UNIVERSITY OF LAGOS
Inaugural Lecture Series 2009

TOPIC:

FUNGI: THE NON-CHLOROPHYLLOUS PLANTS OF OUR ENVIRONMENT - HOW THEY AFFECT HUMANKIND

By
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University of Lagos Press

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An Inaugural Lecture Delivered at the University of Lagos Main Auditorium on Wednesday, 14th January 2009

By

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University of Lagos Press, 2009

Published 2009

By

University of Lagos Press
Unilag P. O. Box 132,
University of Lagos,
Akoka, Yaba – Lagos,
Nigeria.

ISSN 1119-4456

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The Vice-Chancellor, Deputy Vice-Chancellor (Management Services), Deputy Vice-Chancellor (Academic and Research), Registrar, Provost of College of Medicine, Dean of Science, Other Deans, Members of Senate, Academic and Non-Academic Staff of the University, Invited Guests, Students of this Great Institution, Ladies and Gentlemen.

To God be the glory for making this occasion possible at the beginning of this New Year. My prayer is that, my colleagues and friends, who are yet to deliver their own may also, find favour to do so.

This lecture is intended to enlighten us on the nature and importance of the group of organisms called 'Fungi', which can be studied under two major disciplines: Mycology and Plant Pathology. While Mycology deals with the nature, characteristics, taxonomy, phylogeny, physiology and reproduction of fungi, Plant Pathology addresses fungal interactions with plants that lead to manifestation of disease and how the diseases can be controlled. These two broad areas of study have been adequately covered during my academic career.

What are Fungi?

Fungi are living organisms that are very closely related to plants than to animals. Most are composed of living filaments that grow in a mass, and their size and shape are determined by the environment. Like plants they have rigid cell walls, but they differ from plants in their lack of chlorophyll, the green matter that enables plants to manufacture their own food from water and carbondioxide in the presence of sunlight. As a result, all fungi are heterotrophs and derive their food from organic materials like green plants, animals and even man. They therefore live as saprophytes if their source of food is dead organic material or as parasites if they are able to feed on living organisms. Fungi secrete extracellular enzymes to help degrade the various organic materials before absorbing them into their system for growth, reproduction and survival. Fungi can reproduce sexually, asexually and parasexually.

It is estimated that probably more than two million species of fungi exist, but only about 5% of this has been discovered. Fungi exhibit great variation in lifestyle and biochemical activity.

MORPHOLOGY OF FUNGI

What do fungi look like?

There are two major categories of fungi: the micro and the macro-fungi. The microfungi are those that cannot be seen with our natural eyes. They need to be enlarged and viewed under various types of microscopes before they can be seen. They have a wide range of forms, shapes and sizes as can be noted on the following illustrations (Plate 1).

On the other hand macrofungi are visible to the unaided eyes. They vary widely in size and shape. Some are edible and are well known even in our villages, but majority are poisonous. Plate 2 illustrates some of the varieties among macrofungi.

HABITAT

Where can fungi be found?

Fungi are not limited to any climatic region. The tropical, temperate, and other climatic regions of the world are teaming with species of fungi. They are present in desert areas and sand dunes. As noted earlier they can be parasitic on living organisms or saprophytic on dead organic materials. They are numerous in soils, water, atmosphere as spores, woodwork and furniture, leather materials, clothing materials, crop materials in storage and in the field, food items sold in the markets, meat, fish and beverages in storage. They are therefore ubiquitous.

EFFECT OF FUNGI ON MAN (Economic Importance)

Fungi affect human beings directly and indirectly. Their effect could also be beneficial and non–beneficial.

Beneficial Effects

(a) Symbiotic relationships:

Ecologically fungi are very important because they form various kinds of associations with other plants

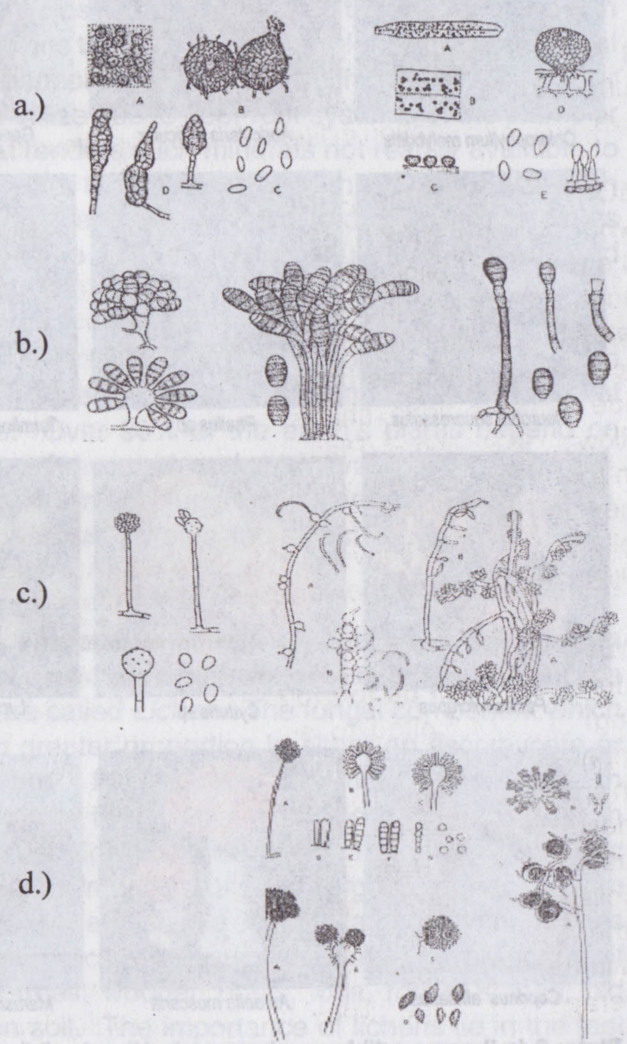


***Plate 1: Some microfungi** Left –right (a) Peyronellaea, Rhizosphaera (b) Cephaliophora, Phragmocephala, and Endophragmiac d (c) Oedocephalum, Harposporium, and Meria (d) Syncephalastrum, Chaenephora, and Dispira*

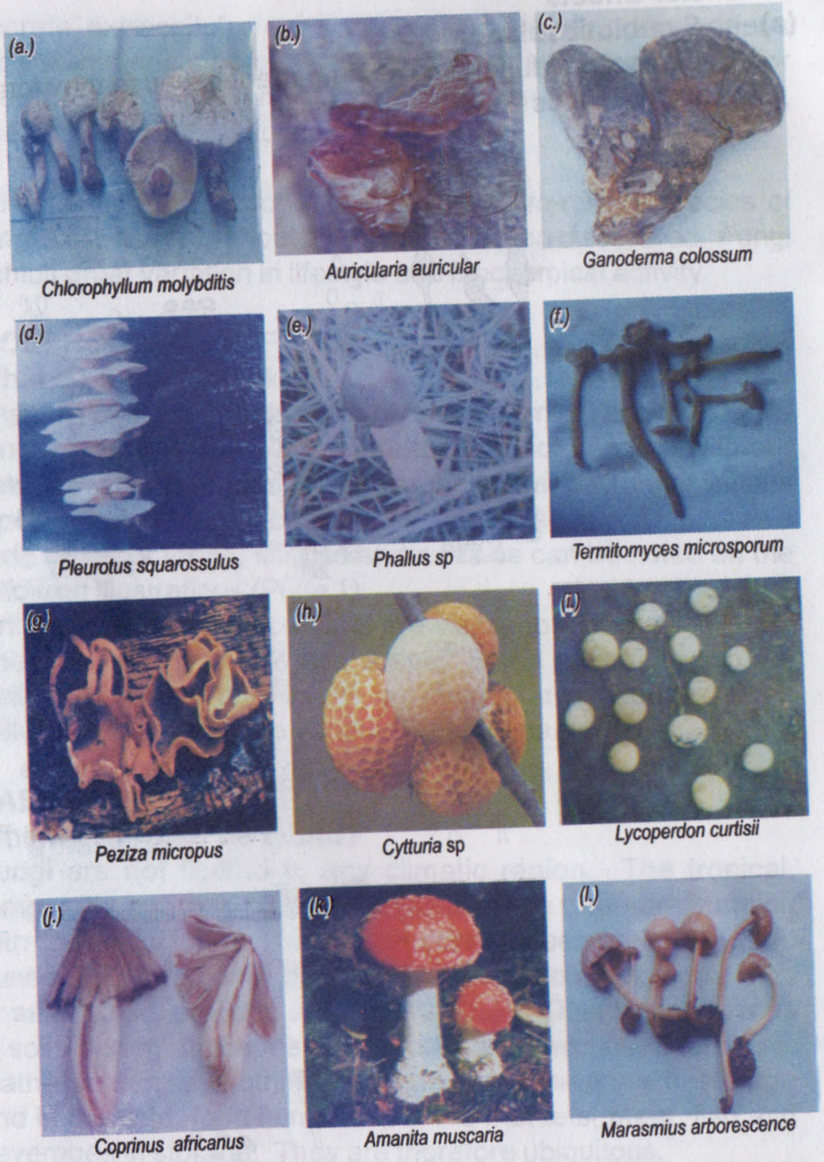


Plate: 2 (a-i) some edible mushrooms in Nigeria. (j-l) some poisonous mushrooms
Pictures courtesy Dr (Mrs) Lauretta Nwanneka Ofodile, Department of Biological Sciences, Yaba College of Technology.

i. **Mycorrhizae**

About 80% of the world's plants especially tree plants that have been studied are found to have what is known as *mycorrhizal* relationships with fungi; a situation in which the plant roots are closely associated with the fungal hyphae. In such associations the fungi enable the plants to utilize mineral salts like phosphorus, and water which the plants, on their own, cannot utilize due to poor root systems of the plants or poor soil that renders such minerals not readily available to the roots. On the other hand the plants, through photosynthesis, manufacture sugars and other carbohydrates which they make available to the fungi for growth and reproduction.

The activities of these fungi have been useful to man particularly in regeneration of forests and recolonization of waste lands. Over 90% of the earth's plants depend on various types of mycorrhizae for survival.
Examples of mycorrhizal fungi include genera like *Endogone*, *Sclerogone*, *Suillus*, *Boletus* and a host of others.

ii. **Lichens**

A symbiotic relationship between a specific fungus and an alga or bluegreen bacterium (cyanobacterium) results in a plant structure called *Lichen.* The fungal component which is usually in greater proportion is either an ascomycete or basidiomycete. Lichens are commonly encrusted on exposed rocks or tree trunks, and also hang from trees in rain forests. The algal portion is believed to contribute organic food from photosynthesis while the fungus is protected from high light intensity and able to absorb water and mineral salts for the algae. Lichens occur on stems and branches of shrubs and trees, wooden posts, logs, rocks, stones, old walls and on soil. The importance of lichens lie in the fact that those on rocks can disintegrate the rocks to form soil suitable for the growth of other plants. They also have a variety of uses, for example the reindeer moss (*Cladonia* sp.) which grows in clumps in the arctic tundra is a valuable source of food for wild animals and cattle. The Iceland moss (*Cetraria* sp.) is used as food and medicine for man. Certain lichens are fried for cattle feed and sometimes for man to eat. Some yield beautiful dyes. Litmus which is used as a chemical indicator for acids is obtained from certain lichens. Some species are used in cosmetics, perfumes and soaps. Lichens are also used in brewing liquor, and those containing tannins are used in making leather from hide. They are often used to monitor environmental pollution.

(b) Fungi as decomposers/recycling agents:

Certain fungi, along with bacteria break down complex organic compounds and make them available for reuse as nutrients. For example the fungus *Phallus impudicus* rots down wood. It recycles the content of wood for the benefit of other plants, and there is an interest in harnessing this activity to make paper without the high chemical input of present day processes.

(c) Fungi in biological control of pests

Some fungal pathogens and fungal competitors with other organisms are considered beneficial because they can control or even eliminate populations of dangerous or unwanted organisms like insect pests, mites, weeds, nematodes and other fungi such as pathogens of plants useful to man. Some of these fungi have been used as bioinsecticides e.g. *Verticillium lecanii*, *Paecilomyces fumosoroseus* and *Beauveria bassiana* are packaged and sold as insecticides.

(d) Fungi as food

Many types of mushrooms and other fungi are eaten. They include: button mushroom (*Agaricus bisporus*) oyster mushroom (*Pleurotus* spp.), the termite fungus *Termitomyces* sp. and others.

Mushrooms have a fairly high protein content, about 20 – 30% crude protein as a percentage of dry matter. They are low in fat and are cholesterol free. Because of their high fibre content, mushrooms are an ideal food for the prevention of atherosclerosis. Mushroom contain the eight essential amino acids that cannot be produced by the human body.

Certain fungi regarded as moulds are used to produce unique colours and flavours in cheeses. Fungi are also cultivated for use in the production of other food stuffs like 'Quorn' which is a single cell protein derived from a *Fusaruim* species. It is also to be noted that one of our staple foods, bread and also beer, are produced using species of fungi called yeast. Soy sauce is also produced by growing a filamentous fungus on soya bean.

Table 1 summarizes the uses of fungi in the food and beverage industries.

Table 1: Fungi used in food and Alcoholic Beverage Industries and their substrates

Fungi	Substrate used	Food/Beverage Produced
1. *Penicillium camberii* *P. roquefortii*	Milk	Cheese
2. *Saccharomyces cerevisiae*	Flour	Bread
3. *Aspergillus oryzae* *Saccharomyces rouxii*	Soyabeans	Soy Sauce
4. *Saccharomyces cerevisiae*	Cereal grain (barley)	Beer
5. *Saccharomyces cerevisiae* *S. ellipsoies*	Fruits (e.g. grape)	Wine
6. *Schizosaccharomyces pombe* *Penicillium* spp. *Aspergillus* spp. *S. cerevisiae*	Fresh palm juice	Palm wine
7. *Saccharomyces cerevisiae* *Schizosaccharomyces*	Fermented palm juice	Ogogoro (netivegin)
8. *Aspergillus oryzae* *Saccharomyces Cerevisiae*	Rice	Sake

Source: Ekundayo, 1980

(e) **Fungi in Medicine**

Fungi have been in use for medicinal purposes for many years. Archeologists discovered the remains of one of the common Puff-Balls (*Bovista nigrescens*) in the Roman remains at an ancient border of Vindolanda. It was suspected that the fungus was used for stopping blood flow from battle wound – a known effective use. Currently a number of medical drugs are manufactured from various fungi. These include antibiotics, immunosuppressants, anti-cholesterol statins and steroids. One of the most famous antibiotics, penicillin, was discovered by a man called Fleming in 1941. This marked the beginning of a new approach to human health and established the importance of fungi.

Fungi have an uncountable list of benefits in the medical field because they serve as sources of useful drugs, and also take part in many reactions that are beneficial to man. Such benefits include drugs and therapy, interconversion of pharmaceutical products and synthesis of vitamins.

i. **Drugs and therapy**

Since the beginning of the 21st century fungi have been involved in the industrial processing of more than ten of the twenty most profitable products used in medicine. The top ten include three anti-cholesterol statins, the antibiolic 'penicillin' and the immunosuppressant cyclosporine A. Pharmaceutical companies are becoming more interested in investigating the simple cures used by primitive people in the tropics.

Major types of drugs produced by fungi and their therapeutic uses are as follows (Table 2).

Table 2: Major forms of drugs produced by fungi and their therapeutic uses

Types of Drug	Fungal Source	Therapeutic effect
A. *Antibiotics* *Penicillin*	*Penicillium chrysogenum*	Effective against gram – positive bacteria
Cephalosporin	*Cephalosporium*	
B. *Ergot Alkaloids* Ergometrine Ergotamine	*Claviceps purpurea* *C. paspalii* *C. fusiformis*	For inducing labour For treating migraines
C. *Immune Supressants* Cyclosporin A	*Trichoderma* sp. *Polysporium* sp. *Cylindrocarpon Incidam*	Used to inhibit the activities lyphocytes
Gliotoxins	Many fungi	Immunological & antibiotic activities
D. *Statins* Lovastatin Pravastatin Mevastatin Simavastatin	*Aspergillus tereus* *Nocardia antotrophica* *Paecilomyces*	Used to remove cholesterol and prevent cardio vascular disease
E. *Steroids* Cortisone	*Rhizopus nigricans*	Treatment of arthritis

Some fungi have both nutritional and medicinal properties with very low toxicity at high dosage. They are called nutriceuticals. Table 3 lists some Nigerian mushrooms that are used therapeutically.

Table 3: Mushrooms used locally in Nigeria and their Therapeutic uses

Mushroom	Therapeutic uses
Termitomyces vesicolor	To inhibit *Candida* infection
Pleurotus tuberreguim	Treats heart problems
Termitomyces microcarpus	Treats Gonorrhoea
Termitomyces robuster	Cures malaria
Lentinula edodes	Cures stomach cancer, reduces cholesterol Treats influenza and polio

Source: Ofodile, 2006

ii. **Synthesis of Vitamins**

Vitamins are essential accessory growth substances required by man and other animals. Many yeasts and filamentous fungi are capable of synthesizing vitamins of the B group. However only a few of them can synthesize vitamin B_{12}. Included in the B group vitamins are nicotinic acid, riboflavin and anuerine hydrochloride. They are used medicinally in the form of dried yeast tablets for treatment of deficiency diseases resulting from lack of vitamin B group. The fungi *Ashbya gossiypi*, *Eremothecium ashloyii*, yeasts and some species of *Fusarium* produce riboflavin.

Fungi are also a good source of the provitamin D, (ergosterol). Ergosterol which is a phytosterol is the principal sterol of yeasts, ergot and certain other higher fungi. This chemical is converted to vitamin D_2 (calciferol) on radiation with ultraviolet rays, and the process is commercially exployed for the preparation of calciferol concentrates employed in anthracitic therapy.

iii. **Antifungal Drugs**

Antifungal drugs are those drugs that are effective in treating fungal infections in man. They could be of oral or topical applications. Some of such drugs are listed on Table 4

Table 4: Groups of antifungal drugs, their sources, active ingredients and uses

Antifungal Drugs	Sources	Active Ingredients	Uses
1. Griseofulvin	*Penicillium griseofulvin*	Grifulvin V	Treats dermatophytes (Fungal skin diseases
2. Echinocandins	*Aspergillus Nidulans*	Caspofungin Anidulafungin Micafungin	Wide spectrust agents against opportunistic infections
3. Polyenes	Double bond organic Compounds (terpenes, Vit. A)	Nystalin Amphotericin B.	Wide spectrum antibiotic agent

Source: William *et al.,* 2002

Other antifungal agents include flucytocine for treatment of meningitis caused by *Cryptococcus neoformans*; Naftifine for topical treatment of dermatophytes and Trebinafine for oral treatment of dermatophytes.

(f) **Bioremediation of organically contaminated soil:**

Mushroom substrates from commercially grown edible fungi have been employed for soil enrichment and for getting rid of organo-pollutants in soil. For example *Agaricus* spent compost was successfully used in remediation of soils contaminated with chlorophenols, aromatic hydrocarbons and volatile organic compounds. The basidiomycete *Phanerochaete chrysosporuim* is also able to degrade environmental pollutants such as polycyclic aromatic hydrocarbons, polychlorinated byphenyls, chlorophenols, dioxins, DDT, trinitrotohene and synthetic dyes. Several species of cultivated edible and medicinal mushrooms, e.g. *Pleurotus ostreatus, Tremetes versicolor* were also found to be able to degrade different organopollutants.

(g) **Fungi in Enzyme Production**

Enzymes are energized protein molecules that catalyse and regulate nearly all biochemical reactions in the human body. There are various kinds of enzymes that can be synthesized on commercial scale using fungi. These are listed on table 5 below.

Table 5: Some enzymes produced by fungi and their uses

Enzymes	Fungal Source	Uses
1. Amylases	*Aspergillus* spp.	Glucose syrup production Fruit processing Baking & brewing
2. Betagalactosidase	*Aspergillus terreus*	Used for digestive discomfort
3. Catalase	*Aspergillus niger* *Penicillium* spp.	Textile Industry
4. Cellulase	*Aspergillus niger*	Fruit processing, Flavour production, Food processing
5. Glucanase	*Penicillium emersonii*	Brewing, Wheat processing
6. Glucose oxidase	*Aspergillus niger*	Removal of oxygen from beverages and food products
7. Invertase	*Saccharomyces cerevisiae*	Converts sugar to hexoses
8. Laccase	*Pyricularia oryzae*	Paper Industry
9. Lactase	*Aspergillus* spp. *A. niger*	Milk processing, Cheese modification & flavouring
10. Lipase	*Aspergillus niger* *Aspergillus oryzae*	Fat modification
11. Pectinase	*Aspergillus* spp.	Fruit and wine processing
12. Protease	*Aspergillus* spp.	Baking & brewing; Flavour production
13. Xylanase	*Aspergillus niger* *Trichoderma reesei*	Wheat processing, baking

Many organic acids are prepared from fungi but few are produced commercially through large scale fungal processes. They include critic acid, lactic, gluconic, itaconic and fumeric acids. Citric and gluconic acids which are prepared by fermentation of glucose or sucrose by *Aspergillus niger* are the largest in quantity of commercial fungal organic acids. Table 6 lists some of the acids with their sources and uses.

Table 6: Some fungal organic acids, their sources and uses

Organic Acids	Fungal Sources	Application
Citric acid	*Aspergillus niger*	Food preservative, flavour enhancer, antioxidant used in cheese processing. Used in production of shamposs, toothpastes, hair rinses, textile printing, electroplating & paper making
Gallic acid	*Penicillium glaucum* *Aspergillus galomyces*	
Gluconic acid	*Aspergillus niger* *Penicillium chrysogenum*	In manufacture of black ink, dye stuff (alizaria), and in medicine for treatment of skin diseases.
Itaconic acid	*Aspergillus terreus*	In manufacture of synthetic fibres, adhesives, thickners and coatings
Gibberellic acid	*Gibberella fujkuroi*	In horticulture for germinaton, leaf expansion, flowering and parthenocarpy. A promoties growth in plants
Lactic acid	*Rhizopus oryzae*	In food industry as a preservative, flavour enhancer and acidulant

(i) Fungi in Textile and Furniture Industry:

Fungal pigments are used in textile industries. Certain micro fungi are capable of yielding up to 30% of their biomass as pigments. Enzymes from fungi are used to treat and modify fibres during textile processing.

Trichoderma spp. produce enzymes used in stone-washing jeans. *Fomes fomentarius* and *Ganoderma* applanatumare are used to produce suede-like materials from which hats and various articles of dress are made.

Coriolus versicolor sporophores have been used in making hats for costume decoration.

Polyporus bispidus produces a brown dye used for silk, cotton and wool colouring. It is also used by leather dressers to give a fawn chestnut colour, and by carpenters to give a brown colour to furniture.

Polyporus sulphurous gives a yellow colour

(j) **Fungi in Paper-making Industry**

Lignin is a sticky, dark, water resistant, brittle kind of sap that gives strength to plants while living, but causes many problems in paper making. In order for the industry to produce good quality paper, the lignin must be removed. Chemical processes are mostly in use. Biopulping is the cultivation of fungi for the purpose of using them to decompose the lignin. Certain fungi that cause 'white rot' can produce enzymes which degrade lignin. Such fungi are basidiomycetes like *Tremetes* sp. *Phanerochaete* sp and *Bjerkandera* sp. The paper industry uses enzymes from these fungi to soften wood fibres and provide alternative to chemical bleaching. In recent years the enzyme laccase produced by fungi was used to make paper. The process resulted in 30% reduction in energy consumption, a 50% reduction in chemical product usage, and a greater resistance to tearing.

Further study in this field will indeed be very rewarding.

None Beneficial Activities of Fungi to Man and Other Animals

a) *Direct Harmful effects of fungi to man.* This can be discussed under the following: allergies, production of toxins and mycotoxins and human mycoses.

i. **Allergies**

An allergen is any substance that is capable of producing hypersensitivity in an individual, and it makes the sensitive individual to produce antibodies (Wolski *et al.*, 1997).There are many fungal allergens in our environment, being present in the airspora of numerous places such as hospitals, poultry farms, laboratories, living houses, eating places, toilets, factories and wherever 'dust' exists. Allergens are very important to man's health. As a result of man's over exposure to them they can lead to human irritations or allergies and also to mycoses. Fungal allergens include:

Curvalaria spp. which trigger asthma attacks and lead to eye irritation.

Alternaria, *Cladosporium*, *Penicillium* and *Aspergillus* species also trigger asthma attacks (Chang *et al.*, 1997) *Absidia*, *Mucor* and *Rhizopus* species are highly injurious to neuropenic persons, and can lead to diabetes, anaemia and eventual brain damage.

ii. **Fungal Poisons**

Fungal poisons are natural constituents of the fruiting bodies (sporocarp) of some mushrooms and toadstools, which when ingested in error would lead to serious health hazards and even death. Some examples are listed on Table 7. A small quantity of between 5-10mg is considered lethal to men.

Table 7: Some fungal poisons, their sources and effects on man

Poison	Fungal Source	Effect on Man
Coprine	*Coprinus* spp.	Serious discomfort when taken with alcohol
Illudine	*Omhalotus* spp.	Gastrointestinal irritation and vomiting
Orellanin	*Costinarius* spp.	Irreversible Kidney damage and death
Amatoxin	*Amanita muscaria*	Vomiting, diarrhea, degeneration of kidney and liver

Source: Prescott *et al.*, 2005

iii. **Mycotoxins**

Mycotoxins are secondary metabolites with relatively low molecular weight produced by filamentous microfungi as a form of biochemical differentiation. They contaminate any form of medium in which the fungi are growing. Microfungi have long been associated with food, and so when such contaminated human food are eaten, the metabolites affect man adversely. Accumulation of the mycotoxin in the system of man leads to acute degenerative conditions of the liver and kidneys, and may result to various forms of cancer. Toxins produced by fungi have been found to contaminate about 25% of the world's food supply. The toxins are equally toxic to animals. For example in the sixties turkey growers in England experienced a high rate of mortality of their birds. Investigations showed that the turkeys were fed on feed contaminated with aflatoxin. Further investigation revealed that the feed was made with groundnuts imported from Nigeria, and that they were infected with *Aspergillus flavus*, a fungus known to produce a highly cancer inducing toxin called *aflatoxin*. Table 8 presents some of the known lethal mycotoxins.

Table 8: Some fungal mycotoxins and their effect on man and other animals

Toxin	Fungal Sources	Their effect to man and other animals
Aflatoxin	*Aspergillus flavus*	Aflatoxicosis, chronic liver cancer
Fumonisms	*Fusarium moniliforme*	*Oesophageal cancer*
Ochratoxin	*Ochraceus verrucosum*	Liver and kidney necrosis, organ degeneration
Patulin	*Penicillium expansum*	Paralysis of motor nerves
Citrinum	*Penicillium citrinum*	Kidney degeneration

Source: Prescott *et al.*, 2005

iv. Human Mycoses [Plate 3]

Fungal diseases on man are referred to as mycoses. Five categories are distinguished depending on degree of tissue penetration and mode of entry. They include: superficial, subcutaneous, cutaneous, systemic and opportunistic mycoses (Table 9)

Superficial Mycoses

These are fungal cosmetic infections of the skin and hairshaft, no living tissue is invaded and there is no cellular response from the host. Essentially no pathological responses are elicited. The infections are so innocuous that patients are unaware of their condition. They are yeast like in nature. Examples of these organisms include; *Tinea versicolor*, *Malassezia furfur*. These infections could be prevented by good personal hygiene (McClellan *et al.*, 1999).

Subcutaneous Mycoses

These infections are caused by fungi which are saprophytic inhabitants of soil and decaying vegetation. They are said to be geophylic, and the fungi are unable to puncture the skin. They therefore enter the subcutaneous tissue by means of an open wound that comes in contact with the infected soil carrying the fungus. The infection is an occupational hazard for barefooted agricultural workers and those in equally related field; the fungus is an exoparasite as it sends its fruiting bodies to the outer layer of the skin, which causes extracutaneous lesions as in Sporotricosis caused by *Sporothrix schenkii* (Hoffman *et al.*, 2000).

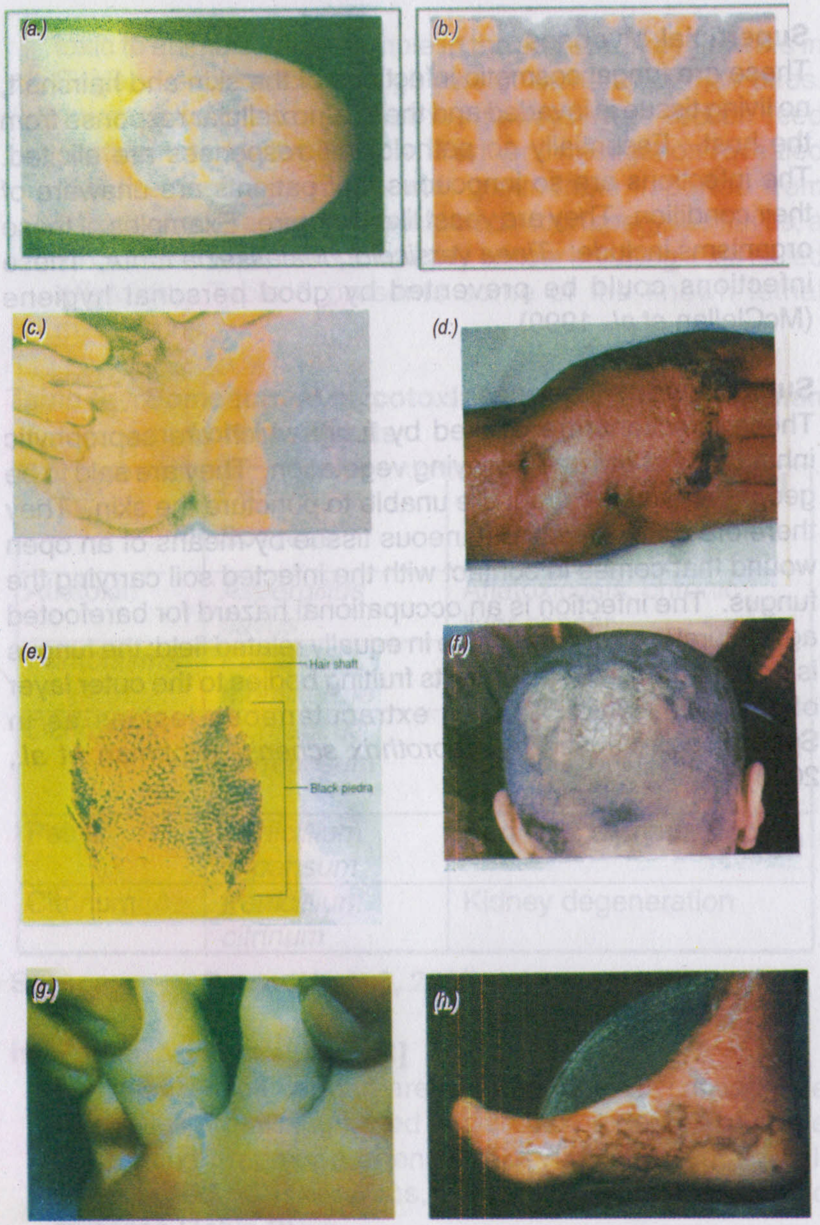


Plate 3: Human mycosis; Candidial nail infection, head infection and skin rashes, Candidial infection of the scrotum, leg and toes

Cutaneous Mycoses
Three genera of fungi are known to this group which include; *Epidermophyton*, *Microsporium* and *Trichophyton*. The infection could be transmitted through person to person contacts. The fungus also occurs in domestic animals, from whom it can be transmitted to humans. An example is *Microsporum canis* which resides on the body of cats (McClellan *et al*., 1999).

Systemic Mycoses
These fungi are dimorphic. They can exhibit a parasitic yeast like phase, but most are acquired by inhalation of spores from soil, in which the mould phase resides. They cause infection in susceptible patients. An example is *Blastomyces dematitides*, which fungus is a budding yeast in humans and a mould in culture. Infection occurs by inhalation of blastospores first in the lungs. The fungus then further spreads to the skin resulting in cutaneous ulcers and abcesses. This infection has no known preventive or control measures. It is common in the soils of Mississippi and Ohio River basins (McClellan *et al*., 1999).

Opportunistic Mycoses
Pathological responses from host infected by these groups of fungi are only elicited during immune compromised conditions like cancer, diabetes, malnutrition, leukemia, alcoholism, trauma from surgery, HIV, prolonged use of antibiotics, hormones, old age. Opportunistic infections are normally harmless and are pathogenic only in immune compromised hosts. Examples are Aspergillosis, Candidiasis and Pneumocystis (Berchiesi *et al*., 1995).

Table 9: Some fungi that cause human mycoses

Types of infection	Pathogen	Location in human body	Disease caused
Superficial mycoses	*Malassezia furfur*	Trunk neck face and arms.	Pityriasis
	Piedraria hortae	Scalp	Black piedra
Cutaneous mycoses	*Microsporum canis*	Bare parts of the skin	Tiriea corporis
	Epidermophyton flaccosum	Groin, Buttocks	Tiriea cruris
Subcutaneous mycoses	*Sporothrix Schenckii*	Puntured wounds	Sporotiricosis
	Madurella mycetomatis	Feet and other parts of the body	Maduromycosis
Systemic mycoses	*Blastomyces dermacitidis*	Lungs and skin	Blastomycosis
	Histoplasma capcapsulatum	Within phagocytes	Histoplasmosis
Opportunistic	*Aspergillus flavus A. fumigalus*	Respiratory system	Aspergillosis
	Candida albicans	Skin or mucous membrane	Candidiasis
	Pneumocystis jirovci	Lungs or brain	Pneumocystis pneumonia

Source: Adapted from Prescott *et al.*, 2005

Fungi also attack other animals, birds and fish (Plate 4) on which they cause various types of disease. They also contaminate infected animals with toxins which may render them unfit for human consumption.

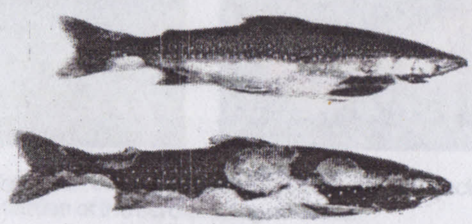


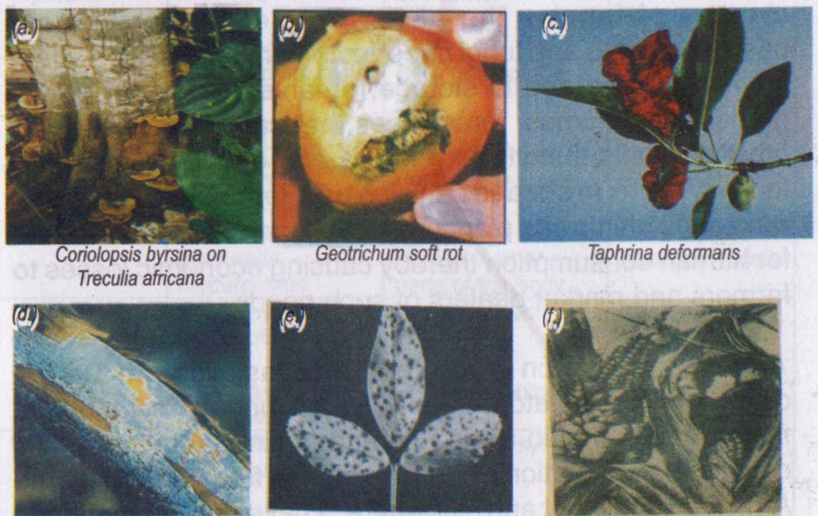
Plate 4: Effect of *Saprolegnia* on fishes

v. Fungal Diseases of Plants (Plate 5)

Most types of diseases found on plants are caused by fungi. Fungi can infect all parts of the plant: roots, stem, leaves, flowers and fruits, and fungal plant pathogens are found in all classes of fungi – the phycomycetes, ascomycetes, basidiomycetes and fungi imperfect. Fungal diseases affect crops on farms and in storage, ornamentals in our flower gardens and homes, forest trees that can yield timber and other products, furniture in homes and offices. Processed food and drink in storage can also be affected. The diseases render the plants and plant products undesirable for sale and for human consumption thereby causing economic losses to farmers and market dealers of such goods.

A fungal disease on crops can be devastating. In 1845 a disease of Irish potatoes caused by the fungus *Phytophthora infestans* resulted in a wide spread famine in Ireland. This caused the emigration of millions of Irish from Island into the American continent and elsewhere. I have earlier mentioned of a high mortality rate of poultry in Europe caused by feed prepared from infected stored groundnuts imported from Nigeria in the sixties. Many house wives who love and cook yams regularly are familiar with rotten tubers of yams especially during the months of March to July before new yams are sold in markets. The yam may look quite healthy on the outside, while the inside is already destroyed by fungi. At mile 12 and other food markets in Lagos one is familiar with the sight of heaps of pepper, tomato, vegetables and other farm produce that have been discarded as a result of decay caused by fungi and bacteria. Economic losses of such produce can be as high as 30 – 50%. The physical appearance of fungal diseases on plants include wilting, club root, root and stem rot, cankers, various types of mildews, blights and leaf spot.

Apart from reducing the quantity of quality food consumable by man, some of the pathogens of food render the food unsafe for human consumption through contaminating them with mycotoxins.



Coriolopsis byrsina on Treculia africana — Geotrichum soft rot — Taphrina deformans

Armillariella — Leaf spot of beans — Smut of maize

Plate 5: Fungal diseases of plants

MY CONTRIBUTIONS

Mr. Vice-Chancellor Sir, by the grace of God, as a Mycologist/Plant Pathologist, I have been involved in diagnosis, description and sometimes designing means of control of plant diseases both in Nigeria and overseas. With my team of Postgraduate students, I have also worked on some aspects of fungal biotechnology, the collection and identification of Nigerian mushrooms and isolation and identification of certain mushroom chemicals with medicinal potential. The area of plant pathology I have worked with includes, diseases of roots, stems, leaves, flowers, fruits and with stored food produce like sweet potatoes, cocoyam, pepper and melon seeds.

My first major contribution was the isolation and identification of fungi that caused root dieback disease of carrot in Ontario, Canada. The disease was wide spread in North America where carrots (*Daucus carota L.*) were grown in agricultural farms for commercial purposes. In 1971 the disease became very severe in Ontario and was of great concern to farmers. By September 1973 when I landed in University of Guelph, Ontario, Canada I was introduced to the farms and the problem. By May/June 1975 I was able to isolate, identify and establish the pathogenicity of fungi of genus *Pythium* as primary agents of carrot root dieback diseases. Eight species of *Pythium* were involved and they affected different carrot cultivars variously. My findings gave impetus for other researchers to discover ways of controlling the disease. Plate 6 illustrates some of the rusty root diseases of carrots.

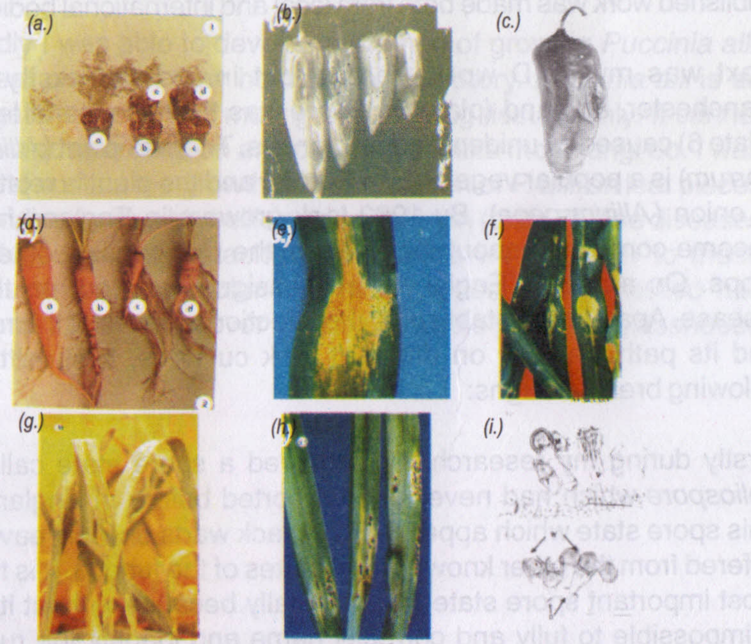


Plate 6: Left-right a & d, dieback disease of carrot; b-c, postharvest disease of pepper; e-g rust disease of leak, h- I Teliospores of *Puccinia allii*

One of the most aggressive *Pythium* sp. had not been described before and so had no specific name. It was therefore tagged *Pythium* sp. NNK 1 after the initial of my maiden name.

In 1981 before I travelled out for my Ph.D I carried out a pioneer research on post-harvest diseases of the Nigerian big red pepper (*Capsicum annuum*) popularly known as 'tatase' in Lagos. The huge amount of this pepper that was discarded in many markets in Lagos drew my attention to it and I discovered that despite its popularity and its widespread use as condiment in Nigeria, no previous report was available on the cause of its deterioration. I was able to discover that fungi were the major causal agents of post-harvest diseases of 'tatase'. The fungi were identified as *Verticillium psalliotae, fusarium sp F. Moniliforme and Alternaria alternate*. The disease included soft and dry rots (plate 6), and either hindered completely or reduced percentage germination of seeds of affected fruits. My findings were so fundamental to post-harvest disease researchers that many requests for the published work was made both from local and international bodies.

Next was my Ph.D work, carried out in the University of Manchester, England (plate 6). There was this disease of leek (plate 6) caused by unidentified rust fungus. The leek plant (*Allium porrum*) is a popular vegetable in Europe and the plant is related to onion (*Allium cepa*). By 1982 leek growers in England had become concerned about the effect of the rust on yield of leek crops. On arrival in England I was assigned to work on this disease. Apart from establishing the infection process of the rust and its pathogenicity on different leek cultivars, I made the following breakthroughs:

Firstly during my research, I discovered a spore state called *Teliospore* which had never been reported before in England. This spore state which appeared like black warts on leek leaves differed from the other known spore states of the fungus. It is the most important spore state taxonomically because without it, it is impossible to fully and correctly name and identify the rust. Specimens of the teliospores were deposited in various herbaria in England and Scotland.

Secondly during my study I also discovered that two types of hanstoria (intracellular hyphae) occurred in uredinospore-derived (dikaryotic) infection of leek leaves. This finding was contrary to existing knowledge that two distinct forms of haustoria occurred in monokaryotic and dikaryptic infections. Monokaryotic haustoria were filamentous and could be branched while dikaryotic infections were club-shaped, non-filamentous and unbranched. But my finding was that both types of haustoria were present in dikaryotic infection of leek by urediniospores of *Puccinia allii* (plate 7). When I sent the paper to USA to be published in the Phytopathology Journal, they began to query it because the author of the former concept is from there. However, *Transactions* of the British Mycological Society quickly published it without any query.

Thirdly I was able to develop a method of growing *Puccinia allii* on leaf pieces of their host in the laboratory. *Puccinia alli* is an obligate parasite that must grow on living tissues only. It cannot grow and sporulate on artificial medium like most fungi do. I was able to sustain the growth and sporulation of *P. allii* on leaf pieces maintained with gibberellic acid and kinetin (plate 7). The diseases produced on the detached leaf pieces were similar to those produced on whole plants in glass houses. This method has several advantages over the use of whole plants in glasshouse or in the field.

Plate 7: a; Intracellular hyphea (haustoria) of *Puccnia allii* in leak, b; detached leaves of leak, c; hyperparasites of *P. allii* urediniospores

During the performance of the detached leaf experiment mentioned above, another breakthrough which originated as a chance event occurred. I suddenly noticed that my detached-leaf culture plates bearing uredinospores of *P. alliii* were overgrown by various other fungi (plate 7). Rather than discard the cultures for having been marred by an unknown contaminant, I decided to examine what was ruining my detached-leaf experiment. Microscopic examinations revealed that four different fungi had parasitized the spores of my pathogen, *P. allii.* The nature of the association and a preliminary survey of their effect on leek rust diseases were carried out. The parasitizing fungi, hyperparasites as they are called, included *Verticillium lecanii, Ramichloridium schulzeri, Trichothecum roseum* and *Cladoporium uredinicola*. These fungi actually penetrated and killed the rust spores and hyphae thereby preventing rush diseases on leek leaf pieces. It was therefore suggested that the hyperparasites might prove useful in the biological control of leek rust disease.

In the section of this write up that dealt with fungi in biological control of pests, *Verticillium lecanii* is one of the fungi that has been package and sold as bio-insecticides.

Back here in Nigeria my team of postgraduate students and I have worked on cassava leaf spot, post-harvest disease of melon seeds, fungal disease of aerial parts of *Panicum maximum,* leaf curl of *Alchornea cordifolia* by *Taphrina deformia*, post-harvest fungal spoilage of cocoyam, protein enrichment of solid waste from cocoyam using *Aspergillus oryzea*, use of crude leaf extract to control post-harvest disease of melon, and other crops, antimicrobial activity of some mushrooms from Nigeria, biological control of pathogens of oil palm by *Trichoderma* species in Nigeria and a host of other research work. The highlights and contribution to knowledge made by some of these include the following:

In the late eighties when faculty of science building was surrounded by farm lands, it was observed that about 80% of cassava leaves found in this area had serious leaf spot. Since plant leaves are the factory for manufacturing food both for the plants growth and for storage in roots which later serves as food for man and livestock, such disease on leaves became a matter of concern. Further observations revealed that the disease was widespread not only on Unilag campus but also in many farms around Lagos. Our research discovered that the fungus *Colletotrichum gloeosporioides* was responsible. The fungus disintegrated the leaf tissue, and this resulted in necrosis that manifested as leaf spot.

A study carried out to determine the cause of disease in cocoyam after harvest showed that six fungi were involved. They included *Sclerotium rolfsii, Fusarium solani, fusarium moiliforme, Sclerotinia Sclerotium, Rhizoctonia solani* and *Mucor racemosus.* All except *Sclerotium rolfsii* and *Mucor racemosus* caused dry rot. Histologically the fungi caused various effects that included maceration of cells, loss of starch grains, and formation of periderm against invading hyphae and discolouration of infected tissue. Results of control experiments showed that harvested cocoyam could be preserved for more than seven months after harvest if treated with either sawdust or any of the ground spices: *Xylopia aethiopicum, piper guineensis* and *Allium sativum.*

A technological process carried out with healthy cornels of cocoyam yielded starch, flour and chips that were of acceptable quality for food. Cocoyam is therefore recommended as a good alternative source of starch and flour and should be exploited further.

Perhaps a more valuable discovery in the cocoyam-fungus biotechnology is the production of single cell protein (SCP) from both solid and liquid wastes of the process technology with cocoyam cornels using mutants of the fungus *Aspergillus oryzae* obtained from spoilt cocoyam flour. The production of SCP helps to solve environmental and industrial waste problem. It also provides a good source of protein substitute that would help lower the high prices of proteinous food like meat, fish and soy meal. In addition the use of SCP as animal feed will make more available to man many of the proteinous widely used feed materials.

Another important contribution is in the work done with stored melon seeds bought from various markets in Lagos. Melon seed (*Cucumeropsis mannii.* Naud-Holk) is a very important ingredient for soup in Nigeria. The oil is for culinary and cosmetic purposes.

In the mid nineties we observed that melon seeds bought from markets had assorted colours: creamy white, yellow-brown, dark brown, grey, redish brown and black which reduces the desirability of the seeds. We decided to investigate the reason for this. It was discovered that the different colours were due to the presence of different fungi in melon seeds. Nineteen fungi including eight species of *Aspergillus,* two species each of *Penicillium* and *Fusarcium* and one each of *Absidia, Botryodiplodia, Curvularia, Macrophomina, Mucor, Rhizopus* and *Talaromyces* were isolated. It was also discovered that the fungi variously affected the biochemical properties of melon seed. While they all increased the carbohydrate content of the seed (a kind of enrichment), all except *Aspergillus wentii* yielded slight increase in the protein content of seeds. The quality of oil in the seeds was adversely affected. A control experiment that was performed showed that

powdered dry leaf of *Ocimum gratissimum* and *Azadirachta indica* prevented infection of melon seeds for six months and promoted 100% germination of the seeds. It was suggested therefore that, those plants could serve as means of controlling the diseases. It was also discovered experimentally that melon seeds were best preserved in the unshelled form at 40°C and a relative humidity of 55%.

A histological study of the effect of the fungi on melon revealed that different fungi had different effects on the anatomy of the seed. *Aspergillus flavus* caused shriveling of embryo and cotyledon and would therefore hinder germination of the seed. *Botryodiplodia theobromae* caused discolouration of the oil globules while *Aspergillius clavatus* and *Fusarium solanii* caused collapse and disintegration of tissue. It was discovered that the strain of *Aspergillus flavus* isolated from melon seeds produced a lethal dose of the carsinogenic mycotoxin called aflatoxin. This should sound a warning to those that purchase melon seeds from the market. They should avoid contaminated melon seeds.

Another research carried out under my supervision was to collect and identify mushroom species in southern Nigeria. Fifteen such fungi were collected and identified. The isolates represented eleven species of polypores and agarics and they belonged to two families. *Ganodermataceae* and *Polyporaceae.* The fungal spp identified were, *Tremetes marianna* (Fe) (Pers). *Ryvarden T. cingulata* (three isolates) *Ganoderma lucidum* (two isolates), *G. boninense, G. colossum* (two isolates), *G. resinaceum, Daedalea quercina* (three isolates), *Coriolopsis byrsina, Schizophyllum Commune, Pleurotus* squarrosulus and *P. tuberregeum.* A key for the identification of these fungi was also developed.

Antimicrobial activity of the crude extracts of the fungal spp. was evaluated using Thin Layer Chromatographic Agar Overlay method and microtitre techniques. The solvent extracts of all the species of fungi inhibited the growth of certain bacteria (*Pseudomonas syringae* and *Bacillus subtilis*) *Ganoderma colossum* was the most active while *Pleurotus squarrosulus* was the least active in this. The extracts were not active against the only fungus, *Cladosporium herbarum,* tested.

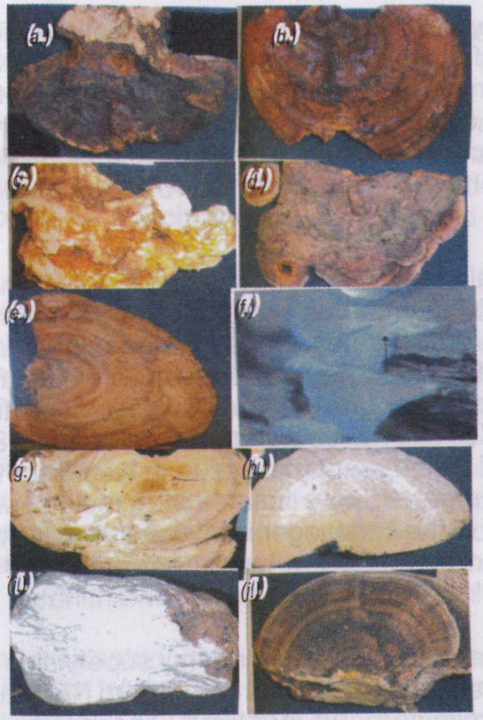


Plate 8: Macrofungi with antibacterial substances A-D *Ganoderma lucidum, G. Boninense, G. colossum, and G. Resinaceum*; E; *Coriolopsis byrsina*, F; *Schyzophyllum commune*, G; *Trametes cingulata*, H; *T. marianna*; I; *Pleurotus tuberrigium* sclerotium,J; *Deadalea quercina* (Copyright: Ofodile, 2006)

Further experiments indicated that the antibacterial activity of the fungal isolates could be associated with presence of terpenes, phenolic compounds and alkaloids. Bioassay guided fractionation of the extracts led to the isolation, purification, identification and structural elucidation of three compounds. The compound discovered thus are: Colossolactone E, 23-hydro-xy-colossolactone E and Colossolactone B (Fig. 1). Colossolactone E and B had earlier been isolated by other researchers but 23-hydroxycolossolactone E was a new discovery from our research. Colossolactone E and 23-hydroxycolossolactone E showed activity against the growth of *Bacillus subtilis* and *Pseudomonas syringae*, but Colossolactone B did not in our experiments.

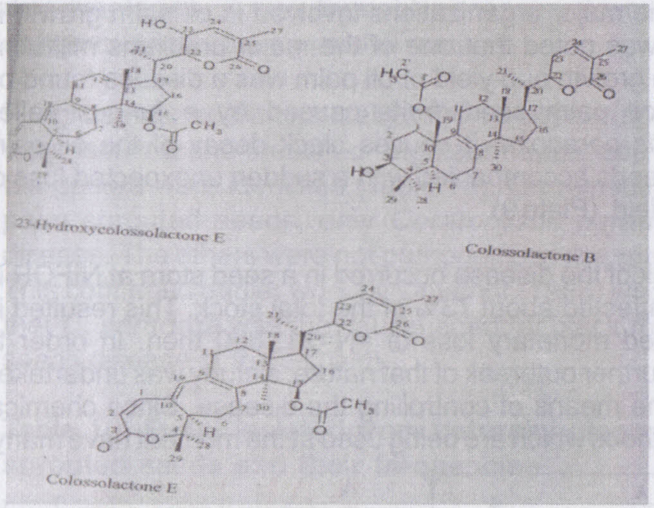


Fig. 1: Structure of antibacterial compounds isolated from *Ganoderma colossum*

Pseudomonas syringae is a well-known fruit, leaf and stem spot pathogen of many plants including beans, avocado, citrus and sorghum. 23-hydroxycolossolacton E is therefore a potent bactericide for the control of these diseases. The species of *Ganoderma* and *Tremetes* tested could be the source of the suggested chemical formulations.

The most recent of our research was to test the effectiveness of *Trichoderma spp* associated with oil palm diseases in controlling the known oil palm pathogen *Ceratocystis paradoxa.* The use of living organisms to hinder growth of or eliminate other living organisms, is known as biological control.

Nigeria was a major palm oil and palm kernel exporter before the Nigerian civil war. Today Nigeria imports palm produce from Malaysia to the tune of about 34million naira annually. This is a huge drain on our resources. The decline in palm produce in Nigeria is attributable, among other things, to pests and diseases on palms. The Nigerian Institute of Oil Palm Research (NIFOR) is one of the major organizations involved in oil palm growth in Nigeria. It was noted that one of the major problems militating against the growth and yield of oil palm was a disease found on sprouting oil palm seeds/fruits caused by a fungus called *Ceratocystis paradoxa*. It causes black decay of the oil palm sprouted seeds accompanied with a sudden unexpected loss of trees and yield. (Plate 9)

An outbreak of the disease occurred in a seed store at NIFOR in 1982 and affected about 73% of the total stock. This resulted in an estimated monetary loss of =N=21, 800 then. In order to forestall a further outbreak of that nature, a study was undertaken to determine means of controlling the disease. Since chemical control methods which are being used at the moment have many

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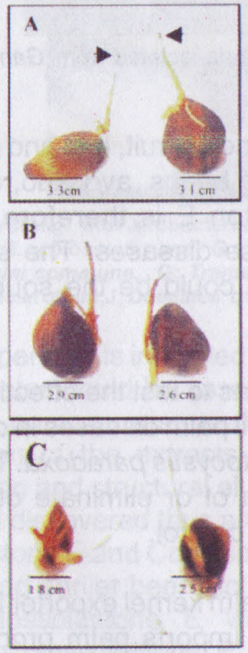

2

Plate 9 (1A-C). 1A Arrow head shows site of infection on oil palm sprouted seeds by *C. paradoxa*. 1B shows infected radicle from the apex to the base. 1C shows the control treatment without *C. paradoxa* (2A-C). 2A shows healthy oil palm seedlings treated with the bioagent (*Trichoderma* spp). and the pathogen *(C. paradoxa)*. B shows oil palm seedlings treated with the pathogen alone, showing germination failures. C shows the control treatment without any organism added.

disadvantages, it was thought necessary to explore a less dangerous and less expensive method.

Fungi associated with naturally infected oil palm sprouted seeds were isolated and identified. Eighteen fungal spp belonging to ten genera were identified (Table 10). On reinoculation into oil palm sprouted seeds, only *Ceratocystis paradoxa* showed disease. The others were not pathogenic to the sprouted seeds. This confirmed earlier work by Omamor (1985) who established that *C. paradoxa* was the causal agent of black rot of sprouted seeds disease of the oil palm.

Table 10: Fungi isolated from naturally diseased oil palm sprouted seeds and their frequencies

FUNGAL ISOLATES	% FREQUENCY
Aspergillus flavus link	7.4
Asergillus niger van Tieghem	9.9
Aspergillus terreus Thom	8.6
Ceratocystis paradoxa (Dade) C. Moreau	11.1
Curvalaria verruculosa Tandon and Billgrami	4.9
Fusarium oxysporum f.sp elaedis	7.4
Fusarium sp.	2.5
Penicillium citrinum Thom	2.5
Penicillium expansum	3.7
Penicillium purpurogenum Scoll	3.7
Pestalotia sp.	2.5
Pythium splender	2.5
Rhizopus oryzae Went and Prinsee Geerligs	7.4
Trichoderma viride	4.9
Trichoderma hamatum	7.4
Trichoderma polysporum	6.2
Trichoderma aureoviride	4.9
Saccaramycopsis sp.	2.5

Reports indicate that one of the genera of fungi isolated from infected sprouted seeds, *Trichoderma* has been used as bioagent in plant disease. For example *T. hamatum* has been used for the control of seed rot cause by *Pythium* and root disease in pea caused by *Rhizoctonia sp. Trichoderma spp* are active ingredients in a variety of commercial biofungicides used to control a range of economically important aerial and soil-borne fungal plant pathogens (Harman, 2000). Studies were therefore carried out to determine the effect of the *Trichoderma spp* isolated from oil palm sprouted seeds on the growth of *C. paradoxa*.

Four *Trichoderma* spp; *T. viride, T. Polysporum, T. hamatum* and *T. aureoviride* were tested for their ability to control the growth of *C. paradoxa* in culture plates. Volatile metabolities of each of the *Trichoderma* spp were collected in sterile potato dextrose agar plates (PDA) and then inoculated with *C. paradoxa*. They were incubated for 3 days after which radial growth measurements were taken and inhibition zones noted. The result (Table 11) showed that volatile compounds from *Trichoderma* spp significantly reduced the growth of *C. paradoxa*. When species of *Trichoderma* were grown side by side with *C. paradoxa* firm attachment of *T. viride* on spores of *C. paradoxa* resulted in penetration of the spores resulting in their subsequent death. *Trichoderma* is therefore a mycoparasite of *Ceratocystis paradoxa*. It destroys the oil palm pathogen by releasing volatile mycotoxin. Chemical analysis (thin layer chromatography, gas chromatography-mass spectrometry) of a column fraction isolated from *T. viride* identified the active bioagent as 1, 2-benzendicaboxylic acid. *Trichoderma viride* is therefore a potential biological control agent for the oil palm disease caused by *Ceratocystic paradoxa*.

Table 11: Growth of C. paradoxa in the presence of volatile compounds released by Trichoderma spp.

Radial growth (cm per day) of C. paradoxa				% Inhibition rate of mycelial growth
Treatment	Days after inoculation			%
	1	2	3	
T. viride	1.3	0.4	0.6	75.80±7.20h
T. polysporum	1.6	0.7	0.9	71.60±3.10h
T. hamatum	3.6	1.7	1.9	65.10±5.00g
T. aureoviride	1.3	0.6	0.7	21.40±7.50d
Control	4.2	2.4	2.4	0.00±0.00a

CONCLUSION

Mr. Vice-Chancellor Sir, I hope I have succeeded in enlightening my hearers on the importance of fungi to man and my contribution to knowledge in areas of Mycology, Plant Pathology, Plant Fungal Biotechnology, Macro Fungal Taxonomy, and Identification of New Fungal Bactericide.

RECOMMENDATIONS

1. Based on my experience, Mr. Vice-Chancellor Sir, I wish to recommend to future researchers in my field that they should not overlook or ignore chance occurrences during their experiment because such could turn out to be a major breakthrough of their work.
2. Because all regions of the world are teaming with populations of fungi that have hardly been explored, more Nigerians should be encouraged, through incentives to study and discover the role of Nigerian spp. in medicine bioremediation, food for man and livestock and various other industrial uses.
3. Our government should be made to realize that there is great potential for improving all areas of man's life through the study and application of findings from mycological and plant pathological studies of the fungi in our Nigerian environment. Such realization I hope, would make her inject fund specifically for this area of study.
4. Having shown the importance of fungi in medicine, and food for man, the cultivation of relevant species of fungi should be a viable project even for University of Lagos revenue generating plans. Some of the ones that could be cultivated are those known to degrade hydrocarbons and related chemicals so that they can be applied for remediating much of our agricultural land that has been devastated by oil spillage.

ACKNOWLEDGEMENTS

I give thanks to the Omnipotent and Omniscient God, who gave me the power and wisdom to undergo my studies successfully in the various institutions I attended. He also made it possible for me to raise men and women that can confidently step into my shoes, if I were to vacate my position. To Him be all the glory, honour, majesty and power forever and ever, Amen.

I am forever grateful to my late parents Elder and Elder Mrs. C.K. Okwun, who did not listen to the advice of their contemporaries not to train me beyond West African School Certificates, on gender basis.

My gratitude goes to Professor Maduewesi and many other Professors of my Alma Mater, The University of Nigeria, Nsukka, who moulded me academically through hard work and exemplary dedication to duty.

Without the funding from various institutions, my higher education may not have been possible. I therefore wish to acknowledge the following for their sponsorship: The University of Lagos for funding my Ph.D programme at the University of Manchester, England; The University of Nigeria, Nsukka and The Federal Government of Nigeria, for their sponsorship during my M.Sc. programme at The University of Guelph, Guelph, Ontario, Canada and again, the Federal Government of Nigeria for sponsoring my Higher School Studies at Queens College, Enugu.

I acknowledge the team of Ph.D. students I supervised. Without their submission to team work, we would not have made good success. The team included Dr. Adekunle, A.A., who is now an Associate Professor at UNILAG; Dr. Duru, C.C. who was formerly a lecturer in my department in UNILAG, but had to travel to USA to keep his family; Dr. (Mrs.) Ofodile, L.N. is a Lecturer at Yaba College of Technology; Dr. Eziashi, Emmanuel is an Officer in

Nigerian Institute of Oil Palm Research, and Dr. Mrs. Grace Arohkesi, a Cameroonian and is back to her home town. I salute all of you.

My stay in UNILAG would not have been that successful if not for the friendship that existed between me and a number of colleagues in my expanded department. Professor Mrs. Makanjuola and her entire family has been a friend indeed. It is impossible for me to reward their kindness and support in every area. May God bless you. My other friends that deserve to be acknowledged are Dr. Mrs. Rosemary Egonmwan, Dr. Mrs. Taiwo, Dr. Mrs. Joy Okpuzor, Dr. Mrs. Otubanjo and Dr. Mrs. Osibona. In fact, every member of Faculty of Science has shown kindness one way or the other. Remain blessed all of you.

Finally, I thank every member of my nuclear family. My dear husband, Elder U.K. Uma and my lovely children, Chisara, Ifemezue, Oluchi Uma, for their love and endurance on occasions when my academic pursuit denied them my presence and the little things I ought to do for them. My brothers, sisters and in-laws have been wonderful. Your love and care for my family cannot be forgotten. God bless you all. Amen.

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