made and the results are given on Table 15 and 16.

Most of the pathogens developed on fresh fruits at 25°C and room temperature (20)°C within 4 – 6 days. No infection was observed at 4°C and at 10°C, Thielaviopsis paradoxa, Botryodiplodia theobroae, Colletotrichum musae, Colletotrichum gloeosporioides, Aspergillus niger and Pseudomonas mangiferae-indicae could not cause spoilage immediately. Fungi, such as Pezicula sp., Rhizopus stolonifer and Fusarium roseum infected their respective hosts at temperatures between 10°C and 25°C. Penicillium expansum, Penicillium digitatum and Pseudomonas mangiferae-indicae could not attack fruits at 35°C (Table 15).

An increase in the incubation period with decrease in temperature was noted with Penicillium expansum, Botryodiplodia theobromae, Pezicula sp. Thielaviopsis paradoxa, Colletotrichum musae, Fusarium roseum, Penicillium digitatum, Aspergillus niger and Pseudomonas mangiferae-indicae, while Rhizopus stolonifer and Colletotrichum gloeosporioides were unaffected.

All the pathogens were able to infect fresh fruits at relative humidities between 70 and 100 per cent, except Rhizopus stolonifer and Pseudomonas mangiferae-indicae which could not attack fruits at 70 to 80 per cent relative humidities (Table 16).

Table 15. The effect of temperature on postharvest infection and disease development on fresh fruits.

Fruit	Pathogen	Infection and disease development at different temperatures and incubation periods after days[a]														
		4			10			Room (20)			25			35		
		1-3	4-6	7-10	1-3	4-6	7-10	1-3	4-6	7-10	1-3	4-6	7-10	1-3	4-6	7-10
Apples	Penicillium expansum	-	-	-			+		+			+		-	-	-
	Pezicula sp.	-	-	-			+	+			+			+		
Bananas	Rhizopus stolonifer	-	-	-		+			+			+			+	
	Botryodiplodia theobromae	-	-	-	-	-	-			+	+			+		
	Thielaviopsis paradoxa	-	-	-	-	-	-		+		+			+		
	Colletotrichum musae	-	-	-	-	-	-		+		+			+		
	Fusarium roseum	-	-	-			+		+		+			+		
Citrus Fruits	Penicillium digitatum	-	-	-			+	+			+			-	-	-
	Botryodiplodia theobromae	-	-	-	-	-	-			+		+			+	
	Colletotrichum gloeosporioides	-	-	-	-	-	-			+			+			+
Mangoes	Rhizopus stolonifer	-	-	-		+			+			+			+	
	Colletotrichum gloeosporioides	-	-	-	-	-	-			+			+			+
	Botryodiplodia theobromae	-	-	-	-	-	-			+		+			+	
	Pseudomonas mangiferae-indicae	-	-	-	-	-	-			+	+			-	-	-
Pawpaw	Colletotrichum gloeosporioides	-	-	-	-	-	-			+			+			+
	Rhizopus stolonifer	-	-	-		+			+			+			+	
	Aspergillus niger	-	-	-	-	-	-		+		+				+	
Pineapple	Thielaviopsis paradoxa	-	-	-	-	-	-		+		+				+	

a = An average of two fruits inoculated per treatment.

+ = Infection with subsequent disease development.

- = No infection.

Table 16. The effect of relative humidity on postharvest infection and disease development on fresh fruits.

Fruit	Pathogen	Infection and disease development at different relative humidities and incubation periods after days[a]											
		70			80			90			100		
		1-3	4-6	7-10	1-3	4-6	7-10	1-3	4-6	7-10	1-3	4-6	7-10
Apples	Penicillum expansum			+		+			+			+	
	Pezicula sp.		+		+			+			+		
Bananas	Thielaviopsis paradoxa			+			+			+			+
	Rhizopus stolonifer	-	-	-	-	-	-		+			+	
	Botryodiplodia theobromae	+			+			+			+		
	Colletotrichum musae	+			+			+			+		
	Fusarium roseum			+			+			+			+
Citrus Fruits	Penicillium digitatum	+			+			+			+		
	Botryodiplodia theobromae	+			+			+			+		
	Colletotrichum gloeosporioides			+			+			+			+
Mangoes	Colletotrichum gloeosporioides			+			+			+			+
	Botryodiplodia theobromae	+			+			+			+		
	Rhizopus stolonifer	-	-	-	-	-	-		+			+	
	Pseudomonas mangiferae-indicae	-	-	-	-	-	-			+			+
Pawpaws	Colletotrichum gloeosporioides			+			+			+			+
	Rhizopus stolonifer	-	-	-	-	-	-		+			+	
	Aspergillus niger		+			+			+			+	
Pineapples	Thielaviopsis paradoxa	+			+			+			+		

a = An average of two fruits inoculated per treatment.

+ = Infection with subsequent disease development.

- = No infection.

The incubation period increased with decrease in relative humidity for Penicillium expansum and Pezicula sp., while the rest were unaffected, the incubation period being constant at all relative humidities. The incubation period of Thielaviopsis paradoxa was 1 - 3 days on pineapple and 7 - 10 days on bananas.

It has also been suggested by Eckert (975), that storage of fruits in an atmosphere of greater than 90 per cent relative humidity favours the development of postharvest diseases by maintaining injuries on fruits in a moist condition. This permits the development of pathogenic fungi. Recommended relative humidities for the storage of most fruits are therefore, in the range of 85 to 95 per cent (Lipton and Harvey, 1977; Lutz and Hardenburg, 1968).

H. DISEASE CONTROL

(a) Inhibition of spore germination.

The effect of benlate, dithane M 45, blitox, zineb and captan on spore germination of ten fungi was evaluated by the slide germination method at room temperature (20) ^{o}C. These fungicides were also incorporated in potato dextrose agar to determine their effect on mycelial growth.

The percentage inhibition at 500 ppm concentration of test fungicides and their relative inhibition were calculated after 24 hours. The data are presented on Table 17.

Benlate and captan gave 100 per cent inhibition against Aspergillus niger, while dithane M 45 gave the least, 76.97. Captan and dithane M 45 provided 100 per cent spore inhibition against Botryodiplodia theobromae, while 100 per cent inhibition against Colletotrichum gloeosporioides was given by benlate, dithane M 45, blitox and captan. Complete spore inhibition against Colletotrichum musae was by benlate, dithane M 45, zineb and captan. Dithane M 45, zineb and captan completely inhibited the spores of Fusarium roseum. Spores of Penicillium digitatum were completely inhibited by benlate, dithane M 45 and captan, while this was provided by all the fungicides evaluated against Penicillium expansum. Dithane M 45, zineb and captan gave 100 per cent spore inhibition against Pezicula sp.

Table 17. Inhibition of spore germination on ten fungi by different fungicides at 500 ppm.

Fungus	Per cent spore inhibition after 24 hours[b]					
	Control	Benlate	Dithane M 45	Blitox	Zineb	Captan
Aspergillus niger	6.42	100	76.97	93.46	69.02	100
Botryodiplodia theobromae	30.50	51.31	100	33.02	79.22	100
Colletotrichum gloeosporioides	23.53	100	100	100	73.28	100
Collectotrichum musae	38.46	100	100	78.69	100	100
Fusarium roseum	40.62	42.73	100	99.90	100	100
Penicillium digitatum	33.33	100	100	85.37	36.36	100
Penicillium expansum	58.06	100	100	100	100	100
Penzicula sp.	10.00	55.56	100	60.57	100	100
Rhizopus stolonifer	8.00	46.36	37.23	93.61	9.19	93.61
Thielaviopsis paradoxa	5.00	35.38	86.74	33.52	61.45	100

b = Average of four slides; 15 - 35 spores per slide.

None of the fungicides gave complete spore inhibition against Rhizopus stolonifer, although the highest per cent spore inhibition of 93.61 was provided by blitox and captan. Thielaviopsis paradoxa was completely inhibited by captan, while blitox gave the least.

From the foregoing results, captan was found to be the most effective in inhibition of spore germination of the ten fungi.

In another series of experiments benlate, dithane M 45, blitox and zineb were also tested at 10, 50, 125, 250, 750, 1000 and 1500 ppm. The data obtained was further subjected to probit analysis by Finney's method (Finley 1951). Lethal dose (Ld50) values were determined and the results are presented on Table - 18 abcd.

From Table 18 a, b, c, d, dithane M 45 was the most effective fungicide against Botryodiplodia theobromae, Colletotrichum gloeosporioides, Fusarium roseum and Thielaviopsis paradoxa. Blitox could control Aspergillus niger and Rhizopus stolonifer, while benlate was most effective against Colletotrichum musae and Penicillium digitatum. Zineb was noted as most effective against Penicillium expansum.

Table 18 c. Estimation of LD50 of blitox against six fungi by probit analysis.

Fungus		Doses in ppm								LD50
		10	50	125	250	500	750	1000	1500	ppm
Aspergillus niger	No. of spores observed	121	104	132	115	124	120			
	No. of spores killed	27	52	77	89	116	120			50
	calculated probit	4.24	5.00	5.21	5.75	6.83	7.64			
Botryodiplodia theobromae	No. of spores observed	84	94	67	79	86	90	69	100	
	No. of spores killed	11	22	36	39	56	82	63	94	300
	calculated probit	3.83	4.27	4.91	4.98	5.39	6.35	6.36	6.56	
Colletotrichum musae	No. of spores observed	75	115	115	117	122	52	122	72	
	No. of spores killed	5	74	97	100	106	49	113	68	30
	calculated probit	3.50	5.37	6.01	6.06	6.12	6.44	6.45	6.59	
Penicillium digitatum	No. of spores observed	79	90	77	80	123	80	140	138	
	No. of spores killed	27	41	40	43	111	74	138	138	123
	calculated probit	4.59	4.89	5.05	5.09	6.30	6.44	7.19	7.69	
Pezicula sp.	No. of spores observed	79	77	64	68	62	43	52	38	
	No.of spores killed	27	31	29	34	40	32	39	29	280
	calculated probit	4.59	4.75	4.88	5.00	5.37	5.66	5.67	5.72	
Rhizopus stolonifer	No. of spores observed	121	104	132	115	68				
	No. of spores killed	27	52	77	89	64				55
	calculated probit	4.24	4.99	5.21	5.75	6.57				

Table 18 a. Estimation of LD50 of benlate against five fungi by probit analysis.

Fungus		Doses in ppm								LD50
		10	50	125	250	500	750	1000	1500	ppm
Botryodiplodia theobromae	No. of spores observed	72	69	55	58	69	55	70	69	
	No. of spores killed	25	31	26	40	35	48	.69	69	150
	calculated probit	4.61	4.87	4.93	5.49	5.02	6.14	7.19	7.45	
Colletotrichum musae	No. of spores observed	104	105	138	116					
	No. of spores killed	53	66	109	116					5
	calculated probit	5.02	5.33	5.81	7.68					
Fusarium roseum	No. of spores observed	78	73	43	81	80	69	60	69	
	No. of spores killed	7	8	6	19	56	52	59	69	415
	calculated probit	3.66	3.77	3.92	4.28	5.52	5.69	7.13	7.45	
Penicillim digitatum	No. of spores observed	49	93	95	97	98				
	No. of spores killed	19	63	77	89	98				30
	calculated probit	4.72	5.46	5.88	6.39	7.57				
Penicillium expansum	No. of spores observed	81	117	130	140					
	No of spores killed	31	44	61	98					122
	calculated probit	4.70	4.68	4.92	5.52					

Table 18 b. Estimation of LD50 of dithane M45 against seven fungi by probit analysis.

Aspergillus niger	No.of spores observed			99	123	88	101	91	89	
	No. of spores killed			1	1	68	81	81	89	430
	calculated probit			2.60	2.68	5.25	5.75	6.23	7.54	
Botryodiplodia theobromae	No. of spores observed	68	49	52						
	No.of spores killed	29	44	52						13
	calculated probit	4.81	6.27	7.34						
Colletotrichum gloeosporioides	No. of spores observed	65	72	70						
	No of spores killed	29	66	70						15
	calculated probit	4.86	6.38	7.45						
Colletotrichum musae	No. of spores observed	74	88	85						
	No. of spores killed	40	83	85						2
	calculated probit	5.10	6.58	7.52						
Fusarium roseum	No. of spores observed	65	73	62	70					
	No. of spores killed	26	59	51	70					50
	calculated probit	4.75	5.87	5.93	7.45					
Rhizopus stolonifer	No. of spores observed			69	69	71	75	104	73	
	No. of spores killed			1	3	30	57	97	73	620
	calculated probit			2.82	3.29	4.80	5.71	6.50	7.47	
Thielaviopsis paradoxa	No. of spores observed	109	93	72	108	127	77	95	121	
	No. of spores killed	27	46	38	36	111	66	88	112	210
	calculated probit	4.32	4.99	5.07	5.83	6.15	6.19	6.44	6.45	

Table 18 d. Estimation of LD50 of zineb against eight fungi by probit analysis.

Fungus		Doses in ppm								LD50
		10	50	125	250	500	750	1000	1500	ppm
Botryodiplodia theobromae	No. of spores observed	83	84	82	103	77	128	80	96	
	No. of spores killed	3	9	9	18	67	124	79	96	370
	calculated probit	3.70	3.76	3.77	4.06	6.13	6.86	7.24	7.50	
Colletotrichum gloeosporioides	No. of spores observed	75	80	65	69	93	83	88	85	
	No. of spores killed	3	4	7	67	74	68	82	85	340
	calculated probit	3.25	3.35	3.76	5.83	5.91	6.90	6.49	7.52	
Colletotrichum musae	No. of spores observed	85	86	88	89	85				
	No. of spores killed	10	26	50	78	85				110
	calculated probit	3.81	4.48	5.17	6.16	7.52				
Fusarium roseum	No. of spores observed	81	87	83	80	85				
	No. of spores killed	17	24	45	68	85				115
	calculated probit	4.19	4.41	5.11	6.04	7.52				
Penicillium expansum	No. of spores observed	91	93	106	106	103				
	No. of spores killed	23	34	67	83	103				100
	calculated probit	4.33	4.66	5.79	5.78	7.69				
Pezicula sp.	No. of spores observed	78	69	68	74	70				
	No. of spores killed	3	10	24	55	70				160
	calculated probit	3.23	3.94	4.62	5.65	7.45				
Rhizopus stolonifer	No. of spores observed	86	81	113	106	79	72	74	96	
	No. of spores killed	1	2	4	10	13	27	31	40	1500
	calculated probit	2.73	3.03	3.19	3.69	4.02	4.68	4.80	4.81	
Thielaviopsis paradoxa	No. of spores observed	120	95	68	100	71	90	116	139	
	No. of spores killed	17	18	27	57	45	62	80	115	225
	calculated probit	3.93	4.12	4.74	5.18	5.34	5.49	5.94	5.94	

(b) Fungicidal inhibition of mycelial growth of different fungi.

Fungicides were evaluated by measuring growth of fungal colonies on potato dextrose agar containing different concentrations of fungicides for 72 hours. The results are given on Table 19.

Benlate was rated as the most effective fungicide to inhibit completely the mycelial growth of all the fungi except Rhizopus stolonifer, at all its three concentrations, followed by dithane M 45, blitox, captan and zineb. Rhizopus stolonifer was completely inhibited by blitox at all concentration.

(c) The value of chemicals in fruit storage.

All the chemicals evaluated were effective for the control of fungi on different fruits. Benlate was rated as the most effective fungicide for controlling diseases in fruits followed by captan, calcium hypochlorite, sodium carbonate, sodium hypochlorite and borax (Appendix c).

Borax controlled Pencicillium expansum on apples at all concentrations for three weeks. Pezicula sp. was controlled for a week by borax at 0.1 to 0.2 per cent and upto three weeks at 0.4 per cent, when fruits were wrapped in polythene bags. Both fungi were controlled for three weeks by borax at all concentrations, when fruits were exposed.

Table 19. Average mycelial growth of 10 fungi on potato dextrose agar incorporated with different concentrations of fungicides.

Fungus	Average mycelial growth in mm at different concentrations of fungicides in ppm after 72 hours at 22°C[a]															
	Control	Benlate			Dithane M45			Blitox			Zineb			Captan		
	0	100	200	500	100	200	500	100	200	500	100	200	500	100	200	500
Aspergillus niger	30.88	0	0	0	0	0	0	15.8	7.0	5.3	26.8	25.0	21.0	11.8	9.5	10.0
Botryodiplodia theobromae	73.54	0	0	0	7.78	0	0	15.3	5.0	0	62.0	48.0	30.0	16.5	13.3	8.5
Colletotrichum gloeosporioides	24.12	0	0	0	7.0	0	0	0	0	0	19.5	17.5	17.0	0	0	0
Colletotrichum musae	29.68	0	0	0	7.3	0	0	7.8	0	0	15.8	13.3	0	6.0	0	0
Fusarium roseum	34.78	0	0	0	20.0	15.8	11.5	10.5	0	0	24.5	22.5	22.0	6.0	0	0
Penicillim digitatum	19.60	0	0	0	15.0	14.5	11.5	18.5	15.0	14.3	20.0	19.3	13.3	11.0	8.5	7.5
Penicillium expansum	16.80	0	0	0	0	0	0	8.5	5.3	0	15.5	14.0	13.8	7.8	7.5	7.3
Pezicula sp.	63.58	0	0	0	0	0	0	7.0	0	0	44.5	36.8	17.5	6.8	6.5	6.0
Rhizopus stolonifer	90.0	90.0	90.0	90.0	90.0	90.0	90.0	0	0	0	90.0	90.0	90.0	90.0	50.0	26.5
Thielaviopsis paradoxa	83.88	0	0	0	0	0	0	23.5	23.3	19.3	69.8	60.5	51.3	18.8	13.3	10.8

a = Average of four petri dishes per treatment.

Colletotrichum musae on banana was controlled for one week by borax at 0.2 percent concentration and for more than a week at 0.4 per cent. Borax at all concentrations was effective against Penicillium digitatum on citrus. However, Botryodiplodia theobromae and Colletotrichum gloeosporioides both on citrus were controlled by borax for a week. None of the pawpaw pathogens was controlled by any concentration of borax.

Sodium hypochlorite could not control Pezicula sp. at low concentrations, but was effective at 0.2 to 0.4 per cent concentrations for one week when fruits were wrapped and for two weeks when fruits were exposed. The pathogens of bananas and those of pawpaws were not controlled by any concentration of this chemical. It was not effective against citrus pathogens. Thielaviopsis paradoxa on pineapple was controlled for three weeks when fruits were exposed at all concentrations.

Both the pathogens of apples were controlled by sodium carbonate when fruits were either exposed or wrapped in polythene bags. None of the pathogens of bananas or pawpaws were controlled by this chemical. Of the citrus pathogens, only Colletotrichum gloeosporioides was effectively controlled. Thielaviopsis paradoxa on pineapples was controlled for one week.

Calcium hypochlorite effectively controlled both fungi on apples for over three weeks when fruits were exposed. The fungi on bananas were controlled by this chemical for a week. On citrus fruits, this chemical was not effective, except at a concentration of 0.4 per cent. At 0.2 - 0.4 per cent, calcium hypochlorite also controlled pawpaw pathogens. Pineapples treated with 0.1 to 0.2 per cent, calcium hypochlorite could only be stored for one week when wrapped in polythene bags and for two weeks when treated with 0.4 per cent and exposed.

Benlate was effective for more than three weeks against all the pathogens of apples when exposed and for two weeks when the fruits are wrapped in polythene bags. Colletotrichum musae and Botryodiplodia theobromae on bananas were controlled for over three weeks while Fusarium roseum could be controlled for one week. Benlate was ineffective against Penicillium digitatum although effective against Botryodiplodia theobromae on citrus for more than three weeks.

Colletotrichum gloeosporioides of pawpaw was also controlled. Thielaviopsis paradoxa of pineapple could be controlled for over one week.

Captan controlled both pathogens of apples for over three weeks, when the fruits were exposed or wrapped in polythene bags. The fungicide was effective on the banana pathogens for only one week at 0.2 to 0.4 per cent concentrations. Control of Colletotrichum gloeosporioides was obtained with captan on citrus, but not of Penicillium digitatum. With exposed pawpaws, control of pathogens for a week was possible with captan at 0.2 per cent and at all concentrations when fruits were wrapped in polythene bags. Captan at 0.2 to 0.4 per cent controlled Thielaviopsis paradoxa for over three weeks when the fruits were exposed and for over one week when the fruits were wrapped in polythene bags.

Fruits stored exposed, seem to last longer than those wrapped in polythene bags as can be observed on the last column of Appendix (c). However, this depends on the type of fruit and the chemical used for treatment.

5. DISCUSSION

It was found that postharvest diseases were present in all the markets surveyed. The markets surveyed, basically had the same storage facilities, but differed in the sense that, each of the Westlands markets is managed by a single dealer or company, trading in several fruit types, which are handled by several employees. The city and retail markets had several stalls and were managed by different dealers each trading in few fruit types, which were handled by few employees and a number of customers. Despite all this, the prevalence of the pathogens and the damage caused varied considerably with the types of fruits, the diseases and the storage conditions prevailing within these markets.

This may be attributed to the fact that in the city and retail markets, where the fruits are handled by both employees and customers, some of the diseases may be spread by the movement of customers, from one stall to another, touching the fruits, pricking and incidentally transferring the inoculum. Secondly, a dealer may not be good at selecting and discarding decayed fruits from his stall so his fruits may serve as a source of inoculum for his fruits as well as that of adjacent dealers.

In the Westlands markets, handling of fruits

seemed better, because fruits were sorted out and sold mainly by employees, whereas in the Retail market and to a lesser extent in the City market, the fruits were handled by both the customers and employees. The fact that there were greater losses in the latter markets, in comparison to the former markets, shows that good sanitation in fruit handling plays an important role in reduction of postharvest wastage of fruits, by pathogens.

Pathogenicity results indicated how the injured fruit surface is ideal for attack by pathogens, in that most of the pathogens were able to infect fruits by scalpel injured surface. This implies that fruits injured at harvest, transportation and handling in storage are more vulnerable to attack by pathogens than carefully handled fruits. Banana stem end rot pathogen Botryodiplodia theobromae has been referred to as a wound parasite in that injury was found to be necessary for infection (Srivastava and Tandon, 1970). On the contrary, it was found in the present study that in addition to wound infection, the organism was also found to penetrate intact surface. Fusarium roseum causing banana crown rot referred to as a weak parasite, infecting only previously injured fruits (U.S. Dept. Agric., 1953), was observed to infect only scalpel injured surface.

Most of the fungi able to grow at temperatures between 20 - 35°C had a high optimum temperature for growth. However, Penicillium sp. had a narrow temperature range and low optimum for growth. Togash (1949), also found that the optima for most plant pathogenic fungi was in the region of 20 - 30°C and about half of them had their optima between 26 - 30°C, a suggestion very close to the above findings. Penicillium expansum and Pezicula sp. grew very slowly at 4°C (refrigeration temperature) unlike other fungi. This is an indication of adaptation of these fungi to thrive under both temperature and tropical conditions.

Germination of spores mostly occurred at a temperature range of 20 - 25°C and the optimum temperature for germination of most fungi was lower than that of growth. This may be due to the fact that germination being a change from an inactive initial state to an active state, is accompanied by several metabolic processes which are usually sensitive to temperature changes. However, this is very close to that for growth in culture. A similar finding has also been suggested by Togash (1949). High relative humidities of 95 to 100 per cent favoured spore germination, whereas the pH range for germination of most fungi was between pH 4.5 and 6.5 with optimum of 5.5 and 6.5. Botryodiplodia theobromae was an exception, that the fungus could not germinate at pH 4.5 and 6.5. Bhargava (1971),

observed a different pH range for germination of spores of Botryodiplodia annanasae. They germinated at pH range of 2.5 to 10.0 with maximum at 5.5 and 6.5. The difference may probably be due to the method used, differences in fungal species and possibly the buffer solution. However, the suggestion that distilled water supported the best germination, ties up with the present investigation. The reason for this is that germination of these spores is not greatly influenced by external supply of nutrients (Bhargava, 1971).

Infection by most fungi and their growth occurred between 20 - 35°C. In general, storage and transit rot diseases are most severe at the temperatures which favour mycelial growth of the pathogen. However, Brooks and Cooley (1971), suggested that it is typical for pathogens to grow in culture at temperatures below the minimum for infection as has been the case with Penicillium expansum and Pezicula sp. No disease development was recorded at 4°C. This temperature is therefore, suitable for storage of fruits. While other fruits were stored at this temperature for three weeks without observable disorders, bananas developed chilling injury within three days at 4°C and within ten days at 10°C. Lutz and Hardenburg (1968), also found that tropical fruits such as bananas and mangoes are sensitive to chilling and suffer

physiological disorders if stored below 7.5°C. Low temperature treatment is however, the most effective and useful method for delaying the development of pathogens in fruits with deep-seated infections which cannot be eradicated by postharvest treatment (Eckert and Sommer, 1967). This retards the development of decay by both maintaining the resistance of the host to parasitism and also by retarding the growth of the pathogen directly (Eckert, 1975). It has been found that, peaches stored below 7.5°C don't suffer from decay caused by Rhizopus stolonifer, (Pierson, 1966; Pierson et al 1958). Relative humidities of 70 to 100 per cent were conducive to disease development, a wider range than that for spore germination. This is because, these fruits were inoculated with both the mycelia and the spores of the fungi.

During the disease survey, it was found that most fruit dealers store their fruits for one week before the intake stock gets exhausted. It is therefore, uneconomical to treat fruits with chemicals if they can remain healthy for one week. From this point of view, it is not advisable to treat apples with any chemicals. When apples were kept in polythene bags, they could last for 7 days and when exposed remained healthy for 15 to 20 days without any treatment. Benlate can be recommended for

bananas. Benlate has also been recommended by Frossard et al (1973) for the control of banana anthracnose, for mango anthracnose (Sohi et al, 1975) and apple lenticular rot caused by Pezicula sp. (Burchill and Edney, 1973). This chemical is however, fairly expensive and may not prove economical to dealers. Calcium hypochlorite is a cheaper and better substitute to prolong the deterioration span of fruits. Citrus fruits in general, especially tangerines have a longer shelf life and need not be treated with any chemicals, but lemons and oranges can be treated with calcium hypochlorite, to extend their shelf life. Pawpaws deteriorate quickily and even when treated with chemicals, don't as a rule last long. However, calcium and sodium hypochlorites could be a reasonable suggestion. It is rather uneconomical to treat pineapples in the local markets with chemicals because they also have a long shelf life.

Storage of fruits exposed would be a better alternative than storage in polythene bags, because exposed fruits seemed to last longer than those in polythene bags. This could be due to high moisture and temperature in polythene bags, which are favourable for postharvest diseases.

6. CONCLUSION

The distribution of postharvest diseases has been found to be influenced not only by environmental factors, but also by the way they are handled and stored in the markets. Where better handling methods are employed, fewer fruits deteriorate. However, the environmental conditions prevailing in the tropical countries, favour disease development.

Fruit losses due to postharvest diseases were estimated at Kshs. 17,552.55 in one market in Nairobi. Assuming that there are about 10 such markets in Nairobi, 3 at Mombasa, 2 at Nakuru and 2 at Kisumu and assuming that the losses calculated are applicable to all the markets, the total loss in the whole country in monetary value may be estimated at Kshs. 300,000 per annum.

High relative humidities and temperatures are conducive to disease development. Low temperature could therefore, be utilized for disease control. However, some of the tropical fruits, such as bananas develop chilling injury when stored at a low temperature. In most cases, fruits stored at low temperatures, don't ripen quickily and so when such fruits are transferred to high temperature conditions for ripening, they become vulnerable to attack by

pathogens. Cherries ripened without an intervening period of cold storage have however, been observed to suffer a great loss from decay than those previously stored at low temperature (Pierson, 1966; Pierson et al, 1958). This is a clear indication that refrigeration is useful in the maintenance of quality in fresh fruits and is the most important loss-reducing factor in the postharvest environment.

Chemicals may be used to control postharvest diseases of fruits, but some chemicals are expensive and cannot be used by common dealers.

Most of the fruit dealers interviewed, had no solutions to the problem of storage spoilage. Some, however, suggested that, when their fruits start deteriorating they sell them away at half the price. Whether this is a reasonable solution or not depends on the type of commodity. However, according to the assessment made, this increases losses in terms of money.

Since only fruit markets in Nairobi were surveyed, and only ten fruits were taken into consideration, it becomes impossible to generalize on Nairobi markets as a whole. This is partly because, the nature of the markets in the country vary, together with their methods of operation and storage.

The fruit marketing chain comprises of a complex linkage of segments, each of which is dynamic and changing as it responds to economic, social, political or other pressure (Harvey, 1978). The fruit industry is therefore, in an era of dynamic changes, especially in the areas of mechanical harvesting, consumer packaging and bulk transportation.

A change in harvesting method may increase mechanical injury to the product, which may in turn increase susceptibility to decay; a new packaging or handiling system may reduce costs, but may also have an undesirable effect on temperature maintenance in storage or transit; or, a new transport vehicle may have a vastly improved refrigeration system, but may not provide a means of air exchange to compensate for modification of the atmosphere caused by respiration of the commodity. Most of the proposals that have been made therefore, tend to intensify postharvest diseases either by increasing the number of inoculation sites on the product or by creating an environment which is favourable for disease development.

In future, scientists engaged in research on the maintenance of quality and prevention of losses after harvest, must be constantly alert to these changes, because of the ultimate biological effects of physical alterations in one or more links of the

marketing chain. A failure in one link may result in a failure of the whole system and thus in a loss, when the fruit reaches the market or consumer's kitchen.

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8. APPENDICES

Appendix (a) - Constituents of solid media.

Potato dextrose agar:

Infusion from potatoes	- 4.0 g
D(+) - Glucose	-20.0 g
Aga agar	-15.0 g

Malt extract agar:

Malt extract	-30.0 g
Peptone from soymeal	- 3.0 g
Aga agar	-15.0 g

Corn meal agar:

Corn meal extract	- 2.0 g
Aga agar	-15.0 g

Czapek-dox-agar:

Sodium nitrate	- 2.0 g
Potassium chloride	- 0.5 g
Magnesium glycerophosphate	- 0.5 g
Ferrous sulphate	- 0.35g
Sucrose	-30.0 g
Agar nO. 3 oxoid L13	-12.0g

Appendix (b) - Ingredients of liquid media.

Richard's solution:

Potassium nitrate	-10.00 g
Potassium hydrogen phosphate	- 5.00 g
Magnesium sulphate	- 2.50 g
Ferric chloride	- 0.02 g
Sucrose	-50.00 g

Czapek's solution:

Sodium nitrate	- 3.0 g
Potassium monohydrogen phosphate	- 1.0 g
Magnesium sulphate	- 0.5 g
Potassium chloride	- 0.5 g
Ferrous sulphate	- 0.01g
Sucrose	-30.0 g

Appendix (c). Effect of chemicals in prolonging storage period of different fruits at room temperature (20)°C using two methods of storage

Fruit	Chemical	Storage of fruits before infection as affected by different chemicals at various concentrations after days[c]					
		1-6	7	8-13	14	15-20	21
Apples	Control		2ps (p)			1ps(e)	
	Borax		1ps(p)xy				-(e)xyz 1ps(p)z
	Sodium hypochlorite	2ps(e)x 1ps(p)x	1ps(p)y	1ps(p)z		1ps(e)yz	
	Sodium carborate						-(e)xyz -(p)xyz
	Calcium hypochlorite		1pe(p)y				
	Benlate				1pe(p)z		-(e)xyz
	Captan						-(e)xyz -(p)xyz
Bananas	Control	3cmbt(e) 3cm(p)					
	Borax	3cm(e)x 3bt(p)x 3cm(p)yz	3cm(e)y	3cm(e)z			
	Sodium hypochlorite	3cm(e)xyz 3cm(p)xy 3frcm(p)y					
	Sodium carbonate	3cm(e)xyz 3fr(p)y 3frcm(p)z	3btcmfr(p)				
	Calcium hypochlorite		3fr(p)x 3btfr(p)y 3btcm(p)z	3cm(e)xyz			
	Benlate			3fr(p)xyz			-(e)xyz
	Captan	3btcmfr(p)x 3cmfs(e)x	3btcmfr(p)xy 3cm(e)y 3btcm(e)z				
Lemon	Control	2pd(1)		1pd(p)			
	Borax		1bt(p)x				-(e)xyz
	Sodium hypochlorite					1cg(e)	-(p)xyz 1cg(e)y

Appendix (c) cont.

Lemons	Sodium carbonate	1pd(e)xy 1pd(p)xy	1pd(p)z	2pd(e)z			
	Calcium hypochlorite	2pd(p)x 1pd(p)y 2pd(e)x 1pd(e)y					-(e)z -(p)z
	Benlate	1pd(e)x	1pd(p)x 1pd(e)y	1pd(p)x			-(e)z -(p)z
	Captan	2pd(e)xyz	1pd(p)xyz				
Oranges	Control	1bt(p) 1pd(e)					
	Borax	1pd(e)x	2bt(p)x	2bt(p)y		1cg(e)y 1bt(p)z	1cg(e)z
	Sodium hypochlorite		2cgpd(p)x 1pd(e)x	1pd(p)yz		1cg(2)x	-(e)z
	Sodium carbonate	2pd(e)x 1pd(p)xy		1bt(p)z			-(e)yz
	Calcium hypochlorite	1pd(p)xy		1pd(p)z			-(e)xyz
	Benlate	2pd(e)xyz	1bt(p)x				-(p)yz
	Captan	1pd(e)xyz					-(p)xyz
Tangerines	Control					2bt(p) 2pd(e)	
	Borax			2bt(e)x	1cg(e)z	1cg(e)z 1bt(p)xy 1cg(p)	
	Sodium hypochlorite		1pd(p)x	1pdcg(p)y 1bt(p)z 1bt(p)z		1bt(e)x	-(e)yz
	Sodium carbonate	1bt(p)y		1pd(p)x	1bt(p)z		-(e)xyz
	Calcium hypochlorite	2bt(e)x	2cg(p)xy 3bt(p)z				1cg(e)y 2bt(e)z
	Benlate		1pd(p)x	1bt(p)y	1pd(p)z		-(e)xyz
	Captan	1bt(p)x					-(e)xyz -(p)yz

Appendix (c) cont.

Pawpaw	Control	1rs(p) 1rs(e) 1cg(e)					
	Borax	1rs(p) 1rs(e) 1cg(e) 1cg(e)x 1rs(e)y 1rs(p)y 3bt(p)y 2rs(p)z					
	Sodium hypochlorite	1cg(e)x 2an(e)x 3rs(p)z	3an(e)yz				
	Sodium carbonate	2an(e)xyz 3rs(p)xyz					
	Calcium hypochlorite	3rs(e)x 3rs(p)xyz		2rsan(e)yz			
	Benlate	2anrs(e)xyz	3rs(p)xyz				
	Captan	2anrs(e)xy	1anrs(e)z 3rs(p)xyz				
Pineapples	Control		1tp(p)	3tp(e)			
	Borax			3tp(p)xyz			-(e)xyz
	Sodium hypochlorite		3tp(p)x	3tp(p)yz	3tp(e)xy		3tp(e)z
	Sodium carbonate		3tp(p)xyz	3tp(e)xyz			
	Calcium hypochlorite		3tp(p)xy	3tp(e)xy 3tp(p)	3tp(e)z		
	Benlate			3tp(p)xyz			-(e)xyz
	Captan		1tp(p)x	1tp(e)x 1tp(p)yz			

C = Average of three fruits per treatment

an = *Aspergillus niger*

bt = *Botryodiplodia theobromae*

cg = *Colletotrichum gloeosporioides*

cm = *Colletotrichum musae*

fr = *Fusarium roseum*

pd = *Penicillium digitatum*

pe = *Penicillium expansum*

ps = *Pezicula* sp.

rs = *Rhizopus stolonifer*

tp = *Thielaviopsis paradoxa*

(e) = Fruits exposed

(p) = Fruits wrapped in polythene bags

x = 0.1 per cent chemical

y = 0.2 per cent chemical

z = 0.4 per cent chemical

\- = No infection after 21 days.

1, 2 and 3 = Number of fruits infected.