UNIVERSITY OF PORT HARCOURT

PLANT DISEASES AND FOOD SECURITY: WAR AGAINST PLANT PATHOGENS

An Inaugural Lecture

By

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ORDER OF PROCEEDINGS

2:45 P.M Guests are seated
3:00 P.M Academic Procession Begins

The procession shall enter the Ebitimi Banigo Auditorium, University Park and the congregation shall stand as the procession enters the Hall in the following order.

ACADEMIC OFFICER
PROFESSORS
DEANS OF FACULTIES/SCHOOL
DEAN, SCHOOL OF GRADUATE SCHOOL
PROVOST, COLLEGE OF HEALTH SCIENCES
ORATOR
REGISTRAR
LECTURER
DEPUTY VICE-CHANCELLOR (ACADEMICS)
DEPUTY VICE-CHANCELLOR (ADMINISTRATION)
VICE – CHANCELLOR

After the Vice-Chancellor has ascended the dias, the congregation shall remain standing for the University of Port Harcourt Anthem. The congregation shall thereafter resume their seats.

THE VICE-CHANCELLOR'S OPENING REMARKS
The registrar shall rise, cap and invite the Vice-Chancellor to make his opening Remarks

THE VICE-CHANCELLOR SHALL THEN RISE, CAP AND MAKE HIS OPENING REMARKS AND RESUME HIS SEAT.

THE INAUGURAL LECTURE

The Registrar shall rise, cap and invite the Orator, Professor Gordian Chibuzo Obute to introduce the Lecturer.

The Orator shall then rise cap and introduce the Lecturer, and resume his seat. The Lecturer shall remain standing during the introduction. The Lecturer shall step on the rostrum, cap and deliver his Inaugural Lecture. After the Lecture, he shall step towards the Vice-Chancellor, cap and deliver a copy of the Inaugural Lecture to the Vice-Chancellor and return to his seat. The Vice-Chancellor shall present the document to the Registrar.

CLOSING

The Registrar shall then rise, cap and invite the Vice-Chancellor to make his closing Remarks.

The Vice-Chancellor shall rise, cap and make his closing Remarks. The Congregation shall rise for the University of Port Harcourt Anthem and remain standing as the Academic (Honour) Procession retreats in the following order:

VICE-CHANCELLOR
DEPUTY VICE-CHANCELLOR (ADMINISTRATION)
DEPUTY VICE-CHANCELLOR (ACADEMICS)
REGISTRAR
LECTURER
ORATOR
PROVOST, COLLEGE OF HEALTH SCIENCES
DEAN, SCHOOL OF GRADUATE SCHOOL
DEANS OF FACULTIES
PROFESSORS
ACADEMIC OFFICER

DEDICATION

I dedicate this lecture to my caring supportive wife, Dr Mrs. Agatha Ataga and my lovely children, Ehi, Usigbe, Ojeaga and Omoye for their unflinching love, encouragement and constant prayers.

ACKNOWLEDGEMENTS

Vice-chancellor Sir, my academic sojourn could not have been attained without the contributions of a number of persons.

Firstly, I wish to express with a deep sense of gratitude to Almighty God my Creator, for my life on earth, protection, achievements and making today a reality.

I am eternally indebted to my late parents, Elder Jonah Usigbe Ataga and Mrs Omon Ataga (Nee Obinyan) for inculcating in me the values of education at the formative age.

I wish to specially acknowledge and appreciate my elder brother, Dr. David Ataga for the sacrifices he made to the education of us, his siblings, by using his scholarship allowance in secondary school and university to pay our school fees. To all my other brothers, sisters, uncles, aunties, cousins, nieces and nephews, I say big thank you for your love and support.

My profound appreciation goes to my in-laws, the Edaki family of Ugbenin Ubiaja for their wonderful love and show of solidarity at all times.

I remain grateful to my supervisor and mentor, Professor C. Akueshi, for introducing me into the field of Mycology and Plant Pathology and also initiating me into academic paper writing.

I acknowledge with profound thanks my former principals at St. John Bosco's College, Ubiaja, Rev. Fr. J. Higgins and Government College, Ughelli, Late Chief D.Akpore, for inculcating in us (students) exceptional leadership qualities and discipline.

To Professor J.J. Trinci, Dr. Harry Epton and Dr. R.R. Frost of the University of Manchester, United Kingdom, I am grateful for their meticulous supervision and interest in my academic progress.

I acknowledge with sincere gratitude Professor A.E. Arinze and his late wife, Uche Arinze, Professor Chris Ejizu, Professor Iniobong Udoidem, Professor and Professor Mrs. J.D. Okoh, Professor Regina Ogali, Dr. and Dr Mrs Onumajuru and Dr. Rev.

Patrick Elukefor the long standing mutual family relationship. May God continue to sustain these cordial relationships in Jesus name, Amen.

Special thanks to my colleagues and friends in the university: Professor B. Efiuvwevwere, Professor Oamen Abumere, Professor John Otaigbe, Prof. and Professor Mrs Ade Ejele, Professor and Professor Mrs. Ethebet Nduka, Professor Henry Njoku, Professor Mrs. Eunice Nwachukwu, Late Professor Edith Elenwo, Professor Mrs. Grace Awi-waadu, Professor Bio Nyananyo, Professor Mrs A. Hart, Professor Ben Ndukwu, Professor Ike Agbagwa, Professor Osi Akpoghomeh, Professor J. Ikimalo, Professor E.G. Akpokodje, Professor and Mrs. Frank Ugiomoh, Professor Ken Anugweje, Dr. Steve Mensah, Dr. C.J. Ogugbue, Dr.Emeka Ehirim, Dr. Edachie Ochekwu and Dr. Ken Umeadi for their assistance and goodwill.

My profound gratitude goes to my Orator and Dean, Professor G.C. Obute, I am grateful for your support, encouragement and cooperation.

I wish to specially thank my present and former students, and the graduate students for their contributions and accepting the challenges we faced in the course of their study. I thank God that some of them have become Professors, Senior Lecturers and administrators in various institutions.

To the University of Port Harcourt that granted me study leave with pay to pursue my Masters and Ph.D degrees, I say thank you. In addition, my gratitude goes to Professor J.A. Ajienka, the 7th Vice-Chancellor, and Professor N.E.S. Lale, the current Vice-Chancellor, for giving me the opportunity to contribute to the academic and administrative growth of the university as Director and Dean of the School of Science Laboratory Technology.

Finally, I wish to thank and appreciate my best friend, my love, pillar of my family, mother of my children and confidante, Dr. Mrs Agatha Ataga, Deputy Registrar in charge of Academic Affairs of the University. To my lovely children, Ehi, Usigbe, Ojeaga and Omoye, i thank you for your love, understanding and constant prayer.

PROTOCOL

The Vice-Chancellor Sir,
Members of the Governing council here present,
Deputy Vice-Chancellors,
Registrar and other Principal Officers
Provost, College of Health Sciences,
Dean of Graduate School,
Deans of faculties/ School,
Distinguished Professors and Colleagues,
Great students of Unique Uniport,
Ladies and Gentlemen of the Press,
My Lords Spiritual and Temporal,
Ladies and Gentlemen.

1.0 Introduction

It is a great honour and with a deep sense of humility that I stand before you, today, to deliver the 136th Lecture in the University of Port Harcourt Inaugural Lecture series.

This is the 7th Inaugural Lecture from the Department of Plant Science and Biotechnology. Professor A.E Arinze (FNSPP), an erudite and respected Professor of Plant Pathology delivered the first Inaugural Lecture from Mycology and Plant Pathology unit of the Department in 2005. I appreciate his contributions and academic Leadership towards the development of the Mycology and Plant Pathology group in the University.

Vice-Chancellor Sir, i wish to thank you for the opportunity to deliver the first Inaugural lecture for the year, 2017, on a day the Lord has made, Let us rejoice and be glad in it. I give all glory and adoration to our creator, in Jesus Name, Amen.

Vice-Chancellor Sir, Ladies and Gentlemen, Man is one of the over two million biological species on earth. We domesticate plants and animals to ensure regular availability of food. Healthy

plants are essential to the survival of humans and animals on earth. In the process of cultivation, plants are subject to the following: Buffeting of the elements, Competition from weeds, Insect pests and Ravages of disease.

The Science of Plant Protection seeks to integrate the sciences of:

- Agronomy- study of weeds
- Entomology- study of harmful insects
- Wild life management- Study of Vernim
- Plant Pathology- Study of Plant diseases.

Ladies and gentlemen, this Lecturer is a Plant Pathologist. The word *Pathology* is derived from two Greek words: *Pathos*- ailments/ suffering; *logos*- knowledge/ Science, meaning the study of the suffering Plant. Therefore, Plant Pathology is a branch of science (agricultural, botanical or biological Sciences) which deals with study of the cause of the disease, resulting losses and control of plant diseases.

Plant Pathology consists of **four** main components:

- **Etiology**: Study of the causal agents(Living entities- Microorganisms, protozoa and parasitic higher plants), and non-living entities (Environmental or Physiological disorders)
- **Pathogenesis**: Study of the mechanisms by which causal agents incite diseases in plants
- **Epidemiology**: Study of the interaction between the causal agent and the plant host
- **Control/Management**: Study of the prevention and control of Plant diseases

2.0 Plant Diseases

Plant Pathologists seek to learn and know the nature of diseases (Science), diagnosize and control diseases (Art). As a basis for this, one must first identify the processes occurring during the growth and development of the healthy plant (Dickson and Lucas, 1982). A plant is said to be healthy or normal when it can carry out its physiological functions to the best of its genetic potential.

Disease in plants may be regarded as a process in which causal agents interfere with one or more plant cell functions. There are different definitions of Plant Disease. For the purpose of this lecture, I am adopting the definition of Agrios (1998). He defined disease in plants as any disturbance brought about by a pathogen or an environmental factors and one that interferes with manufacture translocation or utilization of food, mineral nutrients and water in such a way that the affected plant changes in appearance and/or yields less than a normal, healthy plant of the same variety.

2.1 Plant disease-causing agents

Plants suffer from diseases or disorders due to some interference in the physiological function. These abnormalities may be caused by abiotic factors, mesobiotic agents and living entities (Biotic factors) (Fig. 1)

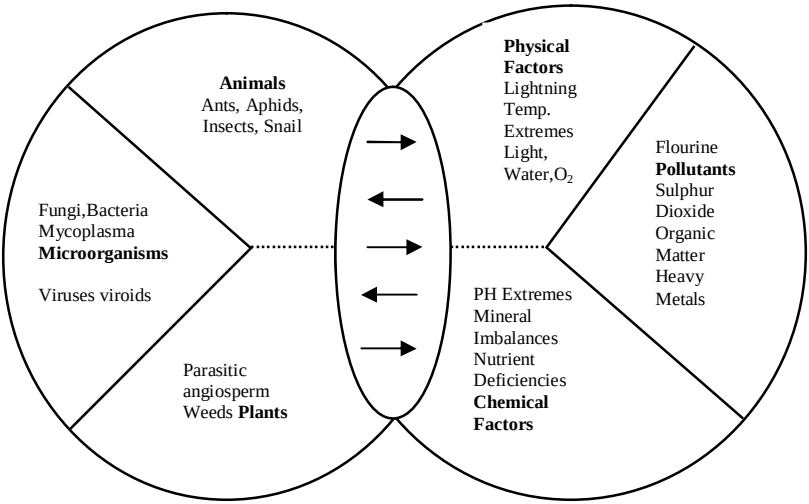


Fig 1: Agents responsible for Plant disease (Source: Dickinson & Lucas, 1982)

2.1.2 Types of plant pathogens

Plant pathogens, like those of animal and human hosts, belong to organisms such as fungi, bacteria viruses, nematodes, protozoa, and parasites higher plants. The most studied pathogens are those causing disease on food crops (e.g cassava, maize, wheat, rice, yam, potatoes etc) incuding cultivated plants for ornamental purposes and those in natural ecosystems (forestry).

- **Fungi as disease causing agent**

  Fungi are the cause of majority of diseases in agricultural and natural ecosystems.

  Most fungi exist as threadlike body (mycelium), reproduce by spores with unique propensities and mechanisms of dispersal and host infection. Fungal pathogens produce

enzymes and toxins. Penetrate plants directly or through natural openings/stomata or wounds.

- **Bacteria as disease causing agent**

  Bacteria pathogens of plants include members of the genera *Pseudomonas Xanthomonas*, *Erwinia*, *Spiroplasma* and *Phytopasmas*, Unlike fungi, bacteria are prokaryotic, grow in colonies, reproduce by binary fission, Enter plants through natural openings, wound or insect feeding site, dispersed by rain, insects and agricultural implements.

- **Viruses as disease causing agent**

  Plant viruses are noncellular and consist of protein coat and nucleic acid. Genomes of most plants viruses are composed of RNA. Viruses cannot reproduce on their own without the help of plant cells. Plant viruses are transmitted by insect vector, use of infected plant material, cutting, seed or pollen.

- **Nematodes as disease causing agent**
  - Nematodes are microscopic worms that live in soil.
  - Cause disease in plants by puncturing the plant cuticles with their stylets
  - Some nematodes feed on the outside of the root or live inside the roots
  - They reproduce by laying eggs.
  - They are spread by soil, water or agricultural equipment.

- **Protozoa as disease causing agent**
  - Few protozoa are phytopathogenic
  - *Phytomonas* spp. cause wilting disease of coconut and palms
  - Members inhabit the xylem vessels of palms.

- **Parasitic higher plants as disease causing agent**

  Certain other plants such as mistletoe and dodder can attack plants. These plants survive by sending parasitic structure, the haustoria into the phloem of host Angiosperms, to absorb water and nutrients.

2.2 How disease develops in plants.

Plant disease results from the interaction of the host, the pathogen and the environment and can be depicted in the form of a disease triangle (Fig. 2). This interaction is influenced by the environmental factors. In pathogenesis, the role of the environment is essential as it affects host plant, the pathogen and the host-pathogen complex (Loegering, 1966). This phenomenon develops for a period, decided by end of crop plant season or the death of the plant host or organ.

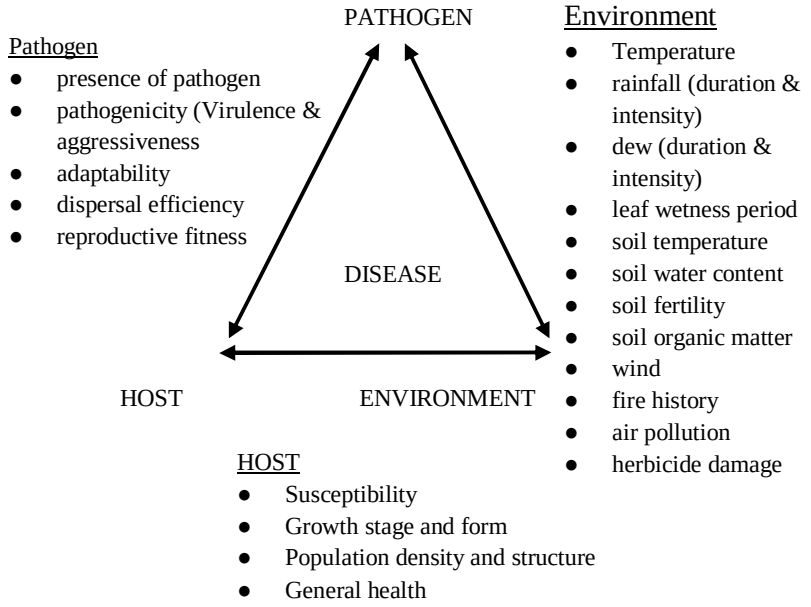


Fig. 2. Disease triangle showing factors that affect the occurrence of a plant disease ⟷ = Possible interactions between these factors. (Source: Keane and Kerr, 1977)

When a pathogen makes contact with a plant it may be able to penetrate the host or it may be completely excluded (Fig. 3)

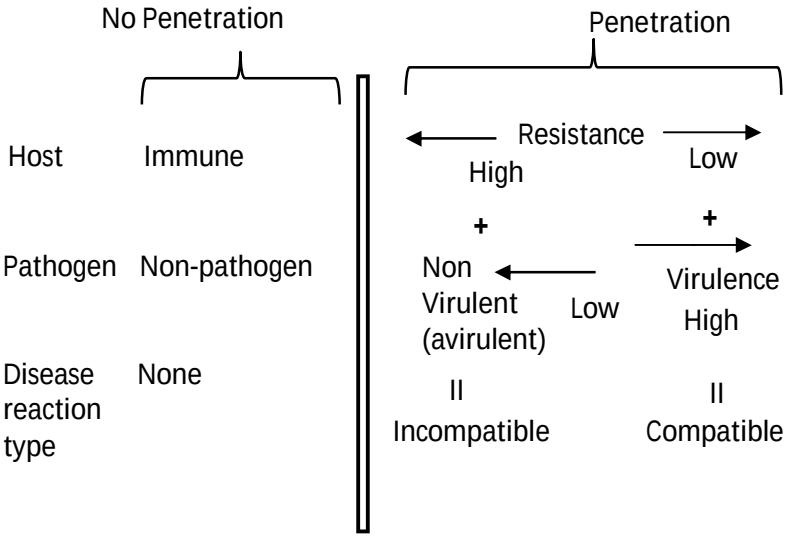


Fig. 3 Relationship between host, pathogen and disease reaction (Source: Dickinson & Lucas, 1982)

Genes determine host resistance and pathogen virulence. An interaction where disease develops is described as *a compartible* disease reaction whereas the incompartible reaction is where there is no disease (Dickinson and Lucas, 1982)

2.2.1 How pathogens cause disease

Pathogens cause disease in plants by the following:

(a) Enzymatic degradation: pathogens secrete enzymes, which catalyse the breakdown of host tissues egrot

(b) Toxins: Pathogens produce toxins, which kill the tissue in advance of the microorganism. In non-obligate pathogens, toxins cause the majority of damage to the host.

(c) Growth regulatory substances: Pathogens produce growth regulators or cause the host to produce them. They cause plant cells to enlarge or divide; eg. tumors and stunting.

(d) Genetic manipulation: All viruses are able to force plant host to produce pathogen proteins (gene products) from pathogen genetic material. This decreases the amount of protein available for normal cell division e.g tumors, stunting, twisting, yellowing, mosaic patterns.

Chaube and Pundhir (2009) described disease development as a dynamic process. This is a sequence of events that lead to disease development.

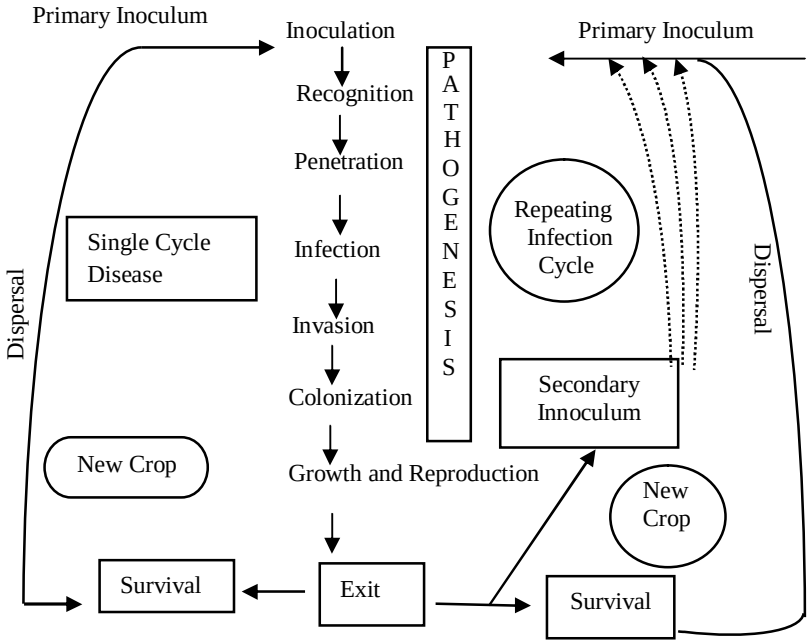


Fig 4: Stages in Pathogenesis and disease cycles (Source: Chaube and Pundhir, 2009)

2.3 Relevance of plant diseases

Vice- Chancellor Sir, Plant diseases can make a difference between a happy life and a life haunted by starvation, hunger or even death. Famine can result if methods are not in place to replace crop losses. Plant diseases may cause **annihilation** (Chestnut blight, coffee rust), **devastation** (Late blight of potato, Dutch elm disease, Citrus canker), **dissiguring** of post harvest food crops (Cankers, Scabs) and **Limiting** (root rots and wilts) (Chaube and Pundhir 2009). Plant diseases reduce the nutritive values of the produce, make the plant Products poisonous, and **limit** the kind of plants and the type of industry in an area (Arinze, 2005). Plant diseases of historical significance are presented in Table 1.

Table 1: Some Important Examples of the Impact of Plant Diseases (Source: Chaube and Pundhir, 2009)

Disease and the agent	**Locations and the impact**
Ergot of rye, wheat, pearl millet (*Claviceps* spp.)	857 AD Rhine Valley, Germany 1089 AD France 11^{th},12^{th} and 13^{th} century(France and Germany)
Late blight of potato (*Phytophthora infestans*)	Worldwide (cool humid climates) **Irish Famine** (1845-46), British defeated the Germans in World War I (1916)
Brown spot of rice (*Drechslera oryzae*)	South –East Asia, Epidemics, **The great Bengal (India) rice famine** (1943-45)
Southern corn leaf blight (*Bipolaris maydis*)	USA, Epidemic (1970), crop worth $1 billion destroyed
Powdery mildew of Grapes (*Uncinula necator*)	Worldwide ,European epidemics (1840-50), great financial loss
Downy mildew of grapes (*Plasmopara viticola*)	USA, Europe, European epidemics (1870-80), threatened wine industry in France
Blue mould of Tobacco (*Peronospora tabacina*)	Europe and USA, European epidemic (1950-60), epidemic in USA (1979), substantial economic loss
Chestnut blight (*Cryphonectria parasitica*)	USA, **annihilated** American chest nut trees between 1904-1940
Dutch elm disease (*Ophiostoma novo-ulmi*)	USA, Europe, destroying elm trees since 1930, adverse ecological impact.

Coffee rust (*Hemiliea vastatrix*)	South-East Asia (Sri Lanka), **annihilated** coffee bushes between 1870-80, changed human culture, spreading to Brazil and Colombia since 1970
Panama disease of banana (*F. Oxysporum f.sp.cubense*)	Central America (1930-55), destroyed plantation and caused financial losses
Jarrah die-back (*Phytophthora cinnamomi*)	Western Australia (1920), distruption of ecology and ecosystem, by 1982 forest area escalated to 14%
Apple scab (*Venturia inaequalis*)	Worldwide, epidemic in Kashmir (India) 1973, crop worth $40,000 lost
Citrus canker (*Xanthomonas axonopodis*)	Worldwide, millions of tress destroyed in Florida (USA) in 1910 and again in 1980s
Cassava bacterial blight (*X. Campestris pv. manihotis*)	Zaire (1970-75) caused famine
Fire blight of apple and pear (*Erwinia amylovora*)	Southern Joaquin valley, between 1901-1904, 95% pear trees destroyed
Bacterial canker of stone fruits (*P. Syringae pv.syringae*)	South Africa, annual damage exceeds $10 million
Citrus Quick decline (Tristeza virus)	Africa, America, million of trees destroyed
Cocoa swollen shoot (CSS virus)	Ghana/ Nigeria, great economic loss
Peach yellows (Phytoplasma)	Eastern US, Russia, 10 million trees destroyed
Pear decline (Phytoplasma)	Pacific Coast States and Canada- million of trees destroyed
Cadang cadang of coconut palm (Viroid)	Philipines- million of trees destroyed, huge financial losses.

3.0 Food Security

Food security is an important aspect in the wealth and economic sustainability of a nation. According to FAO/WHO (2014), it is defined as a condition where all people, at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. More than 800 million people do not have adequate food ; 1.3 million live on less than $1a day and at least 10% of world food production is lost to disease (Christou and Twyman 2004 ; FAO,

2000 and James, 2003). Plant pathologists cannot ignore the impact of these figures for food shortage and the damage to food production caused by plant pathogens.

According to Strange and Scott (2005), fourteen crop plants provide the bulk of food for human consumption (Table : 2). All are subject to disease both in the field, during harvesting, storing and marketing. The major groups of pathogens being fungi, bacteria, viruses, nematodes, and parasitic higher plants. These pathogens can, at times, seriously compromise food security. For example, outbreak of potato blight, caused by *Phytophthora infestans* resulted in death of about 1 million people due to starvation and more than a million attempted to emigrate from Ireland to the United States of America. This calamity was caused by arrival in Europe of a virulent strain of the pathogen, the high dependence of much of the Irish population on potato for sustenance, lack of resistance in the plant to the pathogen and weather conditions favourable to epidemic development. Other disasters caused by plant diseases (Table 1) include : Great Bengal Rice Famine of 1943 (Padmanabhan, 1973), Southern Corn Leaf Blight Epidemic of 1970-1971 in the USA (Ullstrup, 1972), Cassava Bacterial Blight Epidemic of 1970-1975 in Zaire etc.

These painful examples demonstrate that in areas of the world where a large proportion of the population is dependent on a single crop or a few crops, they are at risk should that crop fail owing to one or more devastating diseases. At the present time, threat is particularly great in developing countries, where populations are growing fast, poverty is endemic, the population depends on locally produced staples, and the infrastructure of extension and research and development is poorly resourced.

Table 2 : The world's staple' crops and their principal diseases (Source : Strange and Scott, 2005)

	Principal diseases				
Crop	**Fungal**	**Viral**	**Nematode**	**Bacterial**	**Oomycete**
Barley (*Hordeum vulgare*)	Mildew : *Erysiphe graminis (Blumeria graminis)* Sport blotech : *Cochliobolus sativas* Scald : *Rhynchosporium secalis* Scab :*Gibberella zeae* Rusts : *Puccinia* spp. Net blotch : *Pyrenophora teres* Barley stripe :*Pyrenophora graminea* Smuts :*Ustilago* spp.	Yellow dwarf : barley yellow dwarf luteovirus Stripe mosaic (barley stripe mosaic hordeivirus)	Root-knot nematode *(Melodogyne sp.)* Root-lesion nematode (*Pratylenchus sp*.)		
Cassava (*Manihot esculenta*)	Anthracnose : Colletotrichum gloeosporioides (*Glomerella cingulata*)	Cassava mosaic : African cassava mosaic geminivirus, East African cassava mosaic geminivirus, Indian cassava mosaic geminivirus		Bacterial blight : *Xanthomonas axonopodis pv. manihotis*	
Lentil (Lens culinaris ssp. Culinaris)	Wilt *: Fusarium oxysporum* f.sp. *lentis* Blight : *Ascochyta Lentis* (*Didymella lentis*) Rust : Uromyces *viciae-fabae* Vascular wilt : *Fusarium*				

	oxysporum f.sp. *lentis* Anthracnose : *Colletotrichum truncatum*			
Maize (*Zea mays*)	Northern corn leaf blight : *Helminthosporium turrcicum* (*Setosphaeria turcica*)	Chlorotic dwarf : maize chlorotic *dwarf machlovirus*	Stwart's wilt : *Erwinia stewartii*	Downy mildew : *Sclerospora* spp. and others
:	Southern corn leaf blight : H. mayalis (*Cochliobolas heterosphus*)	Streak : maize streak *geninivirus*	Corn stunt disease : *Spiroplasma kunkelii*	
	Rust Puccinia spp.	Yellow dwarf : barley yellow dwarf luteovirus		
	Smut : *Ustilago zeae* Stalk and ear rots : *Gibberella zeae*, *Diplodia* spp. and others			
Millet : Common millet (*Punicum miliaceum*)				Doway mildew : *Sclerospora granincola*
Finger Millet : (*Eleasine coracana*	Blast : *Pyricularia setariae* Leaf blight : *Cochliobolus nodulosus*			
Foxtail millet (*Setaria italica*)	Blast : *Pyricularia setariae*			Doway mildew : Sclerospora *Graninicola*
	Rust : *Uromyces setariae-italicae* Smut : *Ustilago crameri* Ergot : *Claviceps fusiformis*			Doway mildew : Sclerospora *Graninicola*

Pearl Millet (*Pennisetum glaucum*)			
Teff (Eragrotis lef)	Rust : *Uromyces eragrostidis*		
	Head smudge : *Helminthosporium miyakei*		
Oats *(*Avena sativa)	Crown rust : *Puccinia coronata*	Yellow dwarf : barley yellow dwarf luteovirus	Halo blight : *Pseudomonas syringae pv. Coronafaciens*
	Stem rust : *Puccinia graminis*	Mosaic : out mosaic potyvirus	
	Powdery mildew : *Erysipphe graninis (Blumerria graminis*)	Golden stripe out golden stripe furovirus	
	Smut diseases : *Ustilago avenae* and *U. hordei*		
	Leaf blight : *Phaeosphaeria avenaria*		
	Various diseases caused by Fusarium spp. including root rot and crown rot		
	Seedling blight : *Glomerella graminicola*		
	Snow mold : *Monographella nivalis*		
	Leaf blotch : *Pyrenophera avenae (P. chaetomiodes*)		
	'Groat-blackening' mainly caused by *Alternaria alternata, A. tenuissima, and Cladosporium* spp.		

Potato (*Solanum tuberrosum*)	Ear ly blight : *Alternaria solani* Black scurf : *Rhizoctonia solani*	Leafroll : potato leafroll luteorirus Mosaic viruses : notably potato X potexvirus, potato Y potyvirus		Bacterial wilt : *Ralstonia solanacearum* Bacterial soft rot : *Erwinia carotovora* Common scab : *Streptomyces scabies* Bacterial ring rot : *Clavibacter michiganesis subsp. Sepedonicus*	Late blight : *Phytophthor a infestans* Pink rot : *Phytophthora erythroseptica*
Rice (*Oryza sativa)*	Blast : *Magnaporthe grisea* Brown spot : *Cochliobolus miyabeanus* Sheath blight : *Rhizoctonia solani*		Rice tungro disease : rice tungro spherical machlovirus, rice tangro bacilliform badnavirus Yellow dwarf : barley yellow dwarf luteovirus		Bacterial leaf blight : *xanthomonas oryzae pv. Oryzae*
Rye (*Secale cereale*)	Snow mold : *Monographella nivalis* Brown rust : Puccinia recondita Ergot : *Claviceps purpurea* Eyespot : *Tapesia yallandae* Sharp eyespot : *Rhizoctonia solani* Powdery mildew : *Erysiphe graninis*	Yellow dwarf barley yellow dwarf luteovirus	Eelworm : *Ditylenchus dipsaci*		

	(*Blumeria graninis*) Stem rust : *Puccinia graninis* Glume blotch : *Phaeosphaeria nodorum* Leaf blotch : *Rynchosporium secalis*			
Sorghum (*Sorghum bicolor*)	Grain molds : complex of fungal pathogens, predominantly *Cochliobolus lunatus, Fusarium* spp. and *Mycosphaerella holci* Anthracnose : *Glomerella graminicola* Leaf blight : *Setosphaeria turcica* Zonate leaf spot : *Gloeocercospora sorghi* Tar spot : *Phyllachora sorghi* Charcoal rot : *Macrophomina phaseolina* Rust : *Puccinia purpurea* Ergot : *Claviceps sorghi*	Streak disease : maize streak geminivirus		Downy mildew- *Peronoscler ospora sorghi*
Soybean (*Glycine max*)	Rust : *Phakopsora pachyrhizi* Anthracnose : *Colletotrichum truncatum* and	Mosaic : soybean mosaic poxyvirus Yellow mosaic : bean yellow mosaic potyvirus	Bacterial pustule : *Xanthomonas axonopodis pv. Phaseoli*	Doway mildew : *Peronospora manshurica*

	Glomerella glycines Purple seed stain : *Cercospora kiku chii* Pod and stem blight : *Diaporthe phaseolorum var. sojae*			
Sweet potato (*Ipomoea batatas*)	Scab : *Sphaceiloma batatas* (Elsino batatas)	Feathery mottle : sweet potato feathery mottle potyvirus	Root-knot nematode : *Meloidogyne spp.*	Soil rot : *Streptomyces ipomoea*
	Fusarium wilt : *Fusarium oxysporum*			Little leaf : sweet potato little leaf *Phytoplasma*
	Black rot : *Ceratocystis funbriana* Java black rot : *Botryodiplodia theobromae* Scurf : *Monilochaetes* infuscans			
Wheat (*Triticum aestivum, bread wheat ; Triticum turgidum, durum* wheat)	Stem rust : *Puccinia graminis* f.sp. *tritici*	Yellow dwarf : barley yellow dwarf luteovirus		Bacterial leaf streak or black chaff : *Xanthomonas translucens pv. Undulosa*
	Leaf rust *:* *Puccinia recondita* f.sp. *tritici* Stripe or yellow rust : *Puccinia striformis* Spot blotch : *Cochliobolus sativus* Head scab and foot/root rot *:*			

	Fusarium spp. Sclerotium foot rot : *Corticium rolfsii* Tan spot *: Pyrenophora titici-repentis* Powdery mildew : *Erysiphe graminis (Blumeria graminis)* Speckled leaf blotch : *Mycosphaerella graminicola* Glume blotch : *Phaeosphaeria nodorum* Alternaria leaf blight : *Alternaria* spp. Loose smut : *Ustilago nuda* f.sp. *tritici* Rhizoctoria root rot : *Rhizoctonia* spp.	
Yam (*Dioscorea alata)*	Anthracnose : *Colletotrichum gloeosporioides (Glomerella cingulata*) Tuber rots *:* *Fusarium* spp. *Penicillium* spp. *Rosellinia* spp.)	Yam virus complex : including yam mosaic potyvirus, yam mild mosaic potyvirus.

Table 3a : Losses caused by Plant Diseases (Source : Sharma & Sugha, 1995)

	Disease	Location	Remarks
	Fungal		
1	Cereal rusts	Worldwide	Frequent servere epidemics, huge annual losses
2	Cereal smuts	Worldwide	Continuous, although lesser, loses on all grains
3	Ergot of rye and wheat	Worldwide	Infrequent, poisonous to humans and animals
4	Late blight of potato	Cool, humid climates	Annual epidemics, e.g, Irish famine (1845-1846)
5	Brown spot of rice	Asia	Epidemics, e.g the great Bengal famine (1943)
6	Southern corn leaf blight	U.S	Historical interest, epidemic 1970, $1 billion lost
7	Powdery mildew of grapes	Worldwide	European epidemics (1840s-1850s)
8	Downy mildew of grapes	U.S, Europe	European epidemics (1870s-1880s)
9	Downy mildew of tobacco	U.S, Europe	European epidemic (1950s-1960s) ; epidemic in North America (1979)
10	Chestnut blight	US	Destroyed almost all American chestnut tress (1904-1940)
11	Dutch elm disease	U.S, Europe	Destoying American elm trees (1918 to present)
12	Pine stem rusts	Worldwide	Causing severe losses in many areas
13	Dwarf mistletoes	Worldwide	Serious losses in many areas
14	Coffee rust	Asia, South America	Destroyed all coffee in southeast Asia (1870s-1880s) since 1970 present in South and Central America
15	Banana leaf spot or Sigaroka disease	Worldwide	Great annual losses
16	Rubber leaf blight	South America	Destroys rubber tree plantations
17	Fusariam scab of wheat	North America	Severe losses in wet years
	Viral		
18	Sugar cane mosaic	Worldwide	Great losses on sugar cane and corn
19	Sugar beet yellows	Worldwide	Great losses every year

20	Citrus tristeza (quick decline)	Africa, American	Millions of trees being killed
21	Swollen shoot of cacao	Africa	Continous heavy losses
22	Plum pox or sharka	Europe, North America	Spreading severe epidemic on plums, peaches, apricots
23	Barley yellow dwarf	Worldwide	Important on small grains worldwide
24	Tomato yellow leaf curl	Mediterranean countries, caribbean Basin, U.S.	Severe losses of tomatoes, beans, etc.
25	Tomato spotted wilt virus	Worldwide	On tomato, tobacco, peanuts, ornamentals, etc.
	Bacterial		
26	Citrus canker	Asia, Africa, Brazil, U.S.	Caused eradication of millions of trees in Florida in 1910s and again in the 1980s and 1990s
27	Fire blight of pome fruits	North America, Europe	Kills numerous trees annually
28	Soft rot of vegetables	Worldwide	Huge losses of fleshy vegetables
	Phytoplasmal		
29	Peach yellows	Eastern U.S., Russia	Historical, 10 million peach trees killed
30	Pear decline	Pacific coast states and Canada (1960s), Europe.	Millions of pear trees killed
	Nematode diseases		
31	Root knot	Worldwide	Continuous losses on vegetables and most other plants
32	Sugar beet cyst nematode	Northern Europe, Western U.S	Continous severe annual losses on sugar beets
33	Soybean cyst nematode	Asia, North and South America	Continuous serious losses on soybean

Table 3b : Additional diseases that may cause severe losses in the future (Source : Sharma & Sugha, 1995)

	Disease	Remarks
	Fungal	
1	Late blight of potato and tomato	New mating type of fungus spreading worldwide
2	Downy mildew of corn and sorghum	Just spreading beyond southeast Asia
3	Karnal bunt of wheat	Destructive in Pakistan, India, Nepal ; since the 1980s introduced into Mexico and in the 1990s into U.S.
4	Soybean rust	Spreading from southeast Asia and from Russia ; already in Hawaii, Puerto Rico, and South America
5	Monilia pod rot of cacao	Very destructive in South America ; spreading elsewhere
6	Chrysanthemium white rust	Important in Europe, Asia, and recently in California
7	Sugar cane rust	Destructive in the Americas and elsewhere
8	Citrus black spot	Severe in Central and South American
9	Sweet orange scab	Severe in Australia
	Viral	
10	African cassava mosaic	Destructive in africa ; threatening Asia and the Americas
11	Streak disease of maize (corn)	Spread throughout Africa on sugar cane, corn, wheat, etc.
12	Hoja blanca (white tip) of rice	Destructive in the Americas so far
13	Bunchy top of banana	Destructive in Asia, Australia, Egypt, Pacific Island
14	Rice tungro disease	Destructive in southeast Asia
15	Bean golden mosaic	Caribbean basin, Central America, Florida
16	Tomato yellow leaf curl	East Mediterranean, Caribbean, the Americas
17	Plum pox	Destructive in Europe, spreading into U.S.
	Bacterial	
18	Bacterial leaf blight of rice	Destructive in Japan and India ; spreading

19	Bacterial wilt of banana	Destructive in the Americas ; spreading elsewhere
20	Pierce's disease of grape	Deadly in southeast U.S. ; spreading into California
21	Citrus variegation chlorosis	Destructive in brazil ; spreading
22	Citrus greening disease	Severe in Asia, spreading
	Phytoplasmal	
23	Lethal yellowing of coconut palms	Destructive in Central America ; spreading into U.S.
	Viroid	
24	Cadang-cadang disease of coconut	Killed more than 15 million trees in the Philippines to date
	Nematode	
25	Burrowing nematode	Severe on banana in many areas and citrus in Florida
26	Red ring of palms	Severe in Central America and the Caribbean
27	Pinewood nematode	Widespread and becoming severe in North America

3.1 How do plant pathogen threatens food security

(a) **Fungal Pathogens :**

Fungi may cause devastating plant disease for the following reasons :

(i) Large spores are usually produced, which provide copious inoculums that infect further crops.

(ii) Short latent period, may be only a few days.

(iii) The spores are spread by surface water or in droplets by rain-splash.

(iv) They produce toxins and enzymes that destroy the plants structure.

(v) Pathogens may draw nutrients away from valuable part of the plant by the production or induction of growth regulars, such as cytokinins, and consequently reduce yields (Strange, 2003).

Fungal pathogens cause diseases in several economic crops (Table 3) *Colletotichum gloeosporioides (anamorph*) or *Glomerella cingulata* (teleomorph) are names of organism that causes anthracnose disease in tropical and subtropical crops such as yam (*Dioscorea alata*), cassava (*Manihot esculentus*), etc.

Rice (*Oryza sativium*) is second only to maize (*Zea mays*) in world production (Table 3) and is an important staple food for about half the world's population, including the poorest nations. This important crop is attacked by the fungus, *Pyricularia oryzea*, causing rice blast, resulting in 10%-30% losses of the crop every year (Talbot, 2003). In 1995, 700ha of rice in Bhutan were affected, resulting in losses of 1090 tonnes (Tinlay et al, 2000). *Pyricularia oryzae* also affect other cereals such as finger millet (*Eleusine corocana,)* which, when attacked before grain formation, can suffer complete loss of yield (Ekwamu, 1991). Such an attack has serious consequences in India, East Africa, and Northern Nigeria where millet is an important food security crop.

Some fungi that infect staple foods before and/or after harvest produce powerful poisonous mycotoxins that are not only poisonous but also carcinogenic. Fumonisin toxins, $RB_1(FB_1)$, isolated from cultures of *Gibberella Fujikuroi* (anamorph *Fusarium moniliforme*) that infect maize, were discovered to cause high level of esophageal cancer in Transkei region of South Africa (Merrill *et al*, 1996).

- *Phytophthora infestans* (an Omoycete) meaning plant destroyer, cause excess of $5 billion losses in potato crop and control measures (Brich and Whisson, 2001).
- *Pythium aphanidermatum* and *Pmyriotylum*
  Cause severe root rot in pepper with 42% and 62% plant mortality, respectively (Chellemi *et al*, 2000)

- Members of the downy mildews such as *Peronosclerospora*, *Peronospora*, *Pseudoperonospora*, *Plasmospora*,

Scherophthora and *Sclerospora* regularly cause severe diseases on a variety of Maize, sorghum, millet, Onion, Soybean, Cucurbits and grapes (Thakur and Mathur, *2002*).

(b) **Bacterial Pathogens :**

Several genera of bacteria are devastating Pathogens :

- *Xanthomonas* species cause 350 different Plant diseases (Leyns *et al*; 1984) for example; *Xanthomonas oryzae pr.oryzae* is the cause of bacterial blight disease of rice and severely reduces the production.
- *Ralstonia* (*Pseudomonas solanacearum),* a pathogen with worldwide distribution, causes diseases in more than 200 host species belonging to 50 Families including Potato, bananas, tomatoes, eggplant, Pepper and geranium (Schell, 2000).

(c) **Viral Pathogens :**

- Several of the 700 known Plant Viruses cause devastating disease and have wide host ranges.

- Barley yellow dwarf Viruses (BYDV) are distributed Worldwide and infect over 150 Species of the Poaceae, including Wheat, Rice, Maize oats and barley (Edwards *et al* : 2001).
- African Cassava Mosaic Virus (ACMV) and East African Cassava Mosaic Virus (EACMV) cause diseases, which is a very important food security Crop in Sub- Saharan Africa, Asia and Latin America (Strange and Scott, 2005).

In the later 1980s, a severe form of Cassava Mosaic disease was reported from Uganda. This was caused by double infection with a recombinant Virus derived from ACMV and EACMV called Ugv

and one of the Parental strains, ACMV (Zhou *et al :* 1997) The severity of infection spread rapidly from Uganda to large parts of Kenya, Tanzania, Sudan and the Democratic Republic ofCongo (Legg, 1999), resulting in famers to abandon Cassava Cultivation and destabilizing food security in East Africa (Legg, *et al* : 2004).

(d) **Nematodes :**

- Two orders of Nematodes (out of 17) the *Tylenchida* and the *Dorylaimida*, contain members that are Plant Pathogens and cause serious Crop losses.
- *Ditylenchus dipsaci*, one of the most devastating nematode Species, attacks 450 different Plant Species including weeds.
- *Meloidogyne hapla*, attacking many important Crop Plants such as groundnut, potato, Carrot and Onion and many cause total crop loss (Evans *et al* : 1990).
- Soybean cyst nematode, *Heterodera glycines* caused an estimated & 884 million losses in 1990 (Sciumbato, 1993).

(e) **Parasitic higher Plants**

- Over 3000 species of parasitic plants are documented. *Striga* and *Orobanche* are the most notorious (Stewart and Press, 1990).
- *Striga* Spp. infect more than two thirds of the million hectares of cereals and Legumes grown on the African continent, affecting the lives of over 100million people in 25 Countries. Losses may be total or cultivation of some crops abandoned due to infestation of the area (Estabrok Yoder, 1998).
- Broomrapes (Orobanche, Spp.) are parasitic weeds that infect the roots of dicotyledonous crops. They lack Chlorophyll and derive entire nutrients from their hosts, affecting the health and productivity of the host plant.

4.0 Identification of Plant Diseases

Vice-chancellor, Sir, Ladies and Gentlemen, plant pathologists are usually asked the following questions: "What is wrong with my plant?" How do I get rid of the problem? It may be late to help the diseased plant if proper *diagnosis* is not made.

Diagnosis is an art, science or both. Mclntyre and Sands (1977) considered diagnosis as an art and they rightly argue that diagnosis is done by percept and experience. Today, visual observations based on *experience*, *percept* and *intuitive judgement* is still the mostly used method for identification of plant diseases.

The purpose of pathogen detection and disease diagnosis includes:

- To determine the presence and quantity of the pathogen.
- To assess the effectiveness of the protection techniques.
- To certify planting materials for quarantine and certification.
- To determine disease incidence and yield loss.
- To detect new pathogens rapidly
- To study disease development and gene functions.

The techniques used to observe diseased plants include:

- Microscopy, isolation and identification of microorganism associated with diseased plants (Ataga & Akueshi, 1996; Ataga & Obele 2006; Amieyo & Ataga, 2006; Ataga & Ota-Ibe, 2006).
- Chemo-diagnostic methods for detection of viruses, mycoplasma like-organisms, fungi and bacteria (Chastain and King, 1990; Takenaka and Kawasaki, 1994, Hooker, 1993 and Linder, 1961).
- Electron Microscopy employed for rapid detection of viruses and phytoplasmas in diseased plants (Narayanasamy, 1997).
- Serodiagnostic methods based on the production of antibodies specific to individual which allow the rapid and accurate identification of plant pathogens (Clark, 1997).

- Nucleic acid based method characteristics of plant pathogens are determined by the structure of their genetic material in the form of DNA (Fungi and bacteria) and RNA (Plant viruses).

5.0 Symptoms

What are Symptoms? Symptoms are the visible expression of a disease as a response to a pathogen. They are expression of pathological activities, signs of disease conditions, evidence of sickness or injury on the host plants. The visible presence of pathogen structures or products of a pathogen on a diseased plant are called *signs*. Characteristic symptoms and signs are used for the preliminary diagnosis of diseased plants. Major symptoms caused by fungi, bacteria, viruses, nematodes are summarised in Tables 4 and Plate 1.

Table 4: Symptoms of Disease Caused by Fungal Parasites (Source: Chuabe and Pundihir, 2009)

Symptom	Fungus	Disease
Pathogen seen as a white, gray, brownish, or purple growth on host surface; the superficial growth tangled cotton or downy growth,	Downy mildew fungi, (Members of family-Penonosporaceae).	Downy mildews
Enormous numbers of spores formed on superficial growth giving host surface a dusty or powdery appearance; black fruiting bodies (cleistothecial) may also develop.	Powdery mildew fungi, (members of order-Erysiphales).	Powdery mildews
Pustules of spores, usually breaking through host epidermis, dusty or compact, red, brown, yellow, or black in colour.	Rust fungi (order-Uredinales	Rust diseases
Black or purplish black dusty mass formed on floral organ particularly the ovulary.	Smut fungi (order-Ustilaginales)	Smut diseases

White blister-like pustules breaking open the epidermis and expose powdery mass of spores	*Albugo*	White blister or rust
Excessive growth of host tissues; abnormal increase in size due to abnormally increased cell size (hypertrophy) or increased cell divisions (hyperplasia)	*Albugo*, downy mildew fungi, root knot nematodes, MLO (Phytoplasma)	Galls, curl, pocket bladder, hairy root, knots, witche's, broom, clubbed roots, tumefaction, wart.
Reduced growth of host tissues, abnormally reduced size (atrophy)	Several fungi	Stunting, dwarfing, curling, and puckering.
Localized lesions on host leaves consisting of dead and collapsed cells	Several fungi	Leaf spots
Uniform, general and very rapid browning and death of foliage (leaves, branches, twigs, floral organs)	Several fungi	Blights
Necrosis and sunken ulcer like lesions on stem, leaf, flower, or fruits	*Colletotrichum* spp. *Glomerella* spp.	Anthracnose diseases
Necrosis. Localized usually surrounded by callus	Several fungi	Cankers
Disintegration or decay of part of all the root system	Many fungi	Root rots
Loss of turgidity; flaccid; dropping of leaves; or shoot due to disturbance in the vascular system, of root or the stem	*Fusarium, oxysporum* Group; *Verticillium,* spp:	Wilts
	Pythium; Rhizoctonia	Dumping off of seedlings

Powdery Mildew on *Vernonia amygdalina*

Streak on *Cynbopogon citratus*

Leaf spots on *Psidium quajava*

Necrotic Lesion on *Carica papaya*

Streak on *Allium cepa*

Damping off for watermelon Seedling caused by *Rhizotonia*

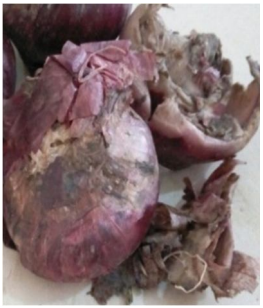
Leaf spots on *Aleo vera*

Galls on *Persia americana*

Stunted growth

Black rot on tomato

Soft rot on Potatos



Watery rot on onion

Fungal mycelia growth on pepper

Leaf spot on *carica papaya* fruit

Tomato canker

Plate 1 : Disease symptoms of Nigerian crops
(Sources : Ataga & Associates/www.erec.ifas.fl.edu/plant pathology guidelines. Accessed 10 September, 2016)

6.0 Plant disease management/war against plant pathogens

Vice-Chancellor Sir, Ladies and Gentlemen, in the past, plant pathologist's main objective was to eradicate pathogen to control diseases. The war against plant pathogen was rarely won on very few diseases. No plant pathogen has ever been wiped out from the face of the earth. Disease incidence will continue to persist as long as the pathogen survives and we continue to cultivate the host plant.

The main objective of plant pathology is the economic control of plant disease. However control evokes the notion of finality, the final disposal of the problem (Apple, 1977), which is not true in nature. Management conveys the concept of a continuous process and is based on the principle of maintaining the damage or loss below an economic injury level. For effective and economic control of plant diseases, knowledge of the cause of disease, mode of survival and spread of the pathogen, host-pathogen relationship and effect of the environment on disease development and spread are essential. The basic requirements for effective management of plant diseases are:

- Correct diagnosis of diseases to identify the causal agents, the pathogen, which is the real target of any disease management,
- Knowledge of the disease/pathogen cycle,
- Environmental factors that influence the cycle
- Cultural requirements of the host plant

Plant disease management requires a detail understanding of all aspects of crop production, economics, environmental, cultural, genetics and epidermiological information upon which the management decisions are made. Disease management can be implemented by manipulating the host, environment and the pathogen.

(a) **Host:**

This is by increasing its resistance to disease. This is the most effective and least expensive method of controlling diseases. It utilizes in-built mechanism to resist activities of pathogens. The infection or subsequent damage by disease causing agents can be rendered ineffective through genetic manipulation or by applying chemicals such as fungicides that prevent or halt infections in plant hosts.

Use of resistant varieties: Development of resistance in host is done by

(i) selection and hybridization for disease resistance
(ii) chemotherapy
(iii) Host nutrition
(iv) use of biotechnological tools such as tissue culture, genetic engineering and protoplast fusion are being used to develop resistant cultivation of economic crops/plants.

(b) **Environment**

The environment can be modified so that it is suitable for plant growth but not for disease development. This can be achieved by improving soil drainage, changing the time of sowing, reducing the density of plants in a crop or changing irrigation practices to produce conditions unfavourable to particular pathogens or diseases.

(c) **Plant Pathogens**

The aim of the raging war against plant pathogens is to reduce inoculum to such a level that economic losses of crops/plants are minimum. The pathogen can be manipulated by using the following principles:

(i) **Avoidance of the pathogen :**

This involves those methods which avoid the contact of the host with pathogen or susceptible stage of the plant and conditions favourable for the pathogen to coincide.

- Choice of geographical areas on suitability of prevailing environmental condition for particular crop e.g temp and relative humidity. Example: certain fungal and bacterial diseases are more serious in wet areas than in dry areas.

- Selection of a field:
  Soil borne diseases can be avoided e.g rot of sugar cane late blight, wilt diseases root knot nematodes, bacterial wilt diseases.

- Adjustment of time of planting:
  In this concidence of susceptible stage of crop and environment favourable for pathogen is taken care of e.g. pea planted soon after rain, when soil temperature and moisture level are high shows high incidence of root rot blight and wilt (Chaube and Singh, 1990), late planting is recommended.

- Use of disease escaping varieties, which depend on the characteristics of growth and time of maturity e.g pea which matures early usually escape damage from powdery mildew and rust.

- Selection of seeds and planting material e.g smuts, rot of sugar cane, virus free potato tubers etc.

(ii) **Exclusion of Inoculum of the pathogen**

This is a legal restriction of the movement of agricultural commodities for the purpose of exclusion, prevention or delay in the spread of diseases in uninfected areas. Exclusion is to prevent spread of the disease and this can be achieved by :

- Treatment of seed and planting material.
- Inspection and seed certification.

This is achieved by setting certification standards which be common for all crops or specific standards, applicable to individual crop or group of crops.

- Quarantines which may be

(i) exclusive quarantine or embargo
(ii) regulatory quarantine
(iii) domestic quarantine

6.1 How do we enforce quarantine.

- Embargoes
  - Prohibits any movement of susceptible or affected plant materials from quarantined area into protected areas.

- Inspection and certification
  - Many plant propagules/seeds entering any region/country are inspected regularly at the point of entry (land, sea, airports) and allowed entry only after

having been declared free of injurious insects and pathogens. It is done at point of origin as well as point of destination.

- Disinfestations of imported material
  - The planting materials entering new area may require disinfestation treatments either at the point of origin or at the point of entry.

- Special permits for imports
  - Plant and plant products

(iii) Eradication of inoculum of the pathogen

Eradication is the methods used to get rid of pathogen which is already present in a diseased host. It does not imply after destruction of a pathogen, but reduce the populations of the plant pathogens below their economic thresholds. Eradicative methods which kill pathogens during the survival stage of their life cycle include :

(a) **Cultural methods**

Practices used to alter the environment, the condition of the host and/or the behaviour of the pathogen, to achieve economic management of disease. Singh (2000) described the procedures used for disease control through cultural practices. (Fig 5)

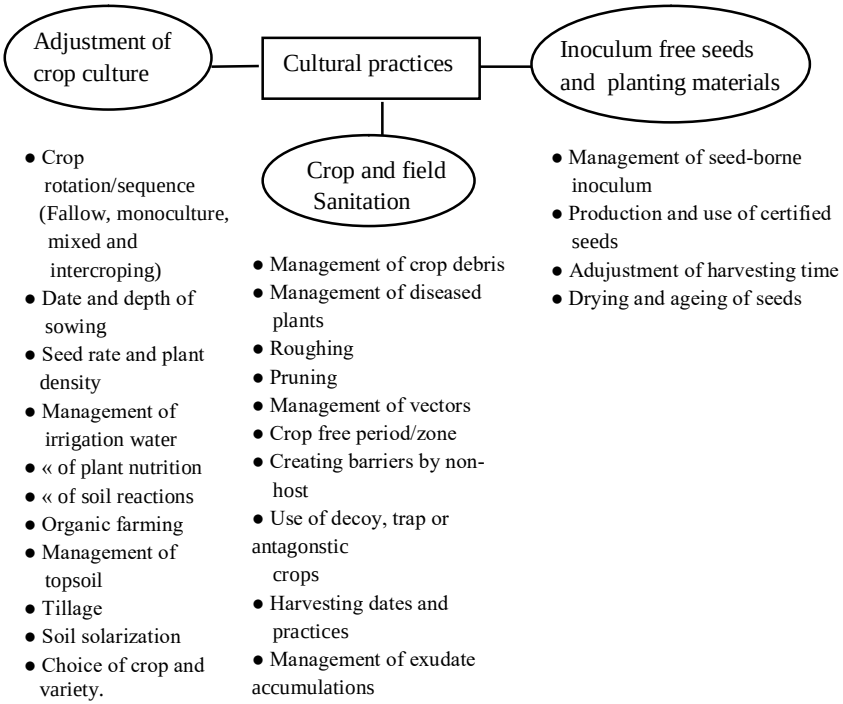


Fig 5: Procedures for disease management by cultural methods (Source: Singh, 2000)

(b) **Biological control of plant pathogen**

Biological control or biocontrol have been used in entomology to describe the use of live predatory insects to suppress populations of different pest insects. This was well documented by Lale (2010). In plant pathology, the term applies to the use of microbial antagonists to suppress diseases. In both fields, the organism that suppresses the pest or pathogen is called biological control agent (BCA). Broadly, biological control has been applied to the use of the natural products extracted or fermented from various sources such as plant extracts.

Biological control of plant pathogens can be achieved by use of three strategies:

(i) Regulation of pathogen population at or below economic threshold e.g. plant parasitic nematodes.

(ii) Exclusionary system of defense, such as rhizosphere or phyllosphere microflora colonizing infection courts and giving protection.

(iii) Self-defense through resistance to disease: This is achieved by cultural practices induction by inoculation of plants with avirulent or mild strains of the pathogen or by expression of genes for biological control mechanisms in transgenic plants.

Biological Control

		Regulate the pest population	Exclusionary defense system	Self defense
Pest used against itself	**A**			
Natural enemies; antagonists		Sterile males	*A. radiobacter*	Cross-protection
Part or animal that benefits		Parasitoids	Protection of fruits	Induced-resistance
		Trapicover crop	Dense sowing of cereals	Host plant resistance
Pest used against Itself	**B**			
Natural enemies ; antagonists		Genetically modified vector	Ice-minus *P. syringae*	Tobacco mosaic Virus coat protein gene
Part or animal that benefits		Bt gene in *B. thuringiensis*	Bt gene in *P. fluorescens*	Bt gene in tobacco
		Trap plants	Modified growth habit	Genetically engineered plants

Fig. 6: Examples of biological control of plant pathogens categorised according to strategy and biocontrol agent –
A = mainly traditional examples
B = mainly experimental, involving research and development (Source: Chaube and Pundhir, 2009).

The agents of biological control of plant pathogens that can be used in the three strategies include:

1. **Use of pest or disease causing agent itself** e.g the ice-minus strain of Pseudomonas syringae are used to exclude ice nucleation strains of *Pseudomonas syringae* from foliage of frost sensitive plants (strategy 2, Lindow, 1983). Cross protection provided by inoculation with mild strain against virulent strains provides control by inducing self-defense (strategy 3, Ataga *et al*, 1998).

2. **Antagonists or natural enemies:**
These are the classical biocontrol agents; reduce weed population (strategy 1). Antagonists are applied to pruning wounds to provide protection against *Fomes* and *Armillaria* (Strategy 2, Rishbeth, 1979). Induced systemic resistance by Rhizobacteria is an example of biocontrol by initiating self-defense in host (strategy 1 Chaube and Pundhir, 2009).

3. **Manipulating Plants**:
Plants can be used as trap to the population of plant parasitic nematodes (strategy 1). Dense sowing cereal crops prevent growth of weeds (strategy 2). Host plants can be manipulated genetically to boost up biochemical disease resistance (Singh *et al*, 2001).

Table 5: Biocontrol Agents used for the Management of plant Diseases (Source: Singh *et al*, 2001).

Antagonistic Genus	Common Species	Type of Pathogens
1	2	3
Fungi		
Ampelomyces	*A. quisqualis*	*Sphaerotheca fuliginia.*
Arthobotrys	*A. dactyloides*	Nematodes
	A. oligospora	*Ditylenchus mycellophagous, Meloidogyne spp.*
Ascocoryne	*A. sarcoides*	*Coniophora puteana, Polysporus tomentosus, Heterobasidium annosum*
Candelabrella	*C. javanica, C. musiformis*	Nematodes
Catenaria	*C. auxilaris, C. anguillulae*	Nematodes *Heterodera schachtii, H. Avenae*
Chaetomium	*C. globosum, C. Cochliodes*	*F. roseum Helminthosporium victoriae, Penicillium, Mucor, Venturia inequalis*
Cladosporium	*C. herbarium, C. cladosporiodes*	*F. roseum, B. cinerea, N. galligena, V. Inequalis*
Coniothyrium	*C. minitans*	*S. sclerotioruml, S. trifolirum, S. cepivorum, B. cineria, b. Fabae, Claviceps purpurea, S. Rolfsii*
Dactylaria	*D. vermicola*	*Various nematodes in soil*
Dactylella	*D. ovipurasitica*	Nematodes, *Heterodera schachtii*
	D. doedycoides	*Trichodorous semipenetrans*
	D. lobata	*Acribeloides* spp. *Meloidogyne*
Fasarium	*F. roseum*	*Fusarium* spp.
	F. lateritium	
	F. oxysporum	
Gliocladium	*G. virens*	*Ceratocytis fimbriata*
	G. roseum	*Helminthosporium sativum,*
	G. catenulatum	*Trichothecium, R. solani.*

		S. sclerotiourum, Fusarium, Pythium
Nematophthora	*N. gynophila*	Nematodes, *H. avenae, H carotae, H. cruciferae,etc.*
Penicillum	*P. liliacium*	*S. cepivorum, Pythium, R. Solani,*
	P.nigricans	*Verticillium*
	P. frequentens	*Alboatrum, P. ultimum,*
	P. oxalicum	*Cephalosporium*
	p. chrysogenum	
Pythium	*P. oligandrum*	*F. roseum* f. sp*. Cerealis, F. nivale, G. graminis.*
Trichoderma	*T. viride*	*R. solani, S. Sclerotiorum, Pythium,*
	T. harzianum	*Armillaria,*
	T. polysorum	*Phytophthora, S. Rolfsii,*
	T. koningii	*Heterobasidium annosum*
Tubercularia	*T. maxima*	*C. rebicola, C. quercuum f. sp. Fusiforme*
Verticillium	*V. chlamydosporium*	*V. dahilae, Heterodera avenae,*
	V. lecanii	*Uromyces dianthi*
	V. bigttatum	
	V. nigrescens	
Bacteria		
Agrobacterium	*A. radiobactor*	*A. radiobactor pv. Tumefaciens*
Bacillus	*B. subtilis*	*Phythium, R. Solani, P. cinnamoni, S.*
	B. cereus	*cepivorum,*
	B. penetrans	*F. roseum*
Bdellovibrio	*B. bacteriovorous*	*P. syringae pv. Glycinea*
Erwinia	*E. herbicola*	*E. amylovora*
	E. uredovora	
Pseudomonas	*P. fluorescens*	*Guanomyces graminis, Fusarium*
	P. cepacia	*oxysporum (*f. sp*)*
	P. putida	*R. solani, S. Rolfsii, Pythium, etc.*
Streptomyces	*S. griseus*	*Phomopsis, Fusarium, Gaeuanomyces*
	S. praecox	
	S. lavendulae	

Integrated Disease Management (IDM)

Integrated Disease Management (IDM) (adopted from Integrated Pest management applicable to insects) is an ecosystem-based strategy that uses all suitable techniques that complement each other with the aim of keeping the disease below the threshold at which economic damage occurs. This system also aims to avoid the problem of developing resistance in pathogens to widely used fungicides or antibiotics. In IDM, various control methods are combined for effective and economic management of the disease

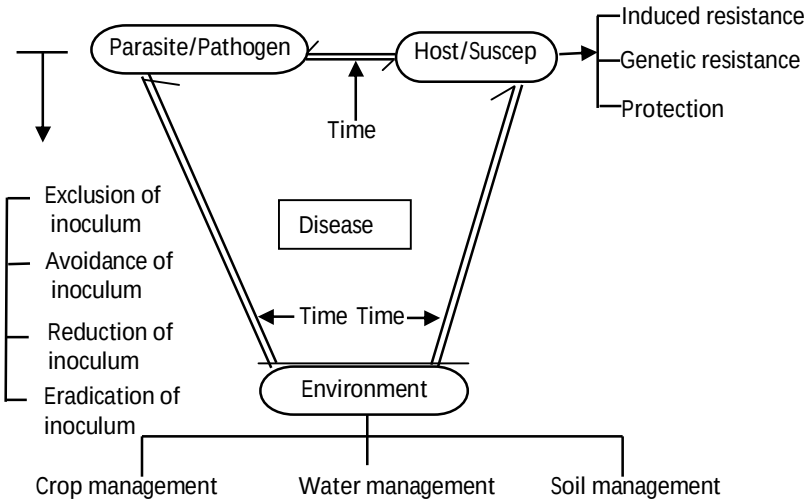


Fig. 7: Integrated disease management (IDM)(Source:Chaube and Pundhir, 2009).

7.0 Contributions to scientific knowledge

Vice-Chancellor Sir, let me now present very briefly on some of our (i.e. associates and I) humble contributions, as plant pathologists, to scientific knowledge.

Crop plants are susceptible to pathogenic attack in the field, during harvesting, and storage. Plant diseases reduce yield, cause economic losses and market values of economic crop plants. We,

therefore, have carried out studies on fungi associated with some Nigerian economic crops, the effect of infection on the nutritional composition of the crop and management of the disease.

7.1 Fungi associated with pre- and post-harvest crops

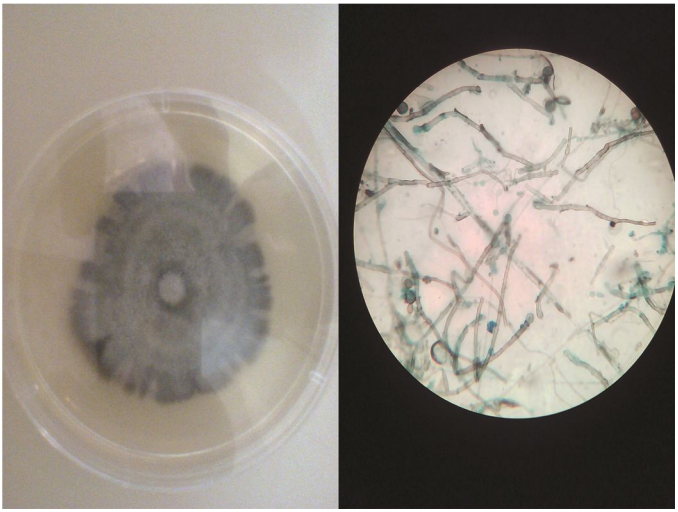
Studies on the mycoflora of: Sunflower (*Helianthus annus L*.) seeds, groundnut (*Arachis hypogaea L*) seeds, African yam bean (*Sphenostylis stenocarpa* (Hoschst ex A. Rich)Harms) seeds, African Pear (*Dacryodes edulis* (G.Don) Lam) fruits, sweet potato (Ipomoea batatas (L.) Lam) tubers, wild mango (Ogbono)(*Irvingia gabonensis* (Aubry-Leconte ex O'rorke) Bail) seeds, maize (*Zea mays L*.) grain, yakwa (*Hibiscus sabdaritta L.)* seeds, cowpea (*Vigna unguiculata* (L.) Walp) seeds and physic nut (*Jatropha curcas)* showed that several genera of fungi are associated with the crops. Many genera of fungi were isolated and identified from the seeds, fruits and tubers of these crops (Table 6 and Plate 2).

Table 6: Fungi isolated from Nigerian crops

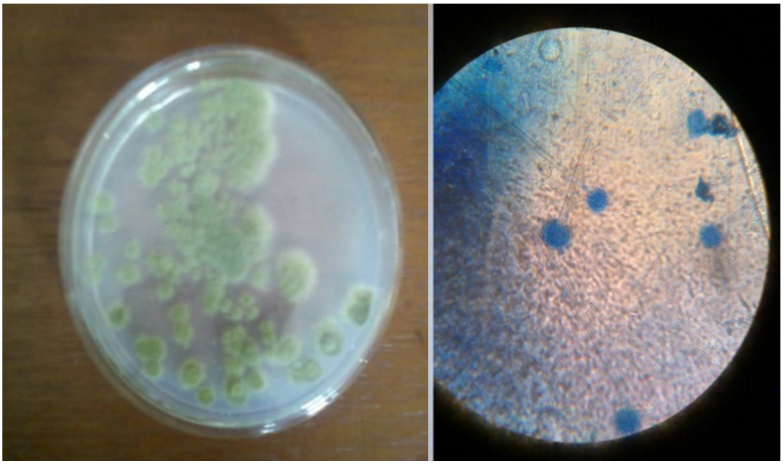
Crop	Fungi Isolated	Reference
Sunflower (seeds)	*Alternaria alternata*	
	Aspergillus niger	
	Chaetomium globosum	Ataga and Akueshi
	Currularia lunata	(1996)
	Fusarium spp.	
	Macrophomina phaseolina	
	Phoma sp.	
	Verticillium dahliae	
Goundnut (Seed)	*Aspergillus flavus*	Umechuruba *et al*
	Aspergillus niger	(1992)
	Macrophomina phaseolina	
African Yam Bean (Seeds)	*Botryodiplodia*	Ataga and
	theobromae	Umechuruba
	Fusarium pallidoroseum	(1998)
	Penicillum oxalicum	
African Pear (Fruit)	*Aspergillus niger*	Ataga and Obele
	Aspergillus flavus	(2006)

	Rhizopus stolonifer *Fusarium pallidoroseum* *Botryodiplodia theobromae*	
Sweet Potato (Tubers)	*Aspergillus flavus* *Aspergillus niger* *Fusarium solani* *Fusarium oxysporum* *Phoma exigua* *Botryodiplodia theobromae* *Rhizopus stolonifer*	Amienyo and Ataga (2006)
Wild Mango (Ogbono) (Seed)	*Aspergillus flavus* *Aspergillus niger* *Botryodiplodia theobromae* *Fusarium semitectum* *Rhizopus stolonifer* *Penicillum expansum*	Ataga and Ota-Ibe (2006)
Maize (Grain)	*Aspergillus flavus* *Aspergillus niger* *Aspergillus tereus*	Chukunda, Ataga and Ukoima (2008)
Okra (Seed)	*Curvularia lunata* *Macrophomina phaseolina*	Chukunda, Ataga and Ukoima (2006a, 2006b)
Hibiscus sabdariffa (Yakwa) Seed Rosella (Yakwa)	*Aspergillus niger* *Aspergillus flavus* *Fusarium oxysporum* *Penicillium chrysogenum*	Nwaukwu and Ataga (2012)
Cowpea (Seed)	*Aspergillus niger* *Botryodiplodia theobromae* *Fusarium oxysporum* *Rhizopus stolonifer*	Iyanyi and Ataga (2014)
Groundnut (Seeds)	*Aspergillus niger* *Aspergillus flavus* *Cercospora arachidicola* *Macrophomina phaseolina* *Phoma exigua* *Fusarium oxysporum*	Akinseye and Ataga (2014)

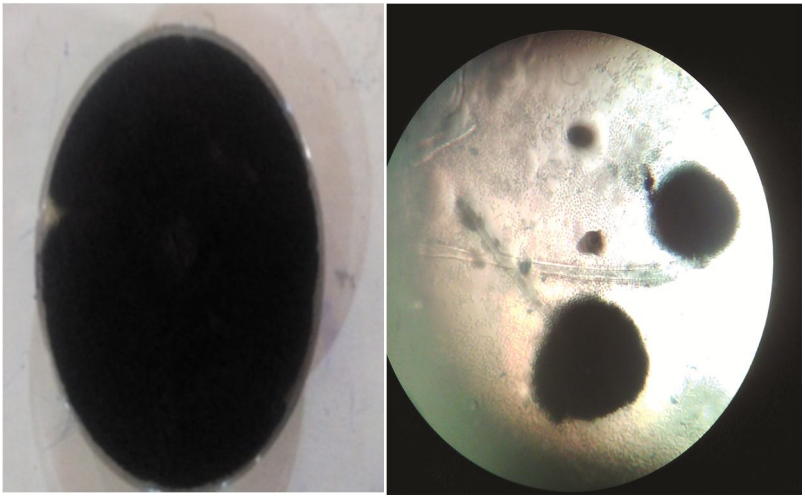
		Cercosporella sp	
		Phyllostica sp	
Physic nut			
	(a) Seeds	*Aspergillus flavus*	
		Collectotriichum capsici	
		Fusarium oxysporum	
		Macrophomina phaseolina	
		Rhizopus stolonifer	
		Penicillium chrysogensium	
	(b) Stem	*Botryodiplodia theobromae*	
		Cercospora beticola	Nwankwu,
		Rhizopus stolonifer	Akinseye and
		Aspergillus flavus	Ataga (2014)
		Fusarium oxysporum	
	(c) Leaves		
		Alternaria alternata	
		Botryodiplodia theobromae	
		Cercospora beticola	
		Macrophomina phaseolina	
	(d) Fruits	*Fusarium oxysporum*	
		Rhizopus stolonifer	
		Macrophomina phaseolina	
		Aspergillus flavus	
		Aspergillus niger	



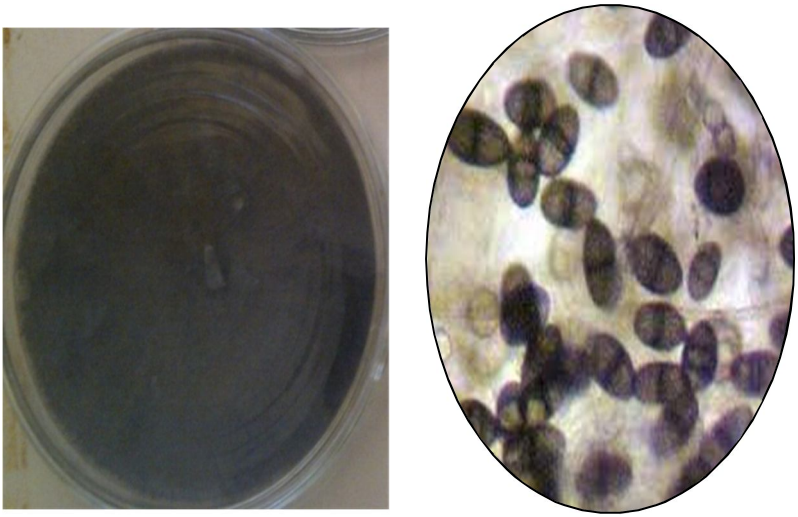
Macroscopic and Microscopic view of Alternaria *alternata*



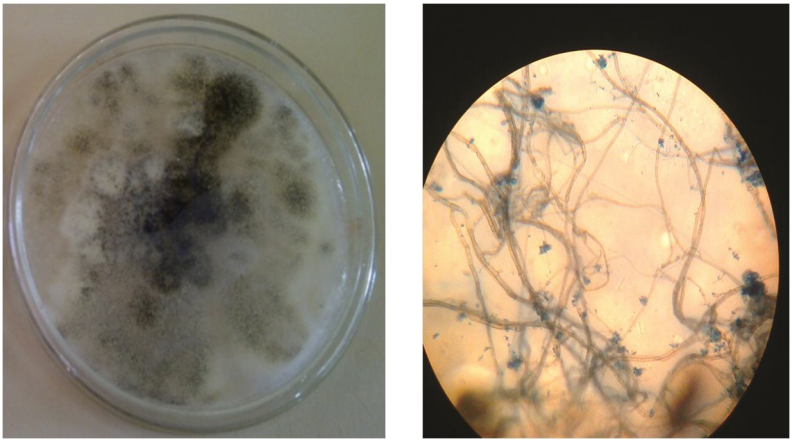
Macroscopic and Microscopic view of *Aspergillus Flavus*



Macroscopic and Microscopic view of *Aspergillus niger*

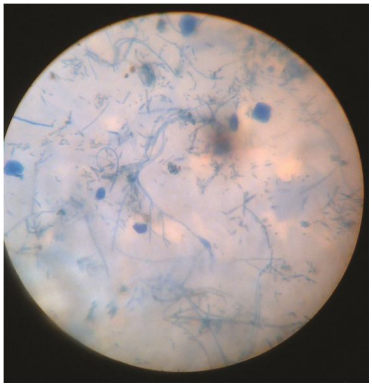


Macroscopic and Microscopic view of *Botryodiplodia theobromae*

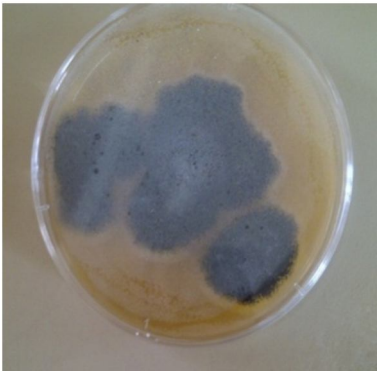


Macroscopic and Microscopic view of *Cercospora beticola*

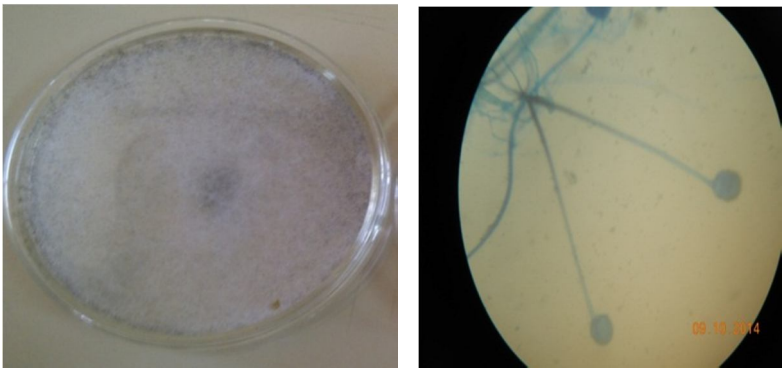
Macroscopic and Microscopic view of *Collectotrichum capsici*

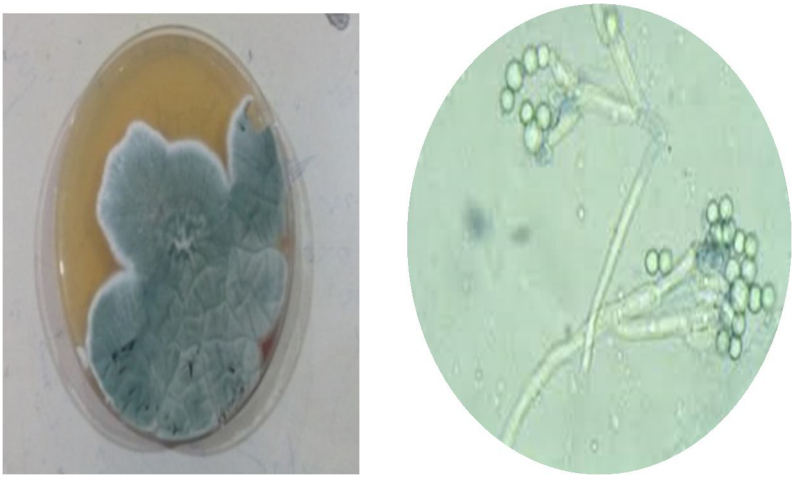
Macroscopic and Microscopic view of *Fusarium oxysporum*




Macroscopic and Microscopic view of *Macrophomina phaseolina*



Macroscopic and Microscopic view of *Rhizopus stolonifer*



Macroscopic and Microscopic view of *Penicillium chrysogenum*

Plate 2 : Pure culture of fungal isolates (Source : Nwankwu et al ; 2014)

We also investigated the field post-harvest diseases of sweet potato (*Ipomea batatas)* (Amienyo and Ataga 2006 and 2008). In the post-harvest study, five different types of rot disease symptoms; black dry rot, yellow dry root, brown dry rot, soft and watery rot were observed from tubers sampled from different parts of Rivers State.

The following fungi: *Aspergillus flavus, Aspergillus niger, Botryodiplodia theobromae, Fusarium Solani, Fusarium oxysporum, Phoma exigna* and *Rhizopus Stolonifer* were isolated from potato tubers and found to cause rot diseases. Rots in potato tubers resulted in qualitative loss, which includes loss of flavour, deterioration in texture and appearance thereby lowering the quality to the point where it cannot be eaten. The study also implicated *Fusarium Solani, Fusarium Oxysporum* and *Aspergillus flavus* as being able to cause rots in sweet potatoes.

In some farms located in Akinima, Joinkrama I, Joinkrama II and Mbiama, Rivers State, Nigeria, three disease symptoms: leaf spot, wilting and leaf blight were observed. Leaf spot disease was the most dominant in the field, occurring in 23.3% and leaf wilt occurred in 1.8% of the diseased leaves. The following fungi: *Alternaria solani, Sclerotium rolfsii, Fusarium Oxysporum, Fusarium culmorum and Verticillium albo-atrum* were found to be associated with diseased leaves (Amienyo and Ataga, 2008) in which pathogenicity test was carried out with the five fungi but Fusarium *culmorum* was the only fungus to cause leaf spot disease on the leaves.

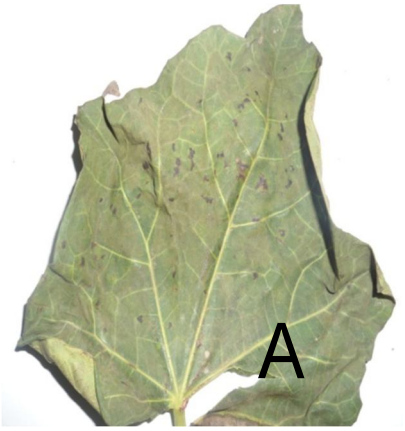
In a field survey of fungi associated with diseased parts of physic nut, several fungi isolated caused disease symptoms (Table 7).

Infection of seeds, fruits, tubers stems, and leaves by the fungi isolated and identified in our investigations, are pathogenic to pre-harvest or post-harvest crops, causing different disease symptoms ranging from seed discoloration, stem canker, leaf spot and wilting (Plates 3-13).

Table 7: Disease symptoms caused by fungi on *Jatropha curcas* (Nwankwu, Akinseye and Ataga, 2014)

Plant Organ	Fungi	Disease Symptoms
Seed	*Aspergillus flavus*	Wooly pinkish texture
	Colletotricum capsici	(discolouration)
	Fusarium oxysporium	Whitish colour with macro-conidia
	Macrophomina phaseolina	Dark thick texture
	Rhizopus stolonifer	Whitish/Gray
	Penicillium chryogenum	Grayish/green texture
Stem	*Botryodiplodia theobromae*	Dark spots on stem
	Cercospora beticola	Stem die back
	Fusarium oxysporum	Canker
	Rhizopus stolonifer	Rot
	Aspergillus niger	Dark spore masses
Leaves	*Alternaria alternata*	Brown leaf spot
	Botryodiplodia theobromae	Dark leaf spot
	Cercospora beticola	Grey leaf Spot
	Macrophomina phaseolina	Black spore mass on the leaves
	Fusarium oxysporum	Wilting
Fruits	*Rhizopus stolonifer*	Soft and watery rot
	Macrophomina phaseolina	Necrotic spot
	Aspergillus flavus	Rust
	Aspergillus niger	Black spore mass on fruits

Plate 3A : Wilting on Diseased leaf of *Jatropha curcas* caused by *Fusarium oxysporum* Schlecht
Plate 3B : Healthy Leaf of *Jatropha curcas*



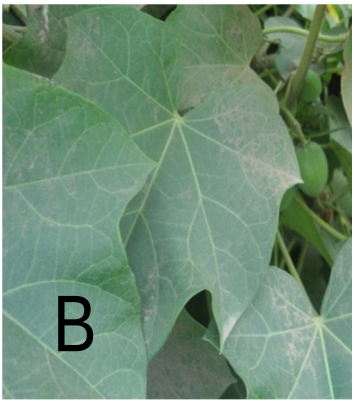


Plate 4A: Smut black spore masses on diseased leaf of *Jatropha curcas* caused by *Macrophomina phaseolina* (Tassi) Goid
Plate 4B: Healthy Leaf of *Jatropha curcas*

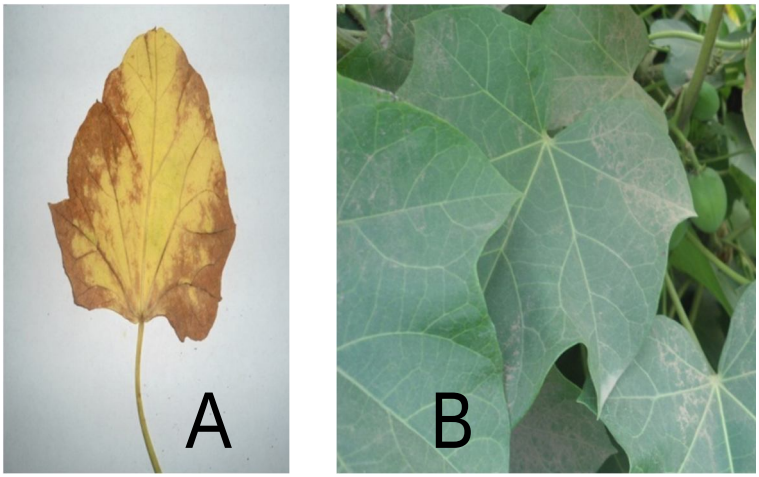


PLATE 5A : Chlorosis on Diseased leaf of *Jatropha curcas* caused by *Fusarium oxysporum* Schlecht
PLATE 6B : Healthy Leaf of *Jatropha curcas*

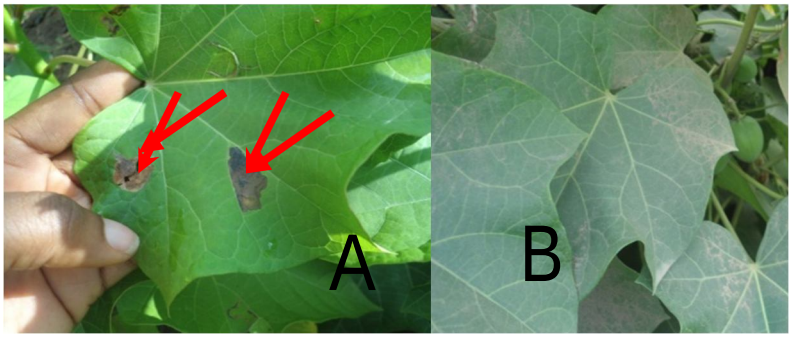


PLATE 7A: Dark Leaf spots on diseased leaf of *Jatropha curcas* caused by *Botryodiplodia theobromae* Pat

PLATE 7B : Healthy Leaf of *Jatropha curcas*

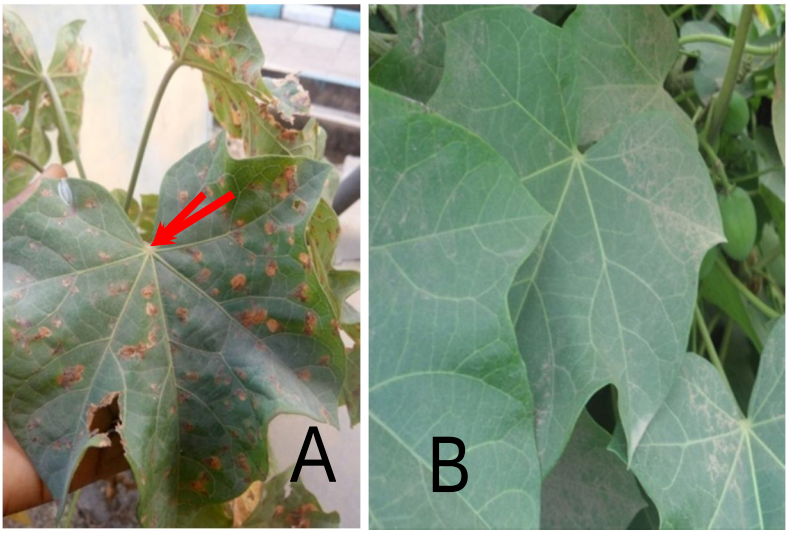


PLATE 8A : Brown leaf spot on Diseased leaf of Jatropha *curcas* caused by Alternaria *alternata* (Fr). Keissl.
PLATE 8B : Healthy Leaf of *Jatropha curcas*

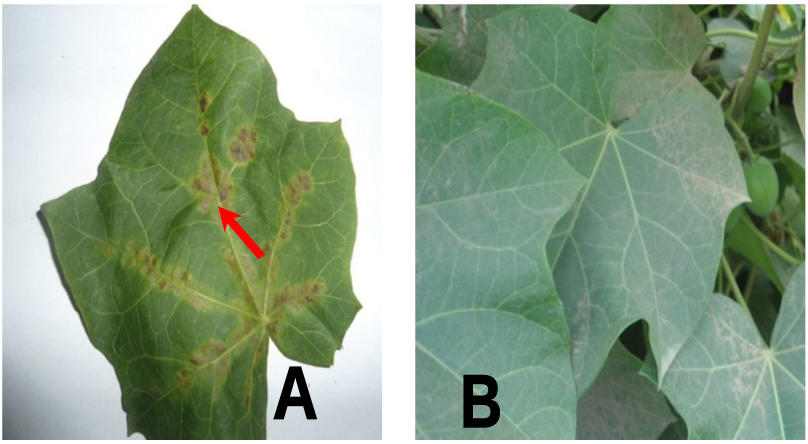


PLATE 9A : Localized Necrotic Lesions on the primary venation of the leaf of Jatropha curcas caused by Alternaria alternata (Fr.) Keissl.
PLATE 9B : Healthy Leaf of Jatropha curcas

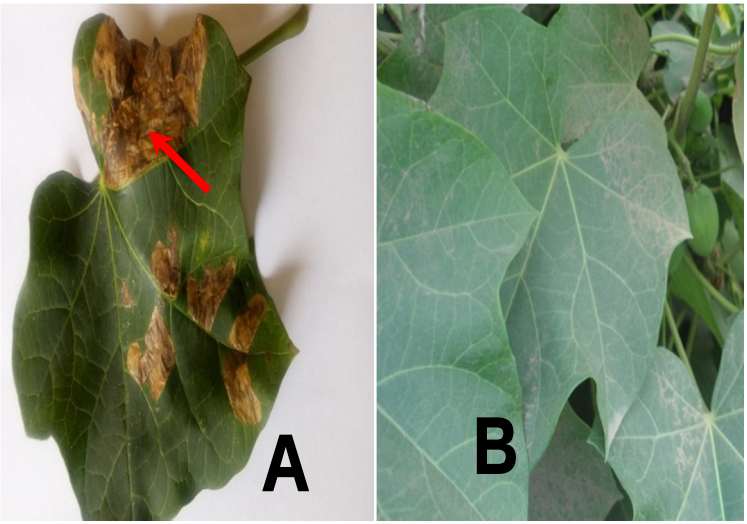
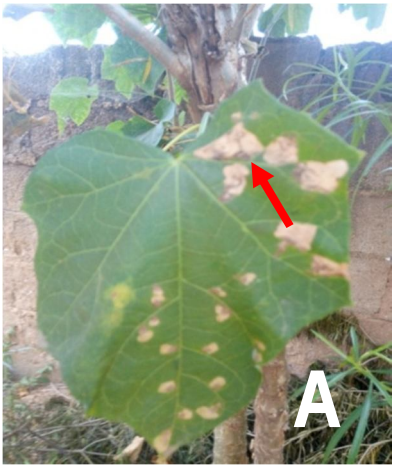


PLATE 10A: leaf Blight on Diseased leaf of Jatropha *curcas* caused by Collectotricum *capsici* (Syd.) E. J. Butler and Bisby
PLATE 10B: Healthy Leaf of *Jatropha curcas*

PLATE 11A: Charcoal Rot on Fruits of *Jatropha curcas* caused by Macrophomina *phaseolina* (Tassi) Goid
PLATE 11B: Healthy Fruits of *Jatropha curcas*

PLATE 12 A : Blotch on Diseased Jatropha *curcas* Fruits caused by *Botryodiplodia* theobromae Pat.
PLATE 12B : Healthy Fruit of *Jatropha curcas*



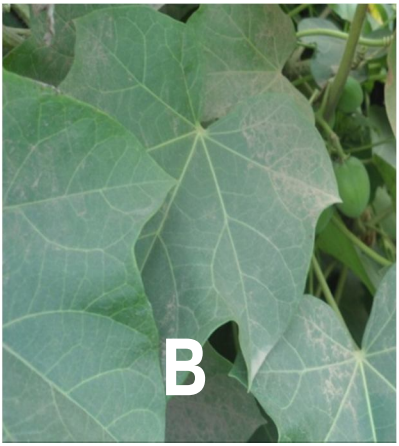


PLATE 13A : Grey leaf spot on Diseased leaf of Jatropha *curcas* caused by *Cercospora beticola* Sacc.
PLATE 13B : Healthy Leaf of *Jatropha curcas*

In all the crops we studied, the following fungal pathogens, *Alternaria, Fusarium, Aspergillus, Penicillium,* and *Rhizopus* species were found to be commonly associated with sunflower seeds, groundnut, wild mango (Ogbono) seeds, okra, maize, Rossele, Jatropha seeds, African Pear etc. Contamination of pre-harvest or post-harvest crops by these fungi have been reported to produce mycotoxins that cause high toxicity in foods, thereby making it harmful to humans and livestocks (Nelson *et al*., 1993; Legan, 2000; Arinze, 2005; Efiuvwevwere, 2014).

Table 8: Mycotoxins produced by fungi (Nelson *et al*, 1993)

Mycotoxin	Produced species	Commodities
Aflatoxins	*Aspergillus flavus, A. parasiticus, A. nomius, A. bombycis, A. ochraceoroseus, A. pseudotamari*	Nuts, spices, Cereals, maize, soybean, rice
Ochratoxin A.	*Penicillium verrucosum, P. auriantiogriseum, P.nordicum, P.palitans, P.commune, P.variabile, Aspergillus ochraceus, A. Melleus, A. Niger, A. Carbonarius, A. Sclerotiorum, A.sulphureus*	Cereals, fruits, spices, coffee, Food of animal origin
Citrinin	*Penicillium citrinum, P.verrucosum, P.viridicatum, Monascus purpureus*	Oats, rice, corn, beans, Fruits, fruit and vegetable Juices, herbs and spices
Sterigmatocystin	*Aspergillus versicolor, A. Nidulans, A. Chevalieri, A.ruber, A. Aureolatus, A. quadrilineatus, Eurotium amstelodami*	Cereals, cheese
Zearalenone	*Fusarium graminearum, F. sporotrichoides, F.culmorum, F.cerealis, F.equiseti, F. incarnaturm*	Maize, soybean, cereals
Deoksynivalenol	*Fusarium graminearum, F.culmorum, F.crokwellense*	Maize, Soybean, cereals

Fumonisins	*Fusarium proliferatum, F.verticillioides,*	Maize, soybean, cereals
Alternariol, alternariol monomethyl ether	*Alternaria alternate, A.brassicae, A.capsici-anui, A.citri, A.cucumerina, A.dauci, a.kikuchiana, A.solani, Altenuissima, A.tomato, A.longipes, A.infectoria, A.oregonensis*	Vegetables, fruit, cereals, soybean
Tenuazonic acid	*Alternaria alternata, A.capsici-anui, A.citri, A.japonica, A.kikuchiana, A.mali, A.solani, A.oryzae,A.porri, A.radicina, A.tenuissima, A.tomato, A.longipes*	Vegetables, fruit, cereals, soybean

8.0 Effect of pathogens on seed germination and seedling growth

Nigerian food crops are susceptible to a range of pathogens, which can cause damage to the crops at all stages of growth, resulting in great losses. Food crops such as cowpea, maize, okra, Roselle (Yakwa), groundnut, physic nut etc, play critical role in the lives of millions of, Nigerian, African and other parts of the developing world as a major source of dietary food and a valuable and dependable source of income to the rural farmers.

A number of studies was conducted to assess the effect of pathogenic fungi and bacteria on seed germination and seedling growth (Chukunda et al, 2006a, 2006b, 2008; Nwaukwu and Ataga, 2013; Iyanyi *et al:* 2015). There was significant reduction in germination of *Hibiscus sabdariffa* seeds treated with *Aspergillus flavus, Aspergillus niger, Fusarium oxysporum, Penicillium chrysogenous, Anthrobacteria* sp, *Erwinia* sp. *Lactobacillus* sp. and *Corynobacteria* sp. (Nwaukwu and Ataga, 2013). Similarly, these microorganisms showed diverse degree of inhibition on the growth parameters, with

significant reduction (P= 05)in the leaf length, leaf area and stem length at 3 weeks after planting when compared with uninfected control (Figs.8-12, Plates 14-15).

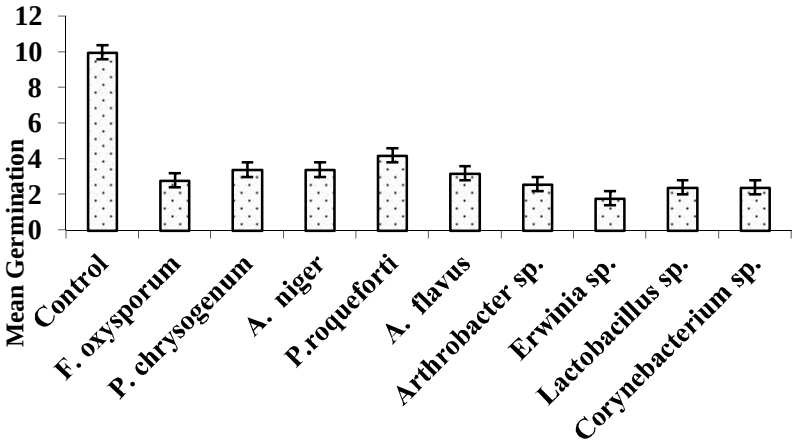


Fig 8 : Effect of Micro-Organism on Germination of *H. sabdariffa* Seed

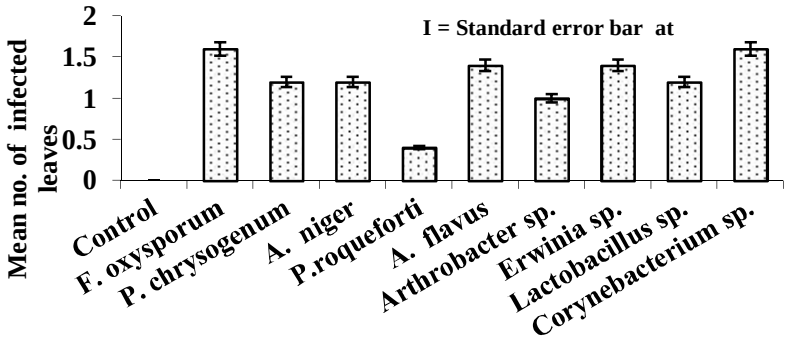


Fig 9: Number of infected leaves (Disease incidence) 2wks after germination of *Hibiscus sabdariffa*

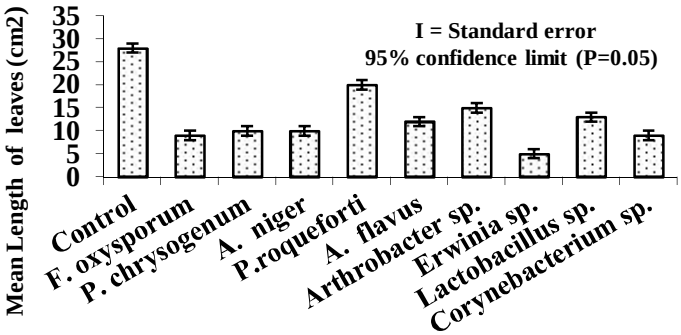


Fig 10 : Effects of Micro-oganisms on length of Leaves 3 weeks after planting of *Hibiscus sabdariffa*

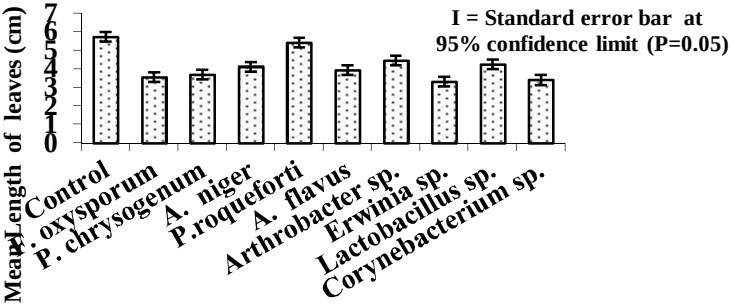


Fig 11 : Effects of Micro-oganisms on Leaf Area 3 weeks after planting of *Hibiscus sabdariffa*

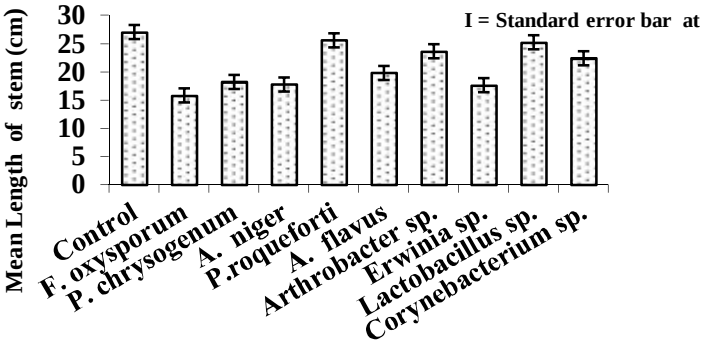


Fig 12 : Effects of Micro-oganisms on Length of Stem, 3 weeks after planting of *Hibiscus sabdariffa*

Plate 14 : Leaf Spot Symptoms with hollows caused be *Fusarium oxysporum on Hibiscus sabdariffa*

Plate 15 : Fire Blight Caused by *Erwinia sp on Hibiscus sabdariffa*

A study on the effect of microorganisms on Cowpea (*Vigna unguiculata*) seed germination and seedling growth showed that *Botryodiplodia theobromae, Aspergillus niger, Rhizopus stolonifer, Xanthomonas* sp., *Pseudomonas* sp., *Corynobacterium* sp. and *Micrococcus* reduced seed germination and seedling growth (Fig.13-16). Different diverse symptoms manifested on the seedlings as a result of the effect of the microorganisms (Table 9).

Table 9: Symptoms manifested by Cowpea infected with microorganisms (Iyanyi, Ataga & Nwaukwu, 2015).

Microorganism	Symptoms
Aspergillus niger	Stunting, yellowing, wilting and drying of leaves
Fusarium oxysporum	Stunted growth, wilting
Rhizopus stolonifer	Darkening of veins, wilting
Pseudomonas sp.	Wilting, yellow to brown leaft spot
Xanthomonas sp.	Leaf blight, defoliation, yellow leaf spots
Corynobacterium sp.	Necrotic leaf spots, dark brown leave
Micrococcus sp.	Drying of leaves

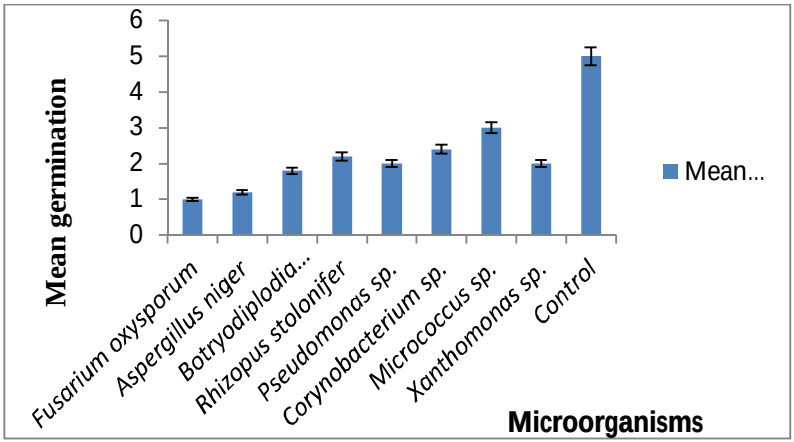


Figure 13 : Effect of microorganisms on percentage (%) germination of cowpea (*Vigna unguiculata*) seed.

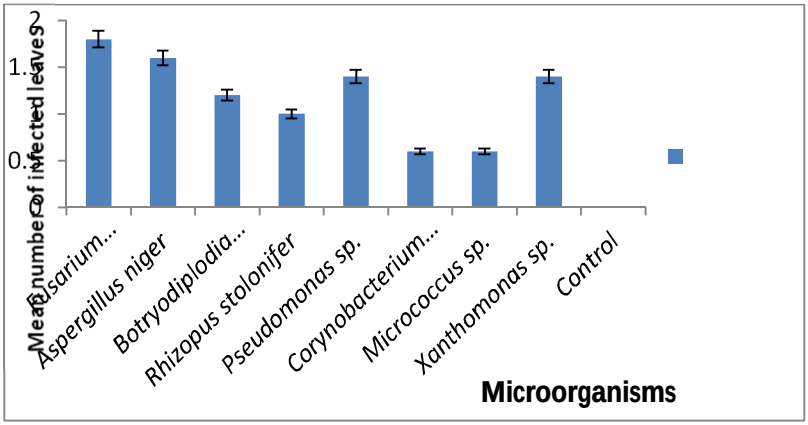


Fig. 14 : Number of infected leaves (disease incidence) 2weeks after germination

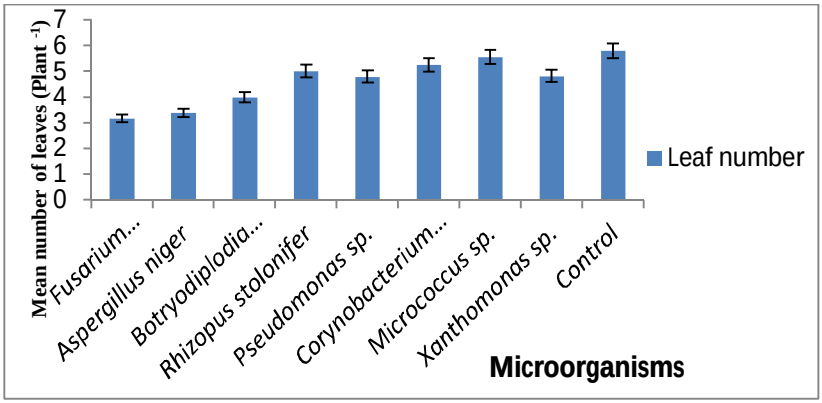


Figure 15 : Effect of microorganisms on number of leaves of cowpea (*Vigna unguiculata*) three weeks after planting.

I= Standard error (P= 0.05)

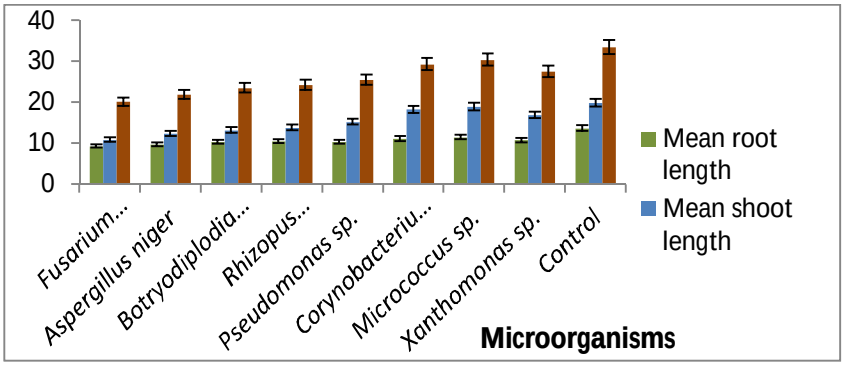


Figure 16 : Effect of microorganisms on root length, shoot length and total seedling height of cowpea (*Vigna unguiculata*) three weeks after planting.

I= Standard error (P= 0.05)

9.0 Effect of fungal pathogens on food composition

Seeds, fruits, tubers and vegetables of food crops are subject to pathogenic attack during harvesting, processing, storage and marketing (Ataga & Akueshi, 1996; Ataga & Umechuruba, 1988; Ataga & Obele, 2006; Amienyo and Ataga, 2006; Ataga & Ota-Ibe, 2006; Nwaukwu and Ataga, 2012; Iyanyi & Ataga, 2014; Akinseye, Nwaukwu & Ataga, 2016). Infection of seeds, tubers or fruits by fungi has been reported to cause a variety of biochemical changes (Christensen, 1957; Oso. 1979; Oyeniran, 1980). We therefore, carried out investigation on the role of fungal infection on several Nigerian food crops; Sunflower seeds – Ataga & Akueshi (1986a, 1986b); groundnut seeds – Umechuruba *et al* (1992), African yam bean – Ataga & Umechuruba (1998), African pear fruits – Ataga & Obele (2006), Potato tubers – Amienyo and Ataga (2006), Wild mango (Ogbono) seeds – Ataga & Ota-Ibe (2006), Roselle seeds – Nwaukwu & Ataga (2013); Cowpea seeds – Iyanyi, Ataga & Nwaukwu (2015) and Jatropha seeds – Akinseye, Nwaukwu and Ataga (2014, 2016) was investigated. The test fungi grew well on the seeds, tubers and fruits and induced various biochemical changes in their compositions (Tables 10-14).

Table 10: Changes in nutrient contents in African pear fruits inoculated with *Botryodiplodia theobromae, Fusarium pallidoroseum* and *Rhizopus solonifer* at 25 ± 2°c for 3 days (Ataga & Obele, 2006).

Test fungi	Biochemical composition (% w/w)						
	Dry matter	Moisture	Extracted oil	Free fatty acids	Protein	Carbohydrate	Ash
Control (uninoculated)	87.1*	11.9	42.4	13.5	27.3	10.6	9.0
Botryodiplodia Theobromae	76.7	23.3	33.9	25.8	29.1	5.0	12.1
Fusarium Pallidoroseum	79.0	21.0	35.2	20.4	28.2	6.1	13.0
Rhizopus Stolonifer	80.2	19.8	35.9	21.2	28.6	5.9	12.8
LSD0,05	0.6	0.3	0.9	0.3	0.5	0.9	0.4

Key: *Means of two determinations with three replicates L.S.D. Least significant difference for comparison of treatment means.

In pear fruits inoculated with *Botryodiplodia theobromae, Fusarium pallidorosrum* and *Rhizopus stolonifer*, there was significant reduction (P=0.05) in total oil, carbohydrates and dry matter, and significant increases (P=0.05) in free fatty acids, protein, ash and moisture as compared to the uninoculated control (Table 10).

Results of *Aspergillus niger, Botryodiplodia theobromae, Fusarium oxysporum* and *Rhizopus stolonifer* inoculated Potato tubers significantly caused an increase (P=0.05) in moisture content, crude protein, lipid and reduction in dry matter and carbohydrate content, when compared to uninoculated control (Amienyo & Ataga, 2006).

Table 11: Changes in levels of nutrients in sweet potato (*Ipomea batatas* (L) Lam) inoculated with fungi and incubated at 28 ± 2° C for 14 days. (Amienyo & Ataga, 2006)

	Nutritional composition (% w/w)					
Fungi	**Dry matter**	**Moisture**	**Carbohydrate**	**Protein**	**Lipid**	**Ash**
uninoculated Control	32.6	67.4	72.1	4.3	2.2	2.9
Aspergillus niger	24.9	75.1	55.8	5.5	3.9	3.5
Botryodplodia Theobromae	26.0	74.0	48.6	5.4	2.9	3.5
Fusarium Oxysporum	27.9	72.1	52.4	5.5	2.7	3.1
Rhizopus stolonifer	25.1	74.9	50.3	6.5	2.5	4.1
LSD (0,05)	1.2	1.2	1.5	0.8	0.5	0.10

Table 12: Nutritional contents of Irvingia gabonensis seed inoculated with *A. Flavus, B. theobromae, F. Maniliforme and P. expansum* and incubated at 25°c for 14 days (Ataga & Ota-Ibe, 2006).

Fungal isoate	Dry matter (% w/w)	Moisture (% w/w)	Total oil (% w/w)	Free fatty acid (% w/w)	Crude protein (%w/w)	Fibre (%w/w)	Ash (% w/w)	Carbohydrate (% w/w)
Control (uninoculated)	87.1	12.9	60.8	3.3	20.5	10.2	2.4	6.1
A. flavus	84.2	15.8	51.8	12.2	25.0	12.5	5.0	5.7
B. theobromae	79.0	21.0	52.2	7.9	27.2	10.8	5.5	4.3
F. moniliforme	83.6	16.4	48.6	7.5	25.8	13.6	6.8	5.2
P. expansum	81.7	18.3	50.3	11.9	26.5	11.8	5.6	4.9
LSD (P=0.05)	1.2	1.3	0.8	1.3	0.9	0.2	2.5	0.3

*Each value is the mean of four determinations, each consisting of 3 replicates.

Table 13: Free fatty acid composition of extracted oil from fungus-inoculated and uninoculated Ogbono seeds incubated for 14 days at 25°C (Ataga & Ota-Ibe, 2006).

	Free fatty acid composition (%)			
Organism	**Decanoic acid**	**Lauric acid**	**Myristic acid**	**Palmitic acid**
Control (uninoculated)	2.8	54.7	42.7	nd
A. flavu	1.4	56.2	42.4	nd
B. theobromae	1.6	60.8	35.7	1.8
F.maniliforme	0.2	56.8	41.8	1.2
P. expansum	1.3	54.7	42.4	1.6
LSD (P=0.05)	0.6	2.6	1.5	0.2

'Each value is the mean of four determinations, each consisting of 3 replicates.
nd = not detected.

Table 14: Changes in viscosity of the fungus-inoculated and uninoculated seeds incubated for 14 days at 25°C.

Organism	**Relative viscometric units**
Control (uninoculated)	5.0
Aspergillus flavus	19.3
Botryodiplodia theobromae	19.5
Fusarium moniliforme	21.1
Penicillium expansum	22.8
LSD(P=0.05)	1.3

'Relative viscometric units calculated from the formula 1000/t where t = time for 50% loss in viscosity of the mixture.

Investigation of *Aspergillus niger*, *Botryodiplodia theobromae*, *Fusarium moniforme* and *Penicillium expansum* found to be associated with post-harvest wild mango (popularly called Ogbono) seeds, were found to grow well on apparently healthy seeds and caused various discolourations (Tables 12, 15 and 14). The results of biochemical analysis showed significant increases (P=0.05) in moisture, crude protein, free fatty acids, ash and significant

reductions in (P=0.05) dry matter, total oil and loss in viscosity (Ataga & Ota-Ibe, 2006).

Infection of seeds, tubers or fruits by pathogenic fungi in the pre- or post-harvest resulted in various biochemical changes (tables10 to 14). The dry matter content of seeds, fruits or tubers decreased significantly (P =0.05) when compared with controls. There was a corresponding significant increase (P =0.05) in moisture content. The decrease in dry matter and increase in moisture was probably due to the fungi using some of the components of the seeds, tubers, or fruits as nutrients, producing water in the process. There was significant reduction in total oil (P = 0.05) extracted from seeds, tubers or fruits inoculated with fungi.

However, we observed increases in free fatty acids in seeds, tubers or fruits inoculated with fungi compared with controls. The decrease in oil content could be due to its hydrolysis to free fatty acid. The increase in the formation of free fatty acid were found to be associated with a decrease in total oil, which is an indication that fungi may be utilizing the fatty acid as a carbon source during infection.

10.0 Use of plant extract in the management of plant pathogens and diseases

Protection of mechanically injured sweet potato tubers from fungal rot with plant extracts such as *Alchornea cordifolia, Annona muricata (Soursop), Allium sativum, (Garlic) Gacinia cola (bitter kola) and Zingiber officinale* (Ginger) was investigated (Amienyo & Ataga 2006). The water extracts of these plants inhibited the mycelia growth of *Aspergillus flavus, Aspergillus niger, Fusarium oxysporum, Botryodiplodia theobromae and Rhizopus stolonifer in vitro (*Table 15).

Results of our study also observed that all the plant extracts significantly reduced rot development in sweet potato caused by the fungal pathogens (Table 16). The degree of protection of the tubers

from rot by different plant extract, varied and was highly significant (P=0.05). This study revealed that fungitoxic compounds were present in *Zingiber officinale, Annona muricata, Gacinia cola, Alchornea cordifolia and Allium sativum* since they were able to inhibit the growth of the fungi tested. These plants have the potential application in the management of plant crop diseases.

Table 15: Inhibition (percentage) of mycelia growth of fungi grown in potato dextrose broth incorporated with plant extracts.

Rot fungi	Plant extract (% inhibition of mycellal growth)					
	Alchornes cordifolia	***Annona muricata***	***Gacinta cola***	***Zingiber officinale***	***Allium sativum***	**Control**
Apergillus flavus	49.62b	24.43b	53.44a	44.64c	38.94b*	0
Aspergillus niger	63.86a	48.8a	37.96a	32.54c	87.96a	0
Fusarium solani	56.35b	25.4b	3.97c	58.74b	42.07b	0
Fusarium oxysporum	81.63a	32.44b	26.36a	81.49b	44.60b	0
Botryodiplodia theobromae	76.7a	65.79a	35.73a	80.46a	81.21a	0
Rhizopus stolonifer	56.00b	44.00a	41.6a	46.6c	28.8c	0

*Values in a column with the same letters are not significantly different at (P=0.05).

Table 16: Effects of plant extracts on the development of rot on sweet potato tubers.

Plant extract	Fungi (% inhibition)					
	Fusarium solani	*Fusarium oxysporum*	*Aspergillus niger*	*Rhizopus stolonifer*	*Apergillus flavus*	Botryodiplodia theobromae
Zingiber officinale	51.71a	73.33a	39.09b	70.99a	28.15c	30.67c
Annona muricata	34.05b	30.10c	30.19c	37.73d	41.35b	40.56b
Gacinia cola	32.01c	31.01c	30.19c	46.89b	28.80c	40.94b
Alchornea cordifolia	22.12d	37.38b	44.09a	42.91c	46.61a	45.84a
Allium Sativum	6.91e	38.27b	44.09a	42.91c	46.61a	45.64a
Uninoculated	0	0	0	0	0	0

Means followed by the same alphabets are not significantly different (P = 0.05).

The efficacy of using aqueous and ethanolic extracts of bitter leaf (*Vernonia amygdalina)* in the control of fungi associated with groundnut seeds was studied (Akinseye and Ataga, 2014). The result of *in vitro* study on the effect of *Vernonia amygdalina* extract on mycelia growth of *Phoma exigua* and *Macrophomina phaseolina* showed reduction in mycelia weight as the plant extracts inhibited spore germination and fungal growth (Fig. 18). The reduction of spore germination and mycelia growth could be due to antimicrobial activities of the plant; *V. amygdalina*. Onifade (2000), Udo et al (2001), Owolade and Osikanu (1999) and Olufolaji (2002) have reported similar significant antifungal effects on mycelial growth with the use of some plant extract. This findings show that *Vernonia amygdalina* extract can be used in plant disease control.

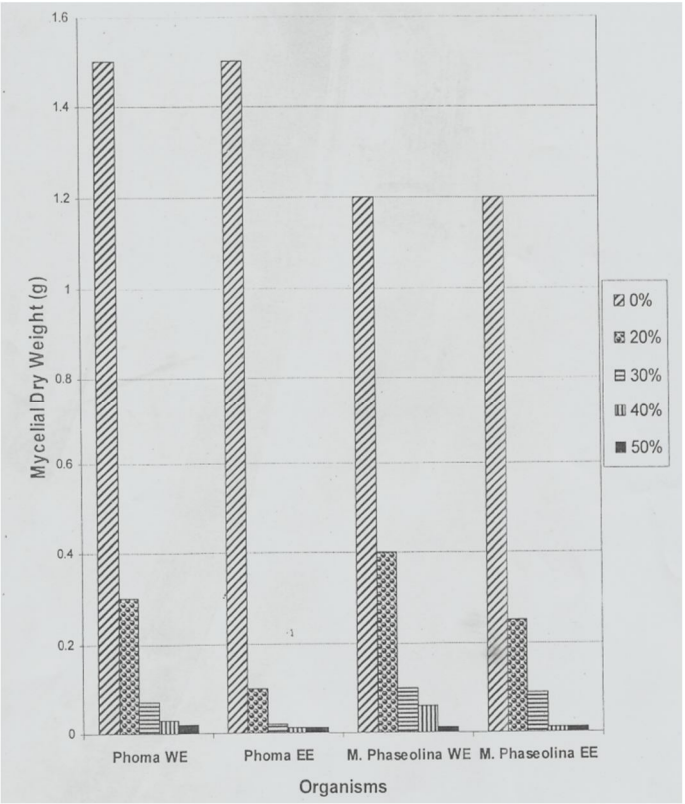


Fig. 17: Efffects of *Vernonia amygdalina* water and ethanolic extracts on the mycelia growth of Phoma exigua and *Macrophomina phaseolina*

11.0 Furanocoumarins in the management of plant diseases

Furanocoumarins are heterocyclic compounds derived from coumarin by the addition of a furan ring at the 6, 7 positions (linear furanocoumarins) or 7, 8 positions (angular Furanocoumarins) (Fig. 18). They occur in a range of plants, especially in species of the Umbelliferae, Leguminosae, Rutaceae, and Moraceae (Pathak et al, 1962).

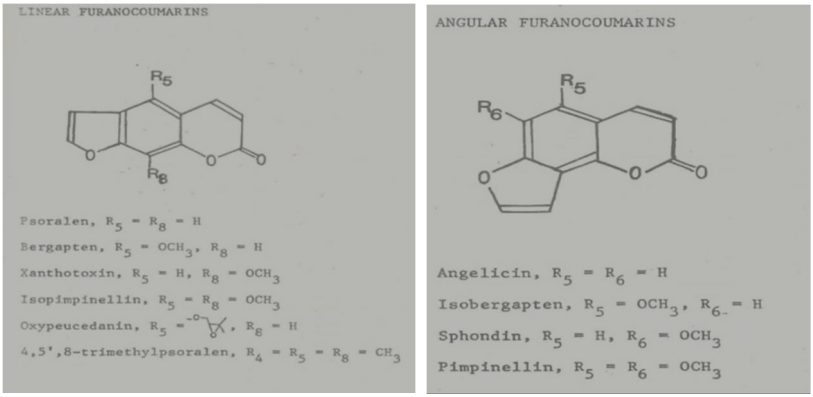


Fig 18 : Structure of Furanocoumarins (Source : Pathak *et al*, 1962).

In nature, plant pathogens seldom occur in isolation; interactions between viral and fungal pathogens of plants have been reported to occur for many years. Prior infection of plants may increase susceptibility to fungal pathogens (Omar *et al*, 1986a), decrease susceptibility (Omar *et al*, 1986b, Potter, 1982), or have no effect (Raju *et al* 1969).

Virus infections have been reported to stimulate the production of phytoalexins in plants (Bailey, 1973, Bailey and Burden, 1973), and Furanocoumarins have been described as phytoalexins in celery (Beier and Oertli, 1983). Ataga et al (1993) have shown that the concentration of furanocoumarins in celery greatly increased because of virus infection. In our investigation, prior infection of celery plants with viruses CV036 and CV506 suppressed blight disease on leaves subsequently infected by *Septoria apiicola* by 17.4% and 54.9% respectively (Table 17 and Plate 16.). There was a significant negative correlations between the amount of blight and the furanocoumarin content of the celery plants ($r = -77$, $P = 0.01$) (Fig. 19).

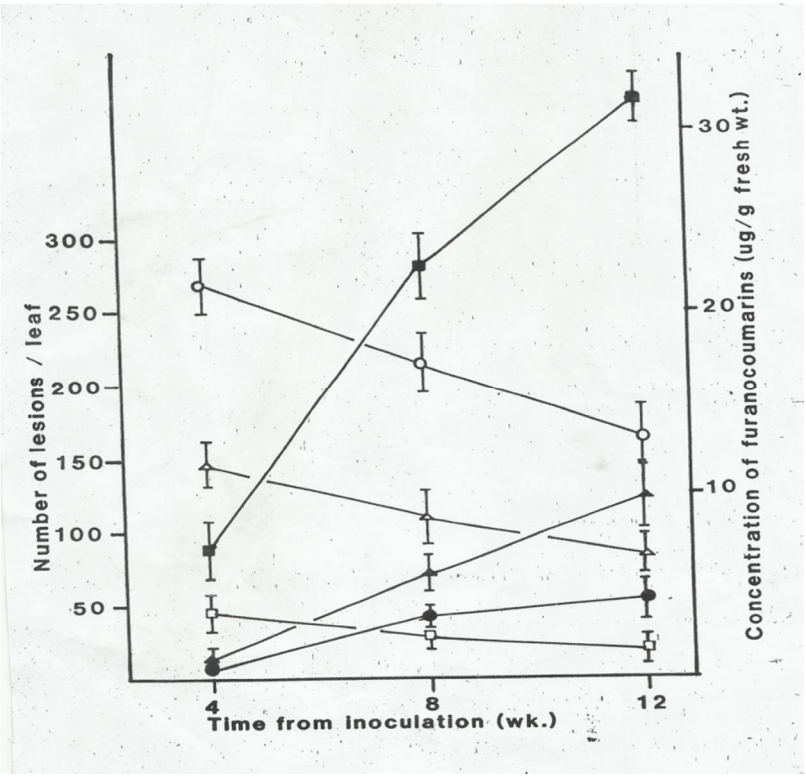


Fig. 19**: Relationship between Septoria blight and linear furanocoumarin content of celery**

	Concentration of <u>furanocoumarins</u>	number of <u>lesions/leaf</u>
Virus-free	●	o
CVo36-infected	▲	Δ
CV506-infected	■	□

I = 95% confidence limits

Table 17: Concentration (µg g^{-1}) of linear furanocoumarins in leaves of virus-free and virus-infected celery

Treatment	cv. Jason Self Blanching			cv. Fenstar		
	4wks[1]	8wks	12wks	4wks	8wks	12wks
Control (virus-free)	0.57[2]	3.69	4.29	0.77	4.61	5.57
CV036	0.90	5.86	9.84	5.43	8.14	13.67
CV506	7.12	22.52	31.94	16.66	34.11	44.26

$L.S.D_{0.05}$[3] treatments = 1.07 1 Time in weeks after virus infection
$L.S.D_{0.05}$ cultivars = 0.77 2 Values are means of three determinations with three replicates
$L.S.D_{0.05}$ periods = 1.07 3 Least significant difference for comparison of means.

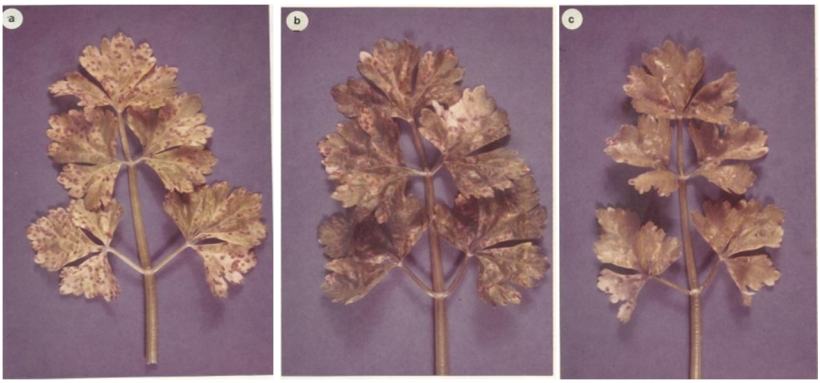


Plate 16 : Celery cv, Jason showing local lesions caused by *S. apiicola.*
a = virus-free ; b = CV036-infected ; and c= CV506-infected.

The antifungal activity of these furanocoumarins was demonstrated by their *in vitro* inhibition of the germination of spores of *S. apiicola* and *Botrytis cinerea* (Table 18). Also, the results of the scanning electron microscopy (SEM) of virus-infected leaves sprayed with spores of *S. apiicola* , showed slight but significant reductions in

gernmination, germ-tube length, and proportion of germ-tubes producing appressoria, when compared with spores on viru-free leaves (Table 19 and Plate 17).

Table 18: The effect of furanococumarins on the germination of fungal spores

	Septoria apiicola		*Botrytis cinera*	
Furanocoumarins	**M.I.C[1]**	**E.D.$_{50}$[2]**	**M.I.C.**	**E.D.$_{50}$**
Angelicin	>500[3]	285.0	>600	335.0
Fsoralen	>70	17.5	>70	28.5
Xathotoxin	>80	24.5	>80	36.5
Bergapten	>80	27.5	>80	41.0
Trimethylpsoralen	>70	33.5	>80	47.0

1 Minimum inhibitory concentration, i.e the lowest concentration required (µg cm^{-3}) to prevent spore germination completely

2 E.D.$_{50}$, i.e the concentration required to cause 50% inhibition of spore germination.

3 Values are means of three determinations with ten replicates.

Table 19: Germination, germ-tube length and formation of appressoria by *S. apiicola* on leaf discs from virus-free and virus-infected celery

Treatment	**Germination * (%)**	**Germ-tube # length (µm)**	**percentage of germ tubes with # apressoria**
Control (virus-free)	49.0	30.83	57.0
CV036	47.1	29.76	19.4
CV506	46.4	29.44	17.2
LSD$ 0.05	1.6	0.57	6.5

*Determined from 100 conidia on each of three replicates

#Determine from 20 germinated conidia on each of three replicates.

$Least significant difference for comparison between control and virus-infected

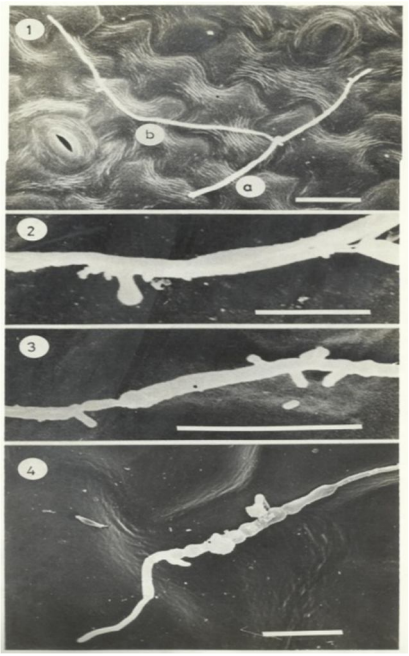


Plate 17: Scanning electron micrographs of celery leaf discs inoculated with *Septoria appiicola* suspension and incubated for 48h.

1. = virus-free leaf disc showing
   (a) Ungerminated condium, (b) germinating mycelium with germ-tubes
2. = Normal appressorium on mycelium of *S.apiicola* on virus-free leaf disc.
3. = Abnormal appressorial structures on mycelium of *S. apiicola* on virus-infected leaf disc
4. = Germinating mycelium of *S.apiicola* on virus-infected leaf disck showing abnormal germ-tubes

We have clearly shown in this study that virus infection of celery does reduce subsequent infection by *Septoria apiicola*, and our other experimental evidence supports the notion that this is due to the production of furanocoumarins. However, in order to be sure that this is a causal relationship, we need to understand the mechanism by which this reduction of infection occurs. Martin et al., (1966) and Stanley & Jurd (1971) have previously reported toxicity of furanocoumarins to fungi. Our results showed that low concentrations of furanocoumarins do inhibit spore germination of *Septoria apiicola in vitro*, and that spore germination, germ-tube growth, and appressorial development are all significantly inhibited on virus-infected plants as compared to the virus-free controls. While the effects on germination and germ-tube length were too small to account for the reduction in infection, the reduction in the number of germ-tubes producing appressoria (from 57% on the virus-free plants to 17-19% on the virus-infected plants) was of the right order of magnitude. However, if furanocoumarins are directly responsible for this effect, they should be detectable on the leaf surface, but so far, our attempts to detect furanocoumarins on the surface of the leaf, in leaf exudates and leaf washings, have failed.

12.0 Recommendations

1. Government at all levels – Federal, State or Local should show more interest in Plant Pathology as plant pathogens pose major challenge to world food security. In our studies, several plant pathogens were implicated to cause crop damage, reduced yield, and poor quality of food products.

2. Many plant pathogens currently exist that are yet to be identified and characterised. These pathogens are potential hazards to food production, processing and storage, and can result in disease epidemics. More plant pathology units or centres should be created in the country to be

charged with training of qualified plant pathologists, early detection and identification of plant pathogens and plant diseases, and disease management.

3. Plant pathogen populations are variable in time and space. Although, some epidemiological studies have been carried out, much remains to be done in the field of limiting inoculums, its multiplication, effectiveness, and spread. The movement of seeds, grains, tubers and vegetative propagules from abroad, within states and local government areas should be monitored by trained plant pathologists. Quarantine and Certification Services at the borders, seaports and international airports should be re- organised, and made to carry out their functions.

4. Politicians and governments are more preoccupied by the threat to peace and prosperity posed by terrorism. It is time that they know and be concerned with a more deadly terrorism caused by plant pathogens and pests on sources of food, which threaten our very security and survival. For plant pathologists, the loss of food to plant disease presents a challenge. There is always some threat to food security, so the challenge is ongoing. More resources from International, Government, and non-governmental bodies should be provided to meet the challenge posed to food requirements by our ever-increasing population.

12.0 Conclusion

Vice- Chancellor Sir, distinguished Ladies and Gentlemen, Plant Pathogens cause disease in economic plants, resulting in devastating, damage, losses in Crop yield, reduced quality, and disfiguring of food products. Plant diseases need to be controlled in order to

maintain the quality and abundance of food, feed and fibre produced by farmers.

There are major principles and practices of disease management with large array of weapons to win the war against Plant Pathogens. Success in any battle does not depend on availability of good and advanced weapons, but from execution of a well- planned and coordinated strategy. New strains of resistant Pathogens are evolving daily.

The war against Plant Pathogens is a continuous one and can only be achieved with proper management of the four components of diseased pyramid (Hoat, pathogen, environment and time).

Thank you for listening and God bless.

REFERENCES

Agrios, G. N. (1998). *Plant Pathology*. 3rd Ed. (1997). 4th Ed. Elsevier Academic Press. New York pp 123 – 178.

Arinze, A. E. (2005). *Plant Pathology and Post –Harvest Food Loss*. An Inaugural Lecture Series, 43:29 – 72.

Ataga, A.E. and C.O. Akueshi (1986a). Changes in oil and free fatty acid content of sunflower seeds inoculated with *Alternaria tenuis Auct., Curvularia Lunata* (Wakker) *Boedijn, Fusarium moniliforme* Sheld and *Macrophomina phaseolina* (Tassi) Goid. Phytopathol, Medit (1986) 25, 44-46.

Ataga, A.E. and C.O. Akueshi (1986b) Changes in protein and amino acid composition of sunflower seeds inoculated with *Curvularia Lunata* and *Macrophomina phaseolina*. *Nigerian Journal of Biotechnology, 2, 45-49.*

Ataga, A.E., H.A.S. Epton and R.R. Frost (1993) Effect of virus infection on the Concentration of *Furano-coumarins* in celery. (Apium graveolensis) *Physiological and Molecular Plant Pathology. 42 :161-168*

Ataga, **A. E.** and Akueshi C. O. (1996). Fungi Associated with Sunflower Seeds in Nigeria. *Seed Research*, 24(1) : 64 – 65.

Ataga, A.E., H.A.S Epton and R.R. Frost (1998). Interaction of virus-infected Celery *and Septoria apiicola*. *Global Journal of Pure and Sciences, Vol. 4:4, 331-338*

Ataga A.E., H.A.S. Epton and R.R. Frost (1998). Microflora of virus-infected Celery and effects on *Septoria apiicola*. *Global Journal of Pure and Applied Sciences* Vol. 4: 3221-226.

Ataga, A. E. and Umechuruba, C. I. (1998). Biochemical Changes in African Yam Bean Caused by *Sphenostylis pallidoroseum* and *Penicillium oxalicum*. *Global Journal of Pure and Applied Sciences*, 4(4): 381 – 384.

Ataga A.E. and N.E. Ota-Ibe (2006). Seedborne Fungi of the wild mango (Ogbono) (*Irvingia gabonensis* (Aubry-Leconte ex'Rorke) ball) and their effects on food composition, Nigerian Journal of Botany, Vol. 19(1) : 54-60.

Ataga, A. E. and Obele, O. (2006). Post-harvest Fungal Diseases of African Pear (*Dacryodes edulis* (G. Dom) Lam) Sold in Selected Markets of Rivers State, Nigeria. *Nigerian Journal of Microbiology*, 20(3) :1334 – 1338.

Akinseye, O. F., **Ataga, A. E**. and Nawaukwu, I. U. (2014). Changes in Fatty Acid and Lipid Content of *Jatropha curcas* L. induced by *Fusarium oysporum* and *Macrophomina phaseolina. Researchjournali's Journal of Agric*, 1(3)

Akinseye, O. F. and **Ataga, A. E.** (2014). Aqueous and Ethanol Extracts of Vernonia *amygdalina* L. in the Control of Fungi Associated with *Arachis hypogea* L. *Scientia Africana*, 13(2): 281 – 289.

Akinseye, O.F., Nwaukwu, I.A and **A.E. Ataga** (2016). Changes in the Amino Acid and Protein content of *Jatropha curcas* induced by *fusarium oxysporium* and *Macrophomina phaseolina*. IOSR Journal of Pharmacy and Biological Sciences. 11(4.1): 44-47.

Amienyo, C. A. and **Ataga, A. E.** (2006). Biochemical Changes Induced by Four Rot Fungi on Sweet Potato (*Ipomea batatas* (L.) Lam) Tubers. *Nigerian Journal of Microbiology*, 20(3) : 1334 – 1335.

Amienyo, C. A. and **Ataga, A. E.** (2006). Post-harvest Fungal Diseases of Sweet Potato (*Ipomea batatas* (L.) Lam) Tubers Sold in Selected Markets of Rivers States, Nigeria. *Scientia Aricana*, 15 (2): 94 – 98.

Amienyo, C.A. and **A.E. Ataga** (2007). Use of indigenous plant extracts for the protection of mechanically injured sweet potato (*Ipomoea batatas* (L). Lam) tubers. Scientific Research and Essay. Vol. 2 (5) : 167-170.

Amienyo, C. A. and **Ataga. A. E.** (2008). Survey of Fungi Associated with Diseased Sweet Potato (*Ipomea batatas* (L.) Lam) Leaves in Some Farms in Rivers state, Nigeria. *Nigeria Journal of Botany*, 21(2): 336 – 341.

Balley, J.A. (1973). Production of antifungal compounds in Cowpea (*Vigna sinensis*) and Pea (*Pisum sativum*) after virus infection. *Journal of General Microbiology 75*, 119-123.

Balley, J.A. and Burden, R.S. (1973). Biochemical changes and phytoalexin accumulation in *Phaseolusvulgaris* following cellular browning caused by tobacco necrosis virus. *Physiological Plant Pathology 3*, 171-177.

Beier, R.C. and Oertli, E.H. (1983). Psoralen and other linear furanocoumarins as phytoalexins in celery. *Phytochemistry 22(ii), 2595-2597.*

Birch, P. R. J. and Whisson, S. C. (2001). *Phytophtora infestans* enters the Genomic Era. *Mol. Plant. Pathol*., 2:257 – 263.

Chastain, T.G. and King, B., 1990, Abiochemical method for estimating viability of teliospore of Tilletia constroversa, *Phytopathology*, 80:474

Chaube, H. S. and Singh, U. S. (1990). *Plant Disease Management : Principles and Practices*, CRC Press, Boca Raton, USA.

Chaube, H. S. and Pundhir, V. S. (2009). *Crop Disease and their Management*. PH Learning Private Limited, New Delhi India. Pp 703.

Chellemi. D. O., Mitchell, D. J., Kannwischer-Mitchell, M. E., Rayside, P. A and Rosskopf, E. N. (2000). *Pythium* sp. Associated with Bell Pepper Production in Florida. *Plant Dis*., 84:1271 – 1274.

Christensen, C. M. (1957). Deterioration of Stored Grains by Fungi. *The Botanical Review*, 23(2) :108 – 134.

Christou, P. and Twyman, R. M. (2004). The Potential of Genetically Enhanced Plants to Address Food Insecurity. *Nutri. Res. Rev.*, 17:23 – 42.

Clark, M.F., 1992, Immunodiagnostic techniques for plant mycoplasm-llike organisms. In : *Techniques for the Rapid Detection of Plant Pathogens,* Deenean, J.M.and Torance, L. (Eds) Brits. Soc. For Plant Pathology, Blackwell Scientific, Oxford, UK.

Chukunda, A. F., **Ataga, A. E**. and H. N. Ukioma (2006). Effect of Culture Filtrates of Curvularia lunata on the Seddling diseases of Okro (*Abelmoschus esculentus* (L.) Moench). *Acta Agronomical Nigeriana,* 7(1): 61 – 64.

Chukunda, A. F., **Ataga, A. E**. and H. N. Ukioma (2006). Effect of Culture Filtrates of *Macrophomina phaseolina* on the germination and Seedling Growth of Okro (Abelmoschus esculentus (L.) Moench). *Acta Agronomical Nigeriana,* 7(1) : 17 – 20.

Chukunda, A. F., **Ataga, A. E**. and H. N. Ukioma (2008). Effect of Storage fungi – *Aspergillus flavus*, *Aspergillus niger* and *Aspergilus terrus* on the Seedling Growth of Maize (*Zea mays* L.). *Journal of Nigerian Environmental Society,* 4(2): 72 – 80.

Dickinson, C. H. and Lucas, J. A. (1982). *Plant Pathology and Plant Pathogens*. 2nd edn. Blackwell, Oxford.

Eastbrook, E. M. and Yoder, J. I. (1998). Plant – plant Communications : Rhizophere Signaling Between Parasitic Angiosperms and Their Hosts. *Plant Physiol*., 116 :1 – 7.

Edwards, M. C., Fetch, T. G. Schwaz, P. B. and Steffenson, B. J. (2001). Effect of Barley Yellow Dwarf Virus Infection on Yield and Malting Quality of Barley. *Plant Diseases*, 85:202 – 207.

Ekwamu, A. (1991). Influence of Head Blast Infection on Seed germination and Yield Components of Fingermillet (*Eleusine c0oracana* (L.) Gaertn). *Trop. Pest. Manag*., 37:122 – 123.

Evans, K., Trudgill, D. L. and Webster, J. M. (1993). *Plant Parasitic Nematodes in Temperate Agriculture*. Wallingford, Uk : CAB Int.

Efiuvwevwere B.J.O. (2014). Inaugural Lecture Series No. 114, University of Port Harcourt.

FAO (2000). *The State of Food Security in the World (SOFI)*. Rome, Italy : FAO, UN. www.fao.org/FOCUS/E/SOFI00/sofi001-e.htm.

FAO/WHO (2014). *Food Security*. www.who.int/trade/glossary/story Accessed 17 September, 2016.

Horsfall, J. G. and Diamond, A. E. (1959). *Plant Pathology*, Vol III, Acad. Press, New York.

Horsfall, J.G. and Dimond, E.A., (1959) Epilogue : The diseased plant, in *Plant Pathology- An Advanced Treatise,* Vol. 1 Horsfall, J. G., and Dimond, E. A. (Eds), Academic Press, New York.

Hooker, M.E. (1993). Reliability of gentisic, a fluorescent marker for diagnosis of citrus greening. *Plant Disease*, 77 :174

Iyanyi, N.G. and **A.E. Ataga** (2014). Fungal Species Associated with Vigna unguuculata (L) Walp (Cowpea) Seeds from parts of Enugu State, Nigeria, Scientia Africana, 13(1):103-108.

Iyanyi, N. G., **Ataga, A. E**. and Nwaukwu, I. A. (2015). Microorganisms of *Vigna unguiculata* (L.) Walp (Cowpea) Seeds and the Effect on Germination and Seedling Growth. *Nigerian Journal of Mydology*, 7: 85 – 92.

James, C. (2003). *Global Status of Commercialized Transgenic Crops* : 2003 : Mania : Int. Serv. Acquis. Agri-Biotech Appl. (ISAAA).

Kane, P. J. and Kerr, A. (1977). *Factors Affecting Disease Development* In : Brown, J. F and Ogle H. J. (eds.). *Plant*

pathogens and Plant Diseases. Rockvale Publications, Armidale, New South Wales, Australia. Pp 287 – 298.

Lale, N. E. S. (2010). *Stealthy Thieves in Homes and Food Stores*. Inaugural Lecture. Series No 68. University of Port Harcourt, Port Harcourt, Nigeria.

Legg, J. P., Ndjelassili, F. and Okao-Okuja, G. (2004). First Report of Cassava Mosaic Disease and cassava Mosaic Geminiirusess in gabon. *Plant Pathol*., 53: 232.

Legg, J. P. (1999). Emergence, Spread and Strategies for Controlling the Pandemic of Cassava Mosaic Virus Disease in East and Central Africa. *Crop Prot*. 18: 627 – 637.

Lindow, S. E. (1983). The Role of Bacterial Ice Nucleation in Frost Injury to Plants. *Annu. Rev. Phytopathol*. 21:363 – 284.

Linder, R.C., (1961). Chemical test in the diagnosis of plant virus diseases, Botanical Review, 27:501

Loegering, W. O. (1966). The Relationship between Host and Pathogen in Stem Rust of Wheat. Proc. 2nd Int. Wheat Genetics Symp.., Lund 1963. *Hereditas, Supp*. 2: 167–177.

Martin, J.T., Barker, E.A. and Byrde, R.J. (1966). The fungitoxicities of plant furanocoumarins. *Annals of Applied Biology 57*, 501-508.

McIntyre, J.L. and Sands, D. C., (1977). How disease is diagnosed. In Horsfall, J. G. and Cowling, E. B. (Eds). *Plant Disease : An Advanced Treatise*, Vol 1, Academic Press, New Yok, 35.

Merill, A. H., Liotta, D. c. and Riley, R. T. (1996). Fumonisins : Fungal Toxins that Shed Light on Sphingolipid Function. *Trends Cell Biol*., 6:218 – 223.

Narayanasamy, P., (1997), *Plant Pathogen Detection and Disease Diagnosis*, Marcel Dekker, Inc. New York, Basel, Hong Kong, 331.

Nelson, P. E., Desjardins, A. E. and Plattner, R. D. (1993). Fumonisins, Mycotoxins Produced by Fusarium Species :

Biology, Chemistry and Signifance. *Annu. Rev. Phypathol*., 31: 233 – 252.

Nwaukwu, I.A. and **A.E. Ataga** (2012).Fungi associated with *Hibiscus Sabdariffa Linn* (Yakwa) Seeds from Plateau State. Scientia Africana, Vol. 11(1):125- 129.

Nwaukwu, I.A. and **A.E. Ataga** (2013). Biological Changes induced by five pathogenic fungi on seeds of *Hibiscus sabdariffa* (Yakwa). Scientia Africana Vol.12 (1):1-6

Nwaukwu, I. A. and **Ataga, A. E.** (2013). Effects of Some Pathogenic Microorganisms on Germination and Seedling Growth of *Hibiscus sabdariffa*. *Nigerian Journal of Mycology*, 15:18 – 25.

Nwaukwu, I. A., Akinseye O. F. and **Ataga, A. E**. (2014) Mycoflora Of *Physic* Nut (*Jatropha Curcas*) A Biofuel Plant. *Nigerian Journal of Botany*. Volume 27(2) :191- 198

Odunfa, V. S. A. and Oso, B. A. (1979). Fungal Populations in the Rhizophere and Rhizoplane of Cowpea. *Transactions of the British Mycological Society*, 73(1) : 2 –26.

Omar, S.A.M., Bailiss, K.W. and Chapman, G.P. (1986). Virus-induced changes in the response of faba bean to infection by Botrytis. *Plant Pathology 35*, 86-92.

Omar, S.A.M., Bailiss, K.W., Chapman, G.P. and Mansfield, J.W. (1986). Effects of virus infection of faba bean on subsequent infection by *Uromyces viciae-fabae*. *Plant Pathology 35*, 535-543.

Olufolaji, D. B. (2002). Efficacy of Plant Extracts in Control of *Curvularia* Leaf Spot Disease of Maize in the Screen House. *J. of Sust. Agric. And Environ*, 4(2) : 170 – 184.

Onifade, A. K. (2000). Antifungal Effect of *Azadirachta indica* A. Juss Extracts on *Colletotrichum lindemuthianum*. *Global Journal of Pure and Applied Sciences*, 6(3) : 423 – 428.

Oso, B. A., (1979). Thermorphilic fungi and the deterioration of Nigerian oil palm kernels *Econ. Bot*. 33: 58-62

Owolade, B. F. and Y. O. K. Osikanlu (1999). Evaluation of Some Plant extracts for the Control of Brown Blotch Disease of Cowpea in South WesternNigeria. *Nig. J. Sust. Agric. Environ*, 1 (2) : 198 – 202.

Pathak, M.A., Daniels, F. and Fitzpatrick, T.B. (1962). The presently known distribution of furanocoumarins (psoralen) in plants. *Journal of Investigative Dermatology 35*, 165- 249.

Padmanabhan, S. Y. (1973). The great Bengal Famine. *Annu. Rev. Phytopathol.* 11:11-26

Potter, L.R. (1982). Interaction between barley yellow dwarf virus and rust in wheat, barley and oats, and on the grain yield and quality. *Annals of Applied Biology 100*, 321-329.

Raju, D.G., Sill, W.H. and Browder, L.E. (1969). The combined effects of two viral diseases and leaf rust on wheat. *Phytopathology 59*, 1488-1492.

Rath, R. C. and Pandmanabham, S. Y. (1972). Studies on the inheritance of Leaf Blast Disease Resistance. *Proceedings of the Indian Academy of Science*, 76: 106 – 116.

Rishbeth, J., (1979). Modern aspects of biological control of *Fomes and Armillaria, Eur. J. for. Pathology*. 9:331

Stanley, W.C. and Jurd, L. (1971). Citrus coumarins. *Journal of Agriculture, Food and Chemistry 19*, 1106-1110.

Schell, M. A. (2000). Control of Virulence and Pathogenecity genes of *Ralstonia solanacearum* by an Elaborate Sensory Network. *Annu. Rev. Phytopathol*., 38:263 – 692.

Sciumbato, G. L. (1993). Soyabean Disease Loss Estimate for the Southern United States During 1988 – 1991. *Plant. Dis.*, 77: 954 – 956.

Sharma, P.N. and Sugha S.K (1995). Management of beans anthracnose through chemicals. *Indian Phytopath*. 48:304-307

Singh, D. P. and Sing, A. (2007). *Disease and Insect Resistance in Plants*. Oxford & IBH, New Delhi.

Singh, R. S. (2000). *Plant Disease Management*. Oxford & IBH, New Delhi.

Singh, S., Sidu, J. S., Huang, N., Vikal, Y, Li, Z. K., Brar, D. S., Dhaliwal, H. S. and Klush, G. S. (2001). Pyramiding three Bacterial Blight Resistance genes (xa5, xa13, xa21) Using Marker- Assisted Selection into indica Rice Cultivar PR-106. *Theor. Appl. Gent. 102*(6) : 1011 – 1015.

Stewart, G. R. and Press, M. C. (1990). The Physiology and Biochemistry of Parasitic Angiosperms. *Annu. Rev. Of Plant Physiol. and Plant Mol. Biol*., 41:127-151.

Strange, R. N. (2003). *Introduction to Plant Pathology*. Chichester, UK, Wiley. xvi + 464pp.

Strange, R. N. and Scott, P.R. (2005). Plant disease : A Global Food Security *Annu. Rev. Phytopathol 43* : 83-116

Talbot, N. J. (2003). On the Trial of a Cereal Killer ; Exploring the Biology of *Magnaporthe grisea*. *Ann. Rev. Microbiol*., 57:197 – 202.

Takenaka S. and Kawasaki, S. (1994). Characterisation of alanine-rich hydroxy proline containing cell wall proteins and their application for identifying *Pythium* species. *Physiological and Molecular Plant Pathology*, 45 : 249.

Thakur, R. P. and Mathur K. (2002). Downy Mildews in India. *Crop Prot.*, 21: 333 – 345.

Thinlay, X., Finch, M. R., Bordeos, A. C. and Zeigler, R. S. (2000). Effects and Possible Causes of an Unprecedented Rice Blast Epidemic on the Traditional Farming System of Bhutan. *Agric. Ecosysst. Environ.*, 78:237 – 248.

Udo, E. S., Madunagu, B. E. and Isenin, C. D. (2001). Inhibitors of Growth and Sporulation of Fungal Pathogens on Potato and Yam by Garlic Extract. *Nigerian Journal of Botany*, 4:35 – 39.

Ullstrup, A.J (1972). The impact of the southern corn leaf blight epidemics of 1970-71. *Annu. Rev. Phytopathol* 10 :37-50

Umechuruba. C. I., Otu, K. A. and **Ataga, A. E**. (1992). The Role of Seedborne *Aspergillus flavus* L. Efr., *Aspergillus niger* Van Tiegh and *Macrophomina phaseolina* (Tass). Goid on Deterioration of Groundnut Seed. *International Biodeterioration and Biodegradation* 30, 57,63.

Zhou, XP, Liu, Y.L, Calvert L, Munoz C, Otim Nape (1997). Evidence that DNA-A of a geminivirus associated with severe cassava mosaic disease in Uganda has arisen by interspecific recombination. J.Gen. Virology. 78 : 2101-11.

CITATION ON

PROFESSOR ANTHONY EROMOSELE ATAGA

B.Sc. (Jos) M.Sc. (Jos) Ph.D. (Manchester)
136th Inaugural Lecture of the
University of Port Harcourt

Early beginnings: Professor Anthony Eromosele Ataga was born on the 25th day of August 1956 at Ubiaja, Esan South East, Edo State to Late Elder Jonah Usigbe Ataga and late Madam Omon Ataga (nee Obinyan). The young Eromosele had his primary education at St. Benedict Primary School. He bagged his First School Leaving Certificate in 1967, and moved on to St. John Bosco Grammar School, Ubiaja from 1968 to 1972 for the West African School Certificate. He concluded his higher School Education at Government College, Ughelli, Delta State in 1974. Thereafter, he took up a job as a Laboratory technician with the Nigerian Institute for Oil Palm Research (NIFOR) Benin from 1975-1976. He took off to the University of Jos, in 1976, where he bagged his BSc (Hons) Degree in Botany with 2nd Class Upper Division in 1980. His

national Service was in Okrika Grammar School, Okrika, Rivers State from 1980 to 1981 after which he joined University of Port Harcourt in 1981 as a Graduate Assistant. University of Jos called again in 1983, and he answered again and got his Master's Degree in Applied Microbiology and Plant Pathology in 1984 from the same university. This achieved, he proceeded to University of Manchester, United Kingdom for his doctorate degree in Plant Pathology in 1985. With the terminal Degree Prof. Ataga returned to University of Port Harcourt in 1988 and so it has been up till today.

Professional life and work

Prof. Ataga has had à smooth ride through the ranks of the university system to what and where he is today. He has served and is still serving the university in various capacities including : Head, PSB Dept. 1999-2001 ; Chairman, Faculty of Science Examination Committee 1992 to 1996 ; Consultant, Environmental and Pollution monitoring Unit CORDEC since 1991. Prof. Ataga was Hall Warden Kwame Nkrumah Hall from 1992 to 1996.

Mr. VC Sir, Prof. Ataga has equally served the university and the larger society in many other capacities including Member of University Board of trustees (Pensions and Gratuities) 1998 to 2003 ; Member Governing Board UDPS ; Member Governing Board Ubiaja Community Secondary School 2002 to 2006 ; Chairman, Accommodation Sub-committee, Convocation Committee 2008-2010 ; Member, Senate Committee on \verification of Certificates 2008 to 2012. Director, Institute of Science Laboratory Technology 2011 to 2012. First Dean, SSLT 2012 to 2014. He is currently the Director, Regional Centre for Biotechnology and Biofuel Research.

Service outside the university

Outside the university campus, Prof. Ataga has served humanity as World Bank Research Fellow 1995/96 ; External Examiner to the University of Jos and Delta State University, Abraka ; Member and

Chairman, NUC, Accreditation Team to several Nigerian Universities.

Professional Societies/Affiliations

Mr. Vice-Chancellor, Sir, our inaugural lecturer today has been active in many professional bodies in the country and beyond. These include : Member, Science Association of Nigeria (SAN) since 1991 ; Member British Mycological Society (BMS) 1985 to Date ; Member Association of Applied Biologists, UK since 1985 ; Member, Botanical Society of Nigeria (BOSON) since 1988 ; Member Nigerian Society for Plant Protection (1988-Date) and Nigerian Mycological Society 2006 to Date.

Research interests

He has supervised several undergraduate and Masters' projects and has graduated (6) PhDs.

His first shot was at implicating Furano-coumarins in the management of leaf blight disease in Celery caused by a fungus *Septoria apicola*. Then he investigated the role of several fungi in the storage and rot diseases of Sunflower, groundnuts, wild mango, African yam bean, African pear and sweet potato. His research interests have extended to the use of fungi in remediation of crude oil polluted soils. He has worked on the application of local plant extracts in the management of plant pathogens and diseases. He has continued in these lines of research only this time focusing on the use of local content from Rivers State.

Prof. Ataga has published several journal articles in high impact, widely circulated local, regional and international Journals. To his credit are monographs, Laboratory Manuals and several chapter contributions in books in his area of specialization. Just to add that he has been involved in many EIA, PIA, EES and other environmental studies and concerns as consultant.

His personage

Mr Vice-Chancellor Sir, Prof Ataga is one of the most *misunderstood* colleagues of our times. His penchant for straightforwardness and due process has earned him such labels as 'harsh' 'mean' 'strict' and even 'wicked'. This is a man however, who feels the pains parents feel when their children are tempted to go astray and would rather nip such tendencies in the bud than allow them blossom and ruin such children. His former students have come back to attest that if not for the way he handled them in their day they would probably have not made it to where they are today. Here stands a strict disciplinarian and teacher extraordinaire – *his children and students bear witness to this.* The last induction of SSLT graduands bears ample testimony to this.

Prof. Ataga you may well know, Mr. Vice-Chancellor, is a big time farmer. No year passes by without him planting his yams and cassava at Ubiaja in an effort to help feed family and the nation. He leaves nothing to chance ; not in the house, farm, church or office. He enjoys playing lawn tennis and being with his family.

Stemming from that, let me declare that Prof A.E. Ataga is married to Dr. (Mrs) Agatha Ataga – a very senior member of administrative staff in the Academic Office. The marriage is blessed with 4 robust children : 3 boys : Ehi, Usigbe, Ojeaga and the Princess of the house - Omoye.

Mr. Vice-Chancellor Sir, my cherished colleagues, distinguished Ladies and Gentlemen, may I then, with your permission, humbly herald unto the stage : An erudite scholar, an astute administrator, a dogged fighter for due process, a farmer and teacher extraordinaire !

A Plant Pathologist *par excellence,* a husband of one wife, a very strict but kind disciplinarian Professor Anthony Eromosele Ataga.

Prof. Gordian Chibuzo Obute

Orator