UNIVERSITY OF ILORIN

THE TWO HUNDRED AND FORTY-SECOND (242ND) INAUGURAL LECTURE

“INTIMATE STRANGERS IN SOIL AND AGRICULTURAL SUSTAINABILITY”

By

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Members of my family, nuclear, extended and In-laws,
Distinguished invited guests,
My Lords Spiritual and Temporal,
Your Royal Highnesses,
Gentlemen of the Print and Electronic Media,
My dear students of the Faculty of Agriculture and other students here present,
Distinguished Ladies and Gentlemen.

Preamble

It is with great pleasure that I stand before this august audience to present the 242ndinaugural lecture of the University of Ilorin. It is a time to give an account of my journey along a career path in academia, my research activities and my contributions to community development that culminated into my appointment as a Professor of Soil Microbiology. I stand to say that this could only have been possible through the guidance of the Almighty GOD. He is Yahweh, the Alpha and Omega. I stand in awe of God, the Creator of the universe as I present this lecture.

I am a native of Esun-Ekiti, Ikole Local Government Area of Ekiti State, Nigeria. I was born at Ilesa, Osun State, to Mr. Z.A. Komolafe of blessed memory and Mrs. R.A. Komolafe. My parents settled down and raised their family at Ilesa. I am the second child in a family of five children. My Mother was a Nurse while my Father was a

School Head Teacher. I attended Ogudu Methodist Primary School and St Margaret's Girls School at Ilesa. My first degree, B.Sc. Microbiology, was obtained from this great University in 1982, with a Second Class (Hons) Upper Division while I had my Masters and Doctorate Degrees from the University of Ibadan in 1985 and 1990 respectively. How did my journey to academia start?, How did I get to becoming a Professor of the University of Ilorin? On completion of the third year of my secondary school education, I went for holidays with my aunt, Mummy Jolaade Olofinboba at Ibadan. My aunt's husband, Professor Michael Ojo Olofinboba of blessed memory, was then an academic staff in the Department of Botany, University of Ibadan. I went along with him to his office and his laboratory, a number of times where I was made to sit and study a biology text book for secondary school student's authored by Stone and Cozens.

The neat laboratory with scientists in white laboratory coats and the serene environment of the University made an impression on my young heart and this guided my choice of career. Biology was my best subject in the secondary school, so I decided to have a degree in the Biological Sciences. As an undergraduate student at the University of Ilorin in the late 1970s, I fell in love with microbiology courses and particularly the practical aspects that showed the importance of microbial processes. While on my Doctorate Degree at the University of Ibadan, a search for microbial enzymes that could be of industrial use led me to work on soils from refuse dumps of fruit processing companies at Ibadan. I got interested in studying metabolites from soil borne microorganisms and the possibility of using the microorganisms as inoculants in improving soil fertility or for control of pests without damaging the environment. Shortly after my Doctorate Degree in 1990, I started my career with the Nigerian Stored Products Research Institute and moved on to Ladoke Akintola University, Ogbomoso, for a few months before joining the services of the University of Ilorin in January 1992as a Lecturer II. My movement from the Research Institute to the University system was borne out of my passion and love for teaching in addition to my duty as a research scientist. I rose through the ranks from the position of Lecturer II to Professor of Soil Microbiology in the Department of Agronomy in the year 2017, to the glory of God.

This Inaugural Lecture is the 4th from the Department of Agronomy and the second from the Soil Science Unit of the Department. Prof. J.A. Ogunwale presented the 76th Inaugural Lecture of the University, the 1st in Soil Science Unit of the then Crop

Production Department titled, “Land: the Beginning, the Sustainer and the End of Man on Earth” in 2004. I remember pronouncing silently to myself at the 160th Inaugural Lecture of the University, which was the last inaugural lecture from the Department of Agronomy, presented by Prof. Gbadebo Olaoye, in year 2015 that the next shall be from me, ***‘emi lokan’***. It has come to fulfillment today. Glory be to God! The journey has been full of interesting and fulfilling activities which I will try to summarise in this one hour lecture. Please relax and go along with me.

Introduction

Vice-Chancellor Sir, this Inaugural Lecture is titled: “**Intimate Strangers in Soil and Agricultural Sustainability”.** A stranger can be defined as an individual that one is not acquainted with, while to be intimate connotes close acquaintance or association, familiarity, linkage and connection. The question then comes to mind, how in the world can a stranger be intimate? Yes, it is rather paradoxical that the unseen life in soil relates intimately with other lives via the activities and transformations they are involved in. Who are these strangers in soil: they are the unseen life in soil. We have an array of microscopic organisms (that cannot be seen with naked eyes) that inhabit our soils. The microscopic nature of these ***“strangers”*** is one major characteristic that makes their activities go unnoticed by the untrained eyes. Man is thus not acquainted with the microbial world and its activities. Alas we are connected with soil micro-organisms in diverse ways. The Holy Bible in Genesis 3:19b declares that *“man was formed from dust and to dust he shall return”*. In many cultures all over the world, dead human bodies are committed to mother earth. These and other naturally occurring and synthetic materials in soil are transformed by the activities of the unseen life in soil that re-echo the essence of the Intimate Strangers.

Soil is the substance on the surface of the earth in which plants grow. It offers plants physical support, air, water and nutrients. It is a mixture of organic matter, minerals, gases, liquids and organisms that together support life. Soil is a living system because it is a home to many living organisms.

Intimate Strangers in Soil

A large diversity of microscopic organisms which are very important in making food, feed, fiber and medicine available to man inhabit the soil. A number of them are also responsible for diseases of plants, livestock and humans. The microbial world in soil range from micro-flora such as bacteria, fungi, actinomycetes and algae to micro-fauna such as protozoa and some nematodes.

Bacteria in Soil: Bacteria are unicellular, prokaryotic, microscopic organisms. They are the smallest and most numerous cellular organisms in soils. The cells are rarely more than several micrometers in length. They are particularly abundant around the rhizospheric region of plants. Bacteria cells exist in a variety of shapes and arrangements. They could be spherical (cocci), rod (bacilli), helical (spiral) or comma (vibrio) shaped. Soil inhabiting bacteria could also be broadly grouped as autochtonous and allochtonous. The autochtonous species are indigenous species, which may occur in resting state, becoming active with the availability of substrate while the allochtonous species may enter the soil through diseased plants or animals or through animal manure.

Bacterial biomass found in soil ranges from 300 to 3000 kg/ha. There are approximately 10^8 to 10^9 bacteria in a gram of soil, most of them (>99%) have not been or cannot be cultured in the laboratory (Sapkota, 2022). Common soil dwelling bacterial genera include *Bacillus, Arthrobacter, Pseudomonas, Agrobacterium, Alcaligenes, Clostridium, Flavobacterium, Corynebacterium, Micrococcus, Xanthomonas* and *Mycobacterium*. Although bacteria have a simple morphology, they have the greatest metabolic diversity. They are grouped as chemoheterotrophs, chemoautotrophs and photoautotrophs based on the energy source. In terms of oxygen relationships, soil bacteria may be classified as strict aerobes, strict anaerobes, facultative anaerobes or microaerophilic.

Fungi in Soil: This is a group of mostly multicellular, nucleated organisms with filamentous branched structures. The extensive network of the fungal mycelia makes them a significant part of the soil biomass. Fungi have more complex morphologies and life cycles compared to bacteria. There are however some single-celled fungi that reproduce asexually through budding known as yeasts. Although most fungi are aerobic, yeasts can survive in anaerobic environments.

Fungi make up the largest biomass of all the soil organisms in many ecosystems, ranging from 500 to 5000 kg/ha. Soil fungi include oomycetes, zygomycetes, ascomycetes, basidiomycetes and deuteromycetes (imperfect fungi). Some of the common soil fungi are *Pythium, Rhizopus, Absidia, Cunninghamella, Pleurotus, Aspergillus, Penicillium, Agaricus, Polyporus, Verticillium, Phytophthora,* *Rhizoctonia, Trichoderma* and *Chaetomium*. Soil fungi are usually decomposers, mutualists (mycorrhizal fungi) or pathogens. They are of great economic importance as sources of antibiotics and commercial enzymes. A number of fungal species are also associated with spoilage of agricultural produce in storage.

Actinomycetes in Soil: This is considered as a transitional group between simple bacteria and fungi though taxonomically they belong to an order of bacteria called Actinomycetales. These are microorganisms that produce slender branched filaments which develop into mycelia in all soil genera with the exception of *Actinomyces*. In some cases, the mycelia might break off, resulting in rod or spherical shaped forms. Actinomycete population is largest in the surface layer of soils and gradually decreases with the depth; although individual actinomycete strains are present in all soil layers. They are widely distributed in the soil with estimated values ranging from 10^4 to 10^8 per gram of soil and are more abundant in neutral to alkaline soils. The most dominant genus in soil is *Streptomyces* followed by *Nocardia* and then *Micromonospora*.

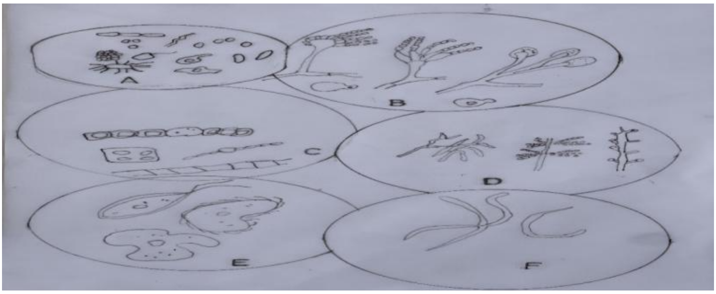
They decompose the more resistant organic substances and produce several dark black to brown pigments which contribute to the dark color of the humus soil and like other groups of microorganisms, some soil borne actinomycetes are pathogens, causing different diseases in plants.

Algae in Soil: These are predominantly aquatic and photosynthetic organisms that occur in lakes, rivers, swamps and oceans. However, many species also occur in surface soils as well as in lower horizons. Algae may be unicellular or may occur in short filaments. The soil species are usually smaller than aquatic forms. These organisms might either occur freely in the soil or in the form of symbiotic relationships with lichen-forming fungi. Many algae are obligate photoautotrophs but some species of the soil inhabitants are facultative photoautotrophs. They are capable of utilizing organic carbon (heterotrophy) when existing below the soil surface where photoautotrophic life is impossible. Algae are usually pioneering invaders of habitats where life has been eliminated by natural or artificial occurrences such as volcanic eruptions, erosion and bush burning. They support the growth of secondary colonizers in food production. The photosynthetic algae liberate molecular oxygen in paddy soils thus providing part of the oxygen required by submerged roots of rice. They also enrich such soils with nitrogen. Blue-green algae in soil survive at the mesophilic temperature range, and are sensitive to acidity (having an optimum pH range 6.5-8.0)and waterlogged soil conditions (Sapkota, 2022). They play significant roles in increasing soil physical structure, porosity and soil moisture retention as a result of their filamentous structure.

Nematodes in Soil: These are bilaterally symmetrical unsegmented pseudocoelomates. Most of the about 10,000 known species of nematodes are either free living in the sea or parasitic. About 1,000 species are soil inhabitants. Most soil nematodes are microscopic, transparent thread-like animals with typically elongated body that tapers at both ends. They are usually found in the upper 10cm of a soil profile. The numbers of nematodes are more abundant in the vicinity of plant roots than elsewhere in the soil. Soil nematodes have a variety of feeding habits. These form a basis of classification. They all appear to feed on living materials, that is, dead organic matter does not form part of their diet. Some of them are plant parasites extracting plants sap by piercing roots e.g. *Meloidogyne* sp. Majority (about 70%) of them feed on other microorganisms such as rotifers, fungi, bacteria, protozoa and algae. Soil nematodes help in the regulation of microbial population and serve as food sources for other living organisms in the ecosystem.

Protozoa in Soil: Protozoa are unicellular eukaryotic microorganisms. They obtain food by ingesting other microbes such as bacteria, yeasts, algae and smaller protozoa. Free-living soil protozoa may be characterized as: Mastigophora (flagellates), Sarcodina (amoebae), and Ciliophora (ciliates). These single-celled animals differ in shape, size, and distribution. Numerous heterotrophic flagellates and naked amoebae are available in agricultural soils, grassland and forest soil as well as in bottom sediment of freshwater, coastal and marine waters. The presence of living and dead plant roots and the organic content of the soil greatly influence the presence of protozoa in the soil. The presence of protozoa in soil depends on the structure and texture of the soil. Ciliates are more commonly found in moist soils, while flagellates are abundant in drier soils. Also, flagellates and amoeboid forms predominate cultivated soils and clay soils while coarse textured soils consist of large flagellates and ciliates.

Viruses in Soil: This is a group of sub-microscopic non-cellular infectious agents that inhabit the soil. A virus particle known as a virion is a complex molecule which consists of the viral genome, which can be either DNA or RNA in a single- or double-stranded state, surrounded by a protein coat, the capsid. They carry out metabolic activities only in the presence of a suitable host. The concentration of viruses in soil has been estimated to range between 10^7 and 10^9 particles per gram dry weight of soil (Srinivasiah *et al*., 2005; Swanson *et al.*, 2009).Soils act as reservoirs of viruses. They are obligate parasites of cellular organisms and thus are of considerable economic and medical importance. They cause diseases of plants, animals and man.



A. **Bacteria**	B. **Fungi**	C. **Algae**
D. **Actinomycetes**	E. **Protozoa**	F. **Nematodes**

Fig. 1: Morphological structures of groups of soil micro-organisms

Source: Adapted from Rangaswami & Bagyaraj (2009).

Studying the intimate strangers in Soil

The microscopic forms in soil are studied basically in the laboratory either by direct microscopic studies or cultural methods. The direct microscopic studies may be by observation of stained soil preparations, stained buried slides or soil samples in the laboratory. A microscope is an optical instrument that uses a lens or an arrangement of lenses to magnify an object. Microscopes used in the study of unseen life in soil include compound microscopes, scanning and transmission electron microscopes, fluorescence microscopes and stereomicroscopes depending on the purpose of the study. Cultural methods on the other hand involve making nutrients available to bacteria, fungi and actinomycetes in soil samples to enhance their growth. They grow in populations that can be seen as colonies on growth media in Petri dishes. Microscopic examination of cells growing in the microbial colonies is then made to observe the morphological structures. Enrichment cultures could also be used for identifying functional groups of these soil microbes as well as cultivation of algal forms. Soil protozoa are studied by direct microscopic examinations of soil dilutions while wet sieving and decanting method is used for isolating soil nematodes which are then observed with aid of stereomicroscopes.

A Compound microscope **B Stereomicroscope**

C Scanning Electron Microscope **D Fluorescence Microscope**

Fig. 2: Some types of microscopes
Source: https://www.pexels.com/search/microscope/

Interactions of Soil Microbiota and the Environment

The soil microbiota is interrelated with abiotic climatic and mineral soil components as well as living components such as plants and soil biota (Wallenstein, 2017).As such, many factors influence the distribution of soil micro-organisms. These include soil factors such as soil temperature, soil pH, moisture content, aeration and fertility. Agrochemicals which are used for improved crop production have been associated with negative effects on the unseen life in soil. There are reports of pesticidal effects on non-target microorganisms in soil (Motta *et al.*, 2018).On the other hand, on a positive note, organic matter promotes soil biological health as it is an important food source for soil flora and fauna. It controls the type and number of soil inhabitants and thus contributes to other soil functions such as nutrient availability and cycling, plant nutrient uptake, root growth and suppression of soil diseases (Chan, 2008). Sufficient soil organic matter enhances the soil biological activities while reduction in soil organic matter has negative effects on soilmicrobes, microbial activities and consequently, plant health.

The Unseen Life in Soil, Climate Change and Agricultural Value Chains

The emission of greenhouse gases in the environment is increasing at an alarming rate globally. These occur in both natural and artificial ways. The artificial source of CO_2 emission due to human activities includes emissions from power plants, industries, automobiles, waste disposal, incineration and burning of fossil fuels. Natural emission of CO_2 includes those from carbon cycle via the activity of unseen life in soil and ashes from volcanic eruptions. Strategies involved in reducing atmospheric CO_2 include reduction in the amount of CO_2 being released into the atmosphere, removal of CO_2 already present in the air and use of atmospheric CO_2 for production of commercial products, all in an attempt to mitigate climate change (Gayathri *et al.*, 2021)The thicker blanket of gases in atmosphere makes the earth to heat up (global warming).The increase in environmental temperature results in increased crop respiration rate, pest infestation, and changes in weed flora (Malhi, 2021).

Soil is the largest reservoir of carbon. According to Singh *et al.* (2010), soils in combination with plant biomass holds nearly 2.5times more carbon than the atmosphere holds. The ability of soil to retain large amounts of carbon helps in mitigating rising levels of atmospheric carbon. Understanding the roles of soil micro-organisms in carbon sequestration is crucial for developing sustainable land management practices that promote carbon storage in soils and mitigate climate change. Soil micro-organisms contribute to the physical stabilization of carbon in the soil. By producing glues and sticky substances, known as extracellular polymeric substances, micro-organisms help bind soil particles together, forming aggregates. These aggregates protect carbon from decomposition and enhance its long-term storage potential. On the other hand, in some cases, micro-organisms may accelerate the decomposition of soil organic matter, leading to the release of stored carbon, a phenomenon, known as the carbon priming effect, which can increase CO_2 emissions from the soil.

Changes in soil temperature, humidity, pH and other soil environmental factors as a result of climate warming may directly or indirectly affect the composition, physiological growth and functions of soil microorganisms in a soil ecosystem (Dong *et. al*., 2012).Flooding results in displacement of air in pore spaces and consequently, buildup of anaerobiosis. A reduction in rate of organic matter decomposition will result and ultimately a decline in nutrient content of soils in affected areas will occur. On the other hand, climate change may lead to a reduction in rainfall resulting in drought and desertification. Worsened cases of water scarcity makes it difficult for farmers to irrigate their crops as they face difficulties in producing crops when less water is available for irrigation. Whenever there is scarcity of water, the unseen life in soil also suffers. This is because micro-organisms require adequate quantity of water for physiological activities and transformations in soil. A decline in microbial activity also has a negative effect on the soil productivity. Global warming as a result of increased temperatures, results in greater incidence of crop diseases as conditions that are favorable for the proliferation of pests and pathogens are brought about by climate change (Finch *et al*., 2021). In addition to increased incidence of locusts and armyworms, pests that cause significant crop damage and economic losses for farmers, the proliferation of some soil borne pathogens- unseen life in soil also lead to increased incidence of diseases in plants.

Impact of Microbes on Biogeochemical Cycles

The biogeochemical cycles involve external transfers of elements among different components of a forest system. Microbes are known to play a very important role in productivity and health of plants. They are involved in cycling of carbon, nitrogen, phosphorus, sulfur nutrient elements and micro nutrients in the global food web. Uptake of nutrients from the soil and return of these nutrients in leaf fall, branch shedding or through tree mortality is a major component of the biogeochemical nutrient cycles. Nutrients returned to the soil in this way are not available for plant reuse until decomposition occurs and nutrients are converted from organic to mineral forms, a process called mineralization. Mineralization of nutrients from organic matter of the forest floor plays an important role in the supply of nutrients available for forest growth (Cavicchioli *et. al*., 2019).Autotrophic soil micro-organisms are involved in carbon dioxide fixation via photosynthesis while heterotrophs break down organic materials for regeneration of carbon dioxide. Nitrifying bacteria in soil include *Nitrosomonas* and *Nitrobacters*. *Rhizobium* species are symbiotic nitrogen fixing bacteria that are commonly found in soil. Other free living bacteria such as *Azotobacters*, *Beijerinckia* and *Clostridium* species are also involved in nitrogen fixation in soil. Some other microbial processes in nutrient cycling are solubilisation, assimilation, oxidation and reduction. The unseen lives in soil decompose plant tissues and animal remains as well as transform hydrocarbons and pesticides in soil. The role of soil microorganisms in the ecosystem should be appreciated to apply effective agronomic measures for soil carbon sequestering. Although bacteria occur in large numbers on soil than fungi, soil fungi have been known to be involved in carbon sequestration more than bacteria (Li *et al.*, 2015). Bacteria could contribute to carbon sequestration through many pathways. *Pseudomonas fluorescence* is a plant growth promoting bacterium that could be a useful tool for carbon sequestration and climate change mitigation.

Microbial Interactions in Soil

Many types of associations occur in soil. Some are interactions between different groups of soil microorganisms while others are interactions with other soil living organisms. Beneficial interactions occurring in soil include symbiosis, proto-cooperation and commensalism.

Symbiosis is the association of two organisms in which the two symbionts rely upon one another both benefiting from the relationship. One example is the *Rhizobium* - legume symbiosis in which case the legumes gain nitrogen from the nitrogen metabolizing bacteria and organic carbon is transferred to the *Rhizobium* from the CO_2 metabolizing host. Another example is the fungus- plant roots association to form mycorrhizas. The fungus in this type of association, obtains essential organic nutrient from the plant while the plant enhance rate of uptake of P, N and other inorganic nutrient. Mycorrhizae play significant roles in plant nutrition and soil biology.

Proto-cooperation is also an association of mutual benefits to two microorganisms. For example there may be nutrient interaction between bacteria and fungi for various vitamins and amino acids. Usually one partner is able to synthesize appropriate growth factor for the other partner. Commensalism is an association of two organisms in which one organism benefits while the other is unaffected. There are numerous examples of commensalism in the ecosystem. Some microorganisms decompose complex organic matter releasing substances which serve as substrates for secondary decomposers e.g. cellulose decomposing organisms will break down cellulose into simpler forms which can now be used by some organisms like *Azotobacter* species that can only use the simple form of carbohydrate. Other examples involve changes in physical environment brought about by one organism thereby making the environment favourable for the development of another organism.

Detrimental Microbial Interactions could be in form of competition, amensalism, parasitism and predation. Competition involves rivalry between two organisms for limiting nutrients or common needs. There is commonly competition for carbon, inorganic nutrient or even oxygen in soil. This is because the supply of these substances in soil is perennially inadequate. Thus, an organism could be suppressed or inhibited in the soil in the presence of a better competitor e.g. some soils saprophytes can inhibit the development of pathogenic fungi in roots. Amensalism is another form of competition which involves antagonism of one organism towards another resulting in the inhibition of another. Toxic metabolites are released into the environment and this suppresses other organisms in the neighborhood. A variety of bacteria, fungi and particularly actinomycetes are capable of synthesizing such toxic metabolites that are used in commercial production of antibiotics such as streptomycin.

Parasitism is a relationship between two organisms in which one is benefitting at the expense of the other. A parasite lives in or on the host causing it harm as it uses it as a source of energy and materials for biosynthesis. Many bacteria and fungi are parasites of plant roots and seedlings in the soil i.e. plant pathogenic microorganisms in soil are able to parasitize on the roots and seedlings of plants. Predation is the direct attack of one organism on another organism. A predator tends to be free-living but uses its prey as source of energy or nutrients but not as habitat. Predation is common among soil animals (fauna) but is restricted to phagotrophic organisms like protozoa in the microbial world. A lot of protozoa prey on bacteria cells. Predacious microorganisms in soil include nematode trapping fungi. Microbial interactions in soil influence the course of microbial succession in soil. Many of the early colonizers of organic substrates are usually involved in negative interactions but in the evolution and development of an ecosystem, negative interactions tend to be minimized in favour of interactions that enhance` the survival of the interacting species.

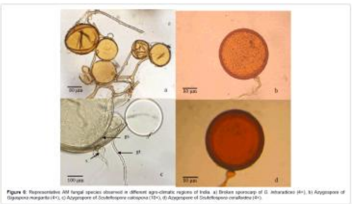


Plate 1a: Arbuscular mychorrhizae mychorrhizae spores

Source: Singh and Adholeya (2013)

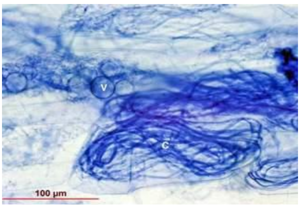


Plate 1b: Arbuscular interactions in soil

Source: www.mycorrhizas.info

The Intimate Strangers in Soil and Biotechnology

Microbial Inoculants

Microbial inoculants are agricultural amendments that use beneficial micro-organisms to promote plant health. The promotion of plant health could thus be through Bio-fertilization, Bio-degradation, Bio-control and Bio-remediation.

Vice-Chancellor Sir, I would dwell briefly on some of the applications of microbial inoculants.

Bio-fertilisation: Formulations of beneficial living microorganisms are added to soil directly or indirectly to improve the nutrient availability to the host plant and promote plant growth. The macronutrients that limit plant growth are usually nitrogen and phosphorus. Soil borne microorganisms that possess the particular trait for nitrogen and phosphorus transformation thus have the potential for use as microbial inoculants in this respect.

The various types of biofertilizers which help to enhance plant growth are: Nitrogen fixing biofertilizers from *Azotobacter, Nostoc, Rhizobium* and *Azospirillum:* Phosphorous solubilising biofertilizers from species of *Bacillus, Pseudomonas, Penicillium and Aspergillus*; Phosphorus mobilizing biofertilizers from Arbuscular Mycorrhiza- AM fungi; biofertilizers for micro-nutrients such as silicate and Zinc solubilisers from *Bacillus* species; and plant growth promoting bacteria from *Pseudomonas sp.* and *Bacillus sp*.

Biodegradation: Living organisms are used to speed up the decomposition of organic residue. Microbial inoculants are used in enhancing composting of agricultural residues for improved soil fertility. Composting is the biological decomposition of organic materials which ranges from backyard piles to complex industrial processes. The activities of unseen life in soil transform the organic materials to simpler more mobile forms in the end product. Organic wastes can thus be converted to organic fertilizers. Mixed cultures of micro-organisms have been found to enhance the rate of lignocellulose degradation due to their synergistic activity through utilization of intermediate degradation products (Singh and Nain, 2014).

Bioremediation: Accumulation of heavy metals and related compounds which could be from natural or anthropogenic sources cause agricultural soil pollution. This becomes a threat to soil health, food quality and consequently food security. The traditional physico-chemical technologies of soil washing used for soil remediation render the land useless as a medium for plant growth, as they remove all biological activities. Others are labor-intensive and have high maintenance cost. The degrading ability of soil microorganisms helps in cleaning up pollutants from soil environments. Micro-organisms are used to break down hazardous substances in the environment into less toxic or non-toxic substances. Soils contaminated by metals have been cleaned up with microbial inoculants which can improve pollutant removal through various mechanisms. Some have the potential to produce metal chelating siderophores, which could improve metal bioavailability. Others produce biosurfactants (rhamnolipids) that can enhance the solubility of poor water-soluble organic compounds and the mobility of heavy metals. Some microbial inoculants assist plants in remediation of polluted soils by forming biofilms. In addition, microbes introduced to soils can transform metals into bioavailable and soluble forms through the action of organic acids.

Bio-control: Microbial inoculants act as antagonists and suppress the incidence of soil borne plant pathogens and thus, help in the bio-control of diseases. Microbial inoculants could be applied as bio-fungicides, bio-pesticides and bio-herbicides for the promotion of plant health.

Microbial Inoculants' Use in Africa

Vice-Chancellor Sir, in order to reduce hunger and food insecurity in Africa, there is a need for considerable increase in crop production. External inputs such as mineral or organic fertilizers are being used to boost crop production since most soils in the region are inherently poor. Though the use of inorganic fertilizers boosts food production it is at the cost of soil health as persistent use of these chemicals in soil will result in pollution and degradation of soil. The need for improvement of crop productivity in an ecofriendly manner has led to the use of microbial inoculants for restoration or enhancement of soil fertility in many countries. Though, the use of microbial inoculants for improvement of crop productivity has been well established in developed countries; it is still in the developing stage in most parts of sub-Saharan Africa.

Indigenous *Bradyrhizobium japonicum* strain IRj 2180A has been isolated from soybean since 1979 and used for inoculation of soybean (Okogun and Sanginga, 2003). Commercial products from foreign countries and indigenous microbial inoculants are used in Africa. These include Nitrogen fixing bio-fertilizers from *Rhizobium, Bradyrhizobium, Azospirillum* and *Azotobacte)*; Phosphorous solubilising bio-fertilizers (PSB) from *Bacillus, Pseudomonas, Aspergillus, Penicillium, Fusarium, Trichoderma, Mucor, Ovularopsis, Tritirachium* and *Candida*; Phosphate mobilizing biofertilizers from Mycorrhizas and Plant growth promoting biofertilizers (*Pseudomonas*). Enriched compost biofertilizers are also produced from cellulolytic fungal cultures of *Chaetomium bostrychodes, C. olivaceum, Humicola fuscoatra, Aspergillus flavus, A. nidulans, A. niger, A. ochraceus, Fusarium solani and F. oxysporum.*

However, many smallholder farmers are not even familiar with these products. Many commercial products were evaluated in selected agro ecological zones in Kenya, Nigeria, Niger and Ethiopia from 2009 to 2011 in Commercial products (COMPRO I) project. The COMPRO I project (funded by Bill and Melinda Gates foundation) was undertaken to develop effective laws and regulations for bio-fertilizers and other agro-inputs in Sub Saharan Africa, communicate information on products proven best or promising; and build the capacity of countries in SSA to implement and enforce such regulations.

Fig. 3: Some commercial microbial inoculants

Source: *https//agritrop.cirad.fr/558112/1/document*

Vice-Chancellor Sir, a search for indigenous soil microorganisms that could be used for production of efficient bio-fertilizers, thus continues.

Other current applications of microbial inoculants include microbial assisted phytoextraction and biocontrol. The remediation by plant using the degrading ability of soil organisms is called phytodegradation. Some soil microbes such as the arbuscular mycorrhizal fungi (AMF) secrete glycoprotein called glomalin which can form complexes with metals. Microbial organisms within the rhizoplane can take part in phytoremediation by protecting the plants from the toxic effect of the contaminants while the plants in return provide the microbial processes the boost they need to remove organic pollutants from the soil more quickly (Alori and **Fawole,** 2017).Microbial-assisted phytoextraction optimizes the synergistic effect of plants and microorganisms and has been used for the cleaning-up of soils contaminated by metals.

A number of microbial inoculants have been produced by Institutions and Organizations in Africa. These include BIOFIX by MIRCEN, University of Nairobi, MEA LTD Kenya, NITROSUA by Sokoine University, Tanzania; Bio-N-Fix by Makerere University, Uganda; Bio-Fertilizer legume inoculant by Madhvani industries, Uganda; NITROZAM by Mt. Makulu Research Station, Zambia; legume inoculant by Marondera, Zimbabwe.

There is hardly any country in West Africa where rhizobial inoculants are regularly used by farmers other than experiments that are limited to research farms. The Microbiological Resource Centre (MIRCEN) in Senegal conducts inoculation trials on grain legumes, especially cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*), soybean (Glycine max), and bean (*Phaseolus vulgaris*).According to Woomer and Mahmadi (2014), IITA and N_2Africa explored commercial inoculant production through its established Business Incubation Platform (BIP). NoduMax, a peat-based carrier containing elite Bradyrhizobia, for soybean cultivation has been introduced to the market in Nigeria. A 100 g package of the product is enough to inoculate 10kg of seed and will plant 0.25 ha. The product can increase the yield by 30% to 45% on an average, is affordable and is environmentally safe.

Soil Conservation and Management for Sustainable Agriculture

Without proper conservation and management techniques, soil erosion, nutrient depletion, and other forms of soil degradation can occur causing significant reduction in crop yields and threats to long–term sustainability of agricultural systems. Farmers can help to prevent soil erosion, improve soil fertility and enhance crop yields by implementing soil conservation and management practices. A reduction in input costs, and greater environmental sustainability in agricultural systems will be achieved (**Fawole,** 2023). Soil conservation and management practices include crop rotation, reduced tillage, cover cropping, cross-slope farming, application of composts and manure and use of biofertilizers. Crop rotation is a traditional practice of growing different kinds of crops in succession on the same piece of land. A well-designed crop rotation promotes good soil structure, helps to control weed, pests and diseases. It fosters a diverse range of soil flora and fauna that contribute to nutrient cycling thereby improving soil fertility, plant nutrition, crop yield and economic gains. Mulching may be defined as the process of covering the soil surface around the plants to create congenial conditions for the crop growth. Mulches can be organic; in form of compost, grass clippings, chopped leaves, straw, shredded bark, sawdust, or inorganic; in form of plastics. Mulching fosters a diverse range of soil flora and fauna that contribute to nutrient cycling. The practice of minimizing soil disturbance and allowing crop residue to remain on the ground instead of being thrown away or incorporated into soil known as reduced tillage results in increased soil organic matter, improved soil quality and increased population of beneficial soil microorganisms. Cover cropping with grasses, legumes, or broadleaf non-legumes is another conservative soil management practice that has positive effects on the microbial population of soil. The use of organic amendments and composting also has positive impacts on the unseen life in soil and agricultural sustainability. All the aforementioned conservation concepts in soil, help to preserve soil biodiversity maintain health and productivity of soil. These methods have also been proposed for increasing soil carbon sequestration. (Luan *et al*., 2021, Yang *et al*., 2019).

My Research Contributions

Vice-Chancellor Sir, while on my Doctorate degree, a search for microbial enzymes that could be of industrial use led me to work on soils from refuse dumps of fruit processing companies at Ibadan. I got interested in studying metabolites from soil borne microorganisms and possibility of using the microorganisms as inoculants in improving soil fertility or for control of pests without damaging the environment. My research focus has thus been on studying diversity of the unseen life in soil, factors that affect their distribution and their possible uses in Biotechnology for Agricultural Sustainability. In recent years, I have concentrated on development of bio-fertilizers and bio-pesticides from soil microorganisms which are ecofriendly alternatives to chemicals for improved Crop Production. I am currently working on the development of Phosphorus solubilising bio-fertilizers from soil fungi in my laboratory.

My contributions will be discussed under three broad areas of interest; contributions to soil microbial ecology, contributions in microbial biotechnology and my contributions in other areas of agricultural microbiology.

Research in the area of soil microbial ecology afforded me the opportunity of understanding some of the factors that affect the occurrence and distribution of soil microorganisms. Knowledge of the presence of varying types of unseen life in different soils point to the type of transformations taking place in such soils. Also, knowledge of the occurrence of beneficial micro-organisms can be useful in scientific manipulations to maximize the benefits of such microorganisms in soil. On the other hand, wherever pathogenic microorganisms are encountered, basic information is provided to help proffer control strategies for the protection of crops and livestock. A study was carried out by **Fawole** and Odunfa (1992) to identify highly pectolytic moulds from decaying food and fruits in refuse dumps at Ibadan. This was in search of moulds that could be used for production of pectic enzymes which are of application in clarification of fruit juices in fruit processing industries. Pectolytic moulds were reported to occur in large number in refuse dumps in Nigeria. Analysis of microbial isolates showed that 82.50 % were pectolytic, 38.75% showed polygalacturonse and pectin lyase activities. Aspergilli formed the largest group of pectolytic isolates encountered. Other pectolytic micro-organisms were *Absidia corymbifera, Cunninghamella elegans, Fusarium pallidoroseum, Fusarium solani, Penicillium aurantiogriseum, Penicillium brevicompactum and Rhizopus oryzae*.The identities of these pectolytic fungi were confirmed by the Commonwealth Mycological Institute, UK. The study added to a list of microorganisms that have the potential for production of commercial pectic enzymes.

In another study, **Fawole** and Olowonihi (2005) carried out a study on the distribution of fungi and bacteria in soils of Afon, Tanke, Badi, Bolorunduro and Ilemona series of Ilorin. The impact of some physicochemical properties of the soils on distribution of microorganisms was investigated. A variety of fungal and bacteria species associated with nitrogen fixation and organic matter decomposition were encountered in all the soils. Afon soil series had the highest microbial load which was attributed to its relatively higher organic matter context (0.20%), effective cation exchange capacity (9.93) and sandy loam texture. Soils of Ilemona series and Bolorunduro series had high numbers plant pathogenic moulds and enteric bacteria. The occurrence of enteric bacteria in soils of Bolorunduro and Ilemona series was attributed to presence of grazing cattle in the farmlands. It was concluded that for optimum crop yield, soils of Afon, Badi, Tanke and Bolorunduro series require fungicidal treatments. The mycoflora of

Ilemona soils was dominated by saprophytic Aspergilli while pathogenic strains of *Colletotrichum* species and *Fusarium* species were high in numbers in the other soil series (87% *Fusarium* spp, in Badi; 52% *Collectotrichum*, in Afon).

Olowonihi, **Fawole** and Afolayan (2012) carried out a study on the diversity, characteristics and distribution of AMF indigenous to the southern Guinea Savanna of Nigeria fungal spores encountered varied in colour (white, orange, reddish brown and black. The spores of *Glomus* and *Scutellospora* were abundant in soils of this zone (30.77% and 23.08%) respectively. Significant negative correlations were observed between AMF spore population and soil factors: Soil pH (r = -0.70*); %OM content (r = -0.98*), ECEC (r = -0.79*); % Nitrogen (r = -0.95*) and available Phosphorus (r = -0.74*).

The hydrolytic activities (cellulases and pectinases) of some arbuscullar mycorrhizal fungi (AMF) from four study sites in southern Guinea savannah were studied by Alori, **Fawole** and Afolayan (2012). The DNA, RNA and protein content of their spores were also quantified. Significant differences were observed in the hydrolytic activities of the isolates. Variations in DNA, RNA and protein contents of isolates were observed. *Scutellospora reticulata* which was predominant in all soils had the highest hydrolytic activity as well as DNA, RNA and protein contents.

A major problem facing crop production in Southern Guinea Savannah ecological zone of Nigeria is low fertility status of the soil. This, therefore, necessitates the use of soil amendments to improve plant growth and yield. The use of chemical fertilizers has become an integral part of modern day farming to enhance crop productivity. It has, however, been reported that many agrochemicals have effects on non-target soil micro-organisms. The response of Arbuscular Mycorrhizae (AM) spores to fertilizer and herbicide applications under a maize mono-culture in southern Guinea savannah ecological zone of Nigeria was studied by **Fawole** and Alori, (2017). Thirteen (13) AM fungi taxa which belong to six genera of AM fungi were identified. These were *Glomus, Paraglomus, Acaulospora, Enthrophospora, Gigaspora and Scutellospora.*We found that increasing atrazine concentrations resulted in significant reduction in AMF spore population while increasing N.P.K. content led to an initial significant increase in AMF spores but later a decline in spore population. Both fertilization and herbicide application resulted in a decrease in AMF spore numbers at maturity of maize crop. It was concluded that application of 160kgN/ha and 3kg a.i.ha^{-1} of atrazine caused a significant reduction in spore density.

Alori, **Fawole** and Akanji (2020) also carried out some studies in our laboratory to determine the effect of some soil properties and phosphorous applications on Arbuscular mycorrhizas in soil. The occurrence of arbuscular mycorrhiza fungi spores in soils of some legumes was investigated. Spores of different species of genera *Glomus* and *Gigaspora* were encountered in the soils of five leguminous plants; *Cajanum cajan* (L) Huth, *Centrosema pascuorum* Martius ex Benth, *Crotalariaochroleuca* G. Don., Lablab purpureus (L) sweet and Mucuna pruriens. Total AMF spore counts were significantly higher (P<0.05) in the soils of *Mucuna pruriens* and *Crotalaria ochroleuca*. A positive correlation was recorded between total AMF spores, predominant AMF spores and soil pH while organic matter content and available phosphorous were negatively correlated with total AM spores and predominant AM spores. The populations of *Glomus mossae* in soils were found to decrease with increasing level of applied phosphorous in soil. It was concluded that inorganic phosphorous fertilization should be used with caution and the use of *Mucuna pruriens* in crop rotation could help improve nutrient status of the study area.

In an attempt to control fungal infections of plants farmers were found to oftentimes use combinations of fungicidal treatments. **Fawole**, Aluko and Olowonihi (2009), therefore, studied the effects of carbendazim-mancozeb fungicidal mixture on soil microbial populations and some enzyme activities in soil. The population of bacteria, fungi and actinomycetes were found to be reduced significantly with the use of these fungicidal mixtures. The fungicidal mixture applied at concentration of 2.34mg/kg soil had a significantly (p<0.05) greater inhibitory effect than recommended rate of 1.67mg/kg soil populations of N_2 fixers, nitrifying bacteria and cellulolytic organisms were also significantly (P<0.05) reduced at the two concentrations. The cellulase and pectinase enzyme activities in soil were lowered significantly. It was concluded that the use of carbendazim-mancozeb mixture should be with caution since it reduced the populations of ecologically important non-target organisms, and that recommended rates should be adhered to if needed to be used. The effect of pesticidal applications on non-target organisms which are competitors with the target microflora in soil may result in onset of a new disease condition in an attempt to get rid of an existing one. The effects of benomyl (benzimidazole), a fungicide on non-target microflora of a tomato cropped soil was studied by **Fawole** (1998) to find out if the use of benomyl in tomato cultivation could predispose the plants to *Pseudomonas* infections. It was observed that *Pseudomonas* counts decreased with increasing concentration of benomyl in soil. It was concluded that the use of benomyl fungicide in cultivation of tomato may not predispose the crop to *Pseudomonas* infections. The effects of different concentrations of pre-emergence herbicide, galex on bacterial and fungal flora of a cowpea cropped soil were also studied (**Fawole**, 2000). Normal field applications rate was found to lower fungal counts significantly while bacteria counts were not affected. However, at concentrations higher than normal rate, both bacterial and fungal counts were significantly reduced in number though the influence was short termed, but *Fusarium* counts were reduced significantly. The interactions amongst microorganisms and other living organisms in soil and those between microorganisms could be positive or negative. These go a long way in shaping succession of microorganisms in soil. I carried out some investigations on microbial interactions in soil and observed varying types of interactions among fungal species in a tomato cropped soil (**Fawole**, 2003). Some fungal species produced toxic metabolites that pushed back the growth of others indicating antagonism while others mingled together on the plate. Fungal isolates were screened for antagonism towards *Fusarium oxysporium*, causal agent of Fusarium wilt of tomato. Interactions observed include mutual intermingling, mutual inhibition and inhibition of test fungus. It was concluded that the low numbers of *F. oxysporum* in the tomato cropped soil under study could be due to the presence of antagonists in high numbers in same soil. *Penicillium expansum* and *Aspergillus flavus* showed potentials for use in bio control of Fusarium wilt of cowpea in this study.

Adetunji, **Fawole**, Olaleye, Williams, *et al*. (2012) investigated the antibacterial activity and phytochemicals screening of extracts from *Aspilia africana*. Preliminary phytochemical analysis showed that the extracts contained tannins, saponins, polyphenols, glycosides, flavonoids, steroids and alkaloids. It was concluded that the plant extract had good properties that promoted antibacterial activities. Inhibition of mycelial growth on *Fusarium* species, the root wilt fungi of cowpea was observed with increasing concentration of parkia husk ethanol extraction (Abikoye and **Fawole**, 2001). Even though benomyl, a systemic fungicide was found to be more effective than the parkia husk extracts, the potential of the husk for use in bio control was established in this study. Yahaya, **Fawole** and Takim, (2018) evaluated the herbicidal properties of soil borne fungi on the biomass of *Eleusine indica*. *Aspergillus fumigatus* and *Penicillium citrinum* gave 88.46% and 34.61% reduction in biomass reduction of *E.indica* respectively and thus the bio-herbicidal potential of these two fungi was established with this study.

Adetunji and **Fawole** (2010) conducted a study to enhance storability of highly perishable and seasonal onion bulbs in Nigeria. Crude extracts of *Jatropha curcars* stems and leaves were used to control pathogens of onion bulbs. Ethanol extracts of *Jatropha*stem were found to contain high levels of saponin, tannin, phenolics, steroids and glycosides. It was concluded that the stem extract have the potential for use in controlling black mould of onion bulb.

A number of studies were undertaken to investigate the activity of soil microorganisms in biological degradation in soil. The unseen life in soil helps to transform organic materials into forms that are available for plant use. The products of degradation may also be useful in the control of pathogenic organisms. These activities oftentimes help in improving the soil physical structure.

Plate 2a: Collection of soil samples for microbial diversity studies on a field trip at Morrisville, North Carolina, USA in 2017 by the researcher.

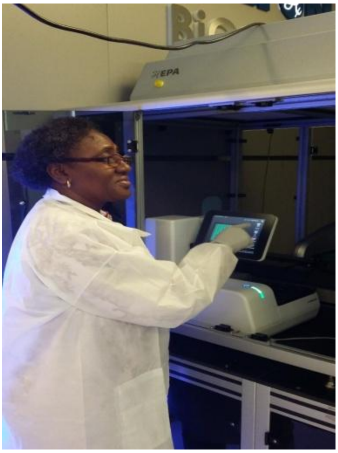


Plate 2b: Searching for a fungal stock culture from the database of Bayer Crop Science Morrisville, North Carolina, USA (2017) by the researcher

Aduloju, **Fawole,** Abubakar and Olaniyan (2011) compared the use of organic materials (sawmill wastes, pullets dropping, pullets beddings, broilers bedding, cow dung) and NPK (15:15:15) fertilizer on the performance of okra. It was observed that more nutrient elements were released from most of the organic materials used in the study than the inorganic fertilizer. The okro plants responded positively to the degradation and release of nutrient elements from the organic materials. The conclusion of the study was that the okro producers can grow good crops without using inorganic fertilizers on the alfisol used for the study. They could make use of degraded organic materials such as sawmill wastes and poultry wastes which were just being wasted as soil microbes would transform these adequately for the benefit of the crops.

Use of soil amendment has been proposed as a means of improving soil quality, crop growth and limiting the severity of soil borne plant diseases. **Fawole,** Alori and Ojo (2016) conducted a study using two compost types to improve the growth and yield of tomato plant. The main organic materials in the two composts were poultry droppings and pig manure. Mycoflora encountered during composting include *Fusarium pallidoroseum, Aspergillus fumigatus*, *Chaetomium sp* and *Phoma sp.* The poultry dropping compost had a higher nutrient status than the pig waste compost. Four agricultural wastes; locust beans chaff, rice husk, maize husk and soya beans chaff were assessed for use as organic amendment. The amendments improved fertility status of soil as well as reduced the incidence of soil borne infections of cowpea (Yusuf, **Fawole** and Balogun (2011). Husks of *Parkia biglobosa* (locust beans) and *Citrulus vulgarus*(melon) waste were used solely and in mixture to amend soilsby **Fawole,** Ajayi, Aduloju, Olaniyan (2010). The available phosphorous of soil was significantly improved by the treatments and a significant reduction in soil bulk density was observed. It was concluded that these wastes had potentials for use in improving soil fertility and soil physical properties. Yusuf and **Fawole** (2006) assessed Guinea grass (*Panicum maximum*) for use as soil amendment to improve the phosphorous status of soil in southern Guinea savannah zone of Nigeria. Significantly higher levels of available soil phosphorous and maize grains yield were obtained with *Panicum maximum* and Phosphorus fertilizer treatments than control treatment (unamended soil). It was concluded that *P. maximum* could be used for improvement of phosphorous status of the soil particularly for maize production in phosphorous deficient tropical soils. Ikuoponiyi and **Fawole** (2021) investigated the use of bioslurry as an amendment for the improvement of soil fertility in southern Guinea savannah, Nigeria. Mineralization of Carbon and Nitrogen of fresh and dry cow dung bioslurry was evaluated for use. Fresh cow dung released higher CO_2, NO_3-N and NH_4-N than dry cow dung bioslurry. A positive correlation between nitrate and ammonium mineralization was observed. *Providencia* species and *Aspergillus* species were the predominant species of bacteria and fungi respectively. The study concluded that drying of the bioslurry before use would not be required.

I worked with a team of researchers to enrich rice husk by solid state fermentation with micro and macro fungi from soil. The aim was to use the enriched rise husk for livestock feed (Belewu, Yousuf, Aderolu….. **Fawole** and Ajibade, 2002). The crude fibre content of the rise husk was reduced while we observed an increase in protein content of the rise husk. It was concluded that incubation and the synergistic activity of the enzymes secreted during fermentation were instrumental in reducing the fibre content while the crude protein was enhanced due to the addition of fungal protein.

The ability of soil microorganisms to produce toxic metabolites has been of great use to humanity. A number of commercial antibiotics are produced from the unseen life in soil which have this capability.

The ability of soil microorganisms to produce toxic metabolites could be further explored to control some pests without damaging the soil. In search of ecofriendly methods of controlling pests, a number of investigations were carried out in our laboratory. **Fawole** and Yahaya (2017) screened twenty fungal isolates from soils of North Central Nigeria for ability to control selected weeds. Eighty percent of the isolates had herbicidal properties. Crude extracts of *Aspergillus fumigatus* and *Penicillum citrinum* showed high potential in controlling two prominent weeds in southern Guinea savannah zone of Nigeria, *Amaranthus hybrids* and *Phyllanthus amarus*.

The unseen lives in soil are sometimes harmful to other organisms. They could have negative effects on other microorganisms, plants or livestock. I took interest in parasitic and predatory relationships. The chemical control method has been associated with soil contamination and degradation. A study was conducted to compare the effectiveness of Parkia husk (organic material) and Benomyl (chemical fungicide) on the incidence of plant infections caused by soil borne microorganisms. The husks of *Parkia biglobosa* were evaluated for use in control of root wilt diseases of cowpea. The alcohol extract of parkia husk was found to be more effective than aqueous extract. There were no significant differences in the ability of the organic extract and inorganic fungicide to suppress the diseases observed and that it was reported that the organic extract stimulated seed yield in addition to controlling the root rot effectively (**Fawole** and Abikoye, 2002).

The effect of chemical pesticides on non-target soil micoflora was investigated by Dare and **Fawole** (2009). Three pesticides; Benomyl (fungicide), Galex (herbicide and Karate (insecticide) were screened for ability to reduce the growth of some pathogenic mycoflora of legumes. Though benomyl, a fungicide, was significantly more effective than the herbicide and insecticide in reducing the growth of the fungi, Galex and Karate were observed to have detrimental effects on the test fungus and it was concluded that they may actually reduce the incidence of diseases caused by these fungi in legume production in southern Guinea savannah of Nigeria.

Vice-Chancellor Sir, I took interest in the use of fungal inoculants for biofertilization and bio-control. My current research focus is on the use of soil fungi in production of phosphorous solubilising biofertilizer and soil bacteria for nitrogen biofertilizers. I also worked on bioherbicides so as to have ecofriendly alternatives to chemical pesticides. The formulations of beneficial living fungi are added to soil to improve the nutrient availability to the host plant and thus promote plant growth, control pathogens in soil and thus enhance plant health.

Soil Fungi for Inoculant Production: Fungal inoculants studied in my laboratory include phosphorous solubilisers from Aspergilli, Penicilli; Solubilisers of other elements and phosphorous mobilizers from Arbuscular Mycorrhiza Fungi (AMF); Biocontrol agents-Biofungicides, Bioherbicides and Biopesticides. Biodegradation agents such as cellulolytic enzyme-producing fungi that are involved in composting of agricultural wastes are also studied in my laboratory.

Plate 3: Pure Cultures of some P Solubilising Fungi Isolated from Soil (**Fawole** and Ajayi, 2012).

Fungal Formulations: A "formulation" is the laboratory or industrial process of unifying a microbial strain with a carrier. Formulation is the crucial issue for successful commercial inoculants. The fungal strain is frequently an intellectual property, the formulation is the second intellectual property and together forms an inoculant which is a market product. The selection of efficient strain is usually through rigorous screening for desired activity which could be biocontrol ability, bioremediation ability, and biodegradability - ability to produce cell wall degrading enzymes, P solubilising ability and P mobilizing ability. My efforts are directed at formulating fungal inoculants of commercial value.

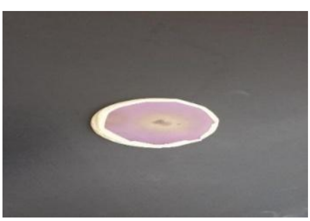


Plate 4a: Halo around the fungus on NBRIP Plate Indicates P solubilising ability

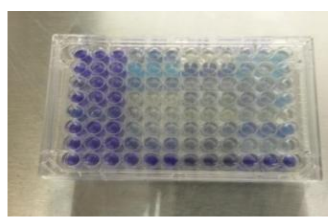


Plate 4b: Assay for P solubilisation in NBRIP broth

Plates 4a and b: Screening For P Solubilising Ability on NBRIP Medium (**Fawole** and Ajayi, 2012).

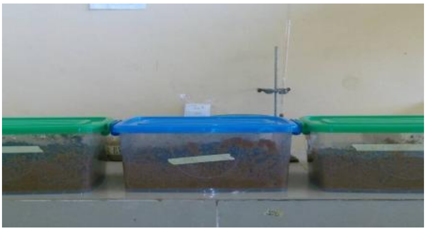


Plate 5: Cultures of efficient strains of P solubilisers on rice bran in our laboratory (**Fawole** and Ajayi, 2012).

Formulation of Inoculants from Fungi

The desired composition of organisms to be included in a formulation is determined and the mass production of fungal inoculum could be by submerged or solid state fermentation methods. Submerged fermentation involves growth of fungal cultures in suitable sterilized growth broth inside fermentors. The fungal biomass would then be introduced into suitable carrier material, incubated, air dried and packaged for storage. A suitable carrier material is one that of easily available, provides favourable micro-environment and keeps the microbes in the formulation viable until use.

An important quality of carrier material is having good water holding capacity and ability to maintain the population load of inoculated culture. The pH, pore space and nutrient content of carrier materials are usually determined when being considered for use in fungal formulations. Carrier materials that are used include charcoal-soil mixture, vermiculite, press mud, peat, cow dung cake powder, farm yard manure, wheat bran, etc. It has been reported that amendment of charcoal soil-mixture carrier with calcium alginate results in better retention of moisture.

Solid-state fermentation is a cultivation technique in which microorganisms are grown under controlled conditions on moist solid particles and sufficient moisture is present to maintain microbial growth and metabolism (Mitchell *etal*., 2011). The production medium is often simple, using agro-industrial by-products like wheat bran, rice bran, or wheat straw as the substrate (Mitchell and Lonsane, 1992). There are a wide variety of formulation types for both liquid and solid bio-fertilizers. The main types, currently used for organisms, have been classified into dry products (dusts, granules and briquettes) and suspension (water based and emulsions).

In recent years, native mycoflora of the University Teaching and Research Farm have been isolated and screened for ability to solubilize phosphorous by my research team. A paper titled "Native phosphofungi for improved crop production ad effects of chemical fertilization on soil population" was presented as the American Society for Microbiology (ASM) Conference in Boston, USA. *Aspergillusglaucus* and *Aspergillus niger* were identified as potent phosphorous solubilisers which stimulated maize seed germination (**Fawole** and Ajayi, 2012). Also, another paper titled "Evaluation of phosphofungi for use as biofertilizer in the production of Okra (*Abelsmoschus esculentus*)" was also presented at the ASM Conference of 2015, New Orleans, USA (**Fawole** and Ezike, 2015).

In a study carried out by **Fawole** and Mustapha (2022) to develop efficient and storable biofertilizers from soil fungi, the two highest P solubilising isolates were identified as strains of *Talaromyces.* Phylogenetic analysis showed one had 99.82% similarity with *Talaromyces yunnanensis* (Accession No. Mz621177) while the other showed 100% similarity with *Talaromyces verruculosum.* The conditions for cultivation of the two fungi were optimized. An inoculum load of 3.62 x 10^6 spores/ml, pH 3, xylitol as carbon source, tryptophan as nitrogen source were found to be optimum conditions for *T. yunnanensis* while pH of 5, inoculum load of 4.84 x 10^4 spores/ml, arabinose as carbon source potassium nitrate as nitrogen source were optimum cultural conditions for *T. verruculosum.* Another graduate research work in my laboratory was aimed at optimizing cultural conditions for development and storage of phosphorous bio-fertilizer from soil borne Aspergilli (**Fawole** and Ayoade, 2022). The study revealed that the *Aspergillusterreus* isolated from soil of University of Ilorin Teaching and Research Farm can be used to develop efficient phosphorous bio-fertilizers on sandy soil as carrier material, while *A.niger* on wood ash gave best results. The best storage condition for the two biofertilizer formulations was reported to be plastic container left at room temperature for four weeks. Biofertilizer use is still very limited in developing countries due to inadequate research technology. Balogun, Oke, Rocha-Meneses, **Fawole** and Omojasola (2022) also studied phosphorous solubilising potentials of some soil fungi. Aspergilli had highest solubilization index out of all the soil fungi tested. The shelf life of bio-fertilizer formulation was extended more on saw dust than charcoal when these were used as carrier materials.

Vice-Chancellor Sir, the search for eco-friendly alternatives to chemical fertilizers and pesticides in crop cultivation continues.

Studies on Bioremediation: In recent years, the Kwara State Government has been dredging the Asa River which runs across Ilorin city periodically to prevent flooding during the raining seasons. It was observed that some local farmers carried out agronomic activities on the dredged sediment along the river bank. The maize and vegetables which were observed on the river banks in 2017 developed well and had luxurious growth. However, considering the fact that many industries along the Asa River emptied their wastes into the river, the question that came to mind was, how healthy were these plants for consumption?. Consequently, **Fawole** *et al*. (2017) carried out characterization and suitability evaluation of the dredged sediments for sustainable reuse from four strategic locations. Physical, chemical and microbial characteristics of the sediments were determined.

Plate 6a: Effluents from the industries located along the river bank being foam, discharged into Asa River

Plate 6b: Domestic wastes, solid wastes from steel**,** paint, pharmaceutical and food producing industries

Fawole *et al*. (2017)

It was observed that the sediments were sandy with slightly acidic pH. The sediments from different locations were rich in organic matter and the microbial characterization showed the presence of *Aspergillus*, *Trichoderma*, *Penicillium* and *Fusarium* species. A need for determination of heavy metal concentration of the sediments was identified and addressed in our laboratory.

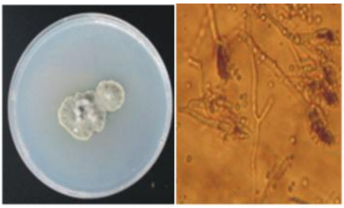


Plate 7a: *Penicillium* species

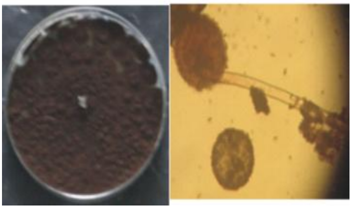


Plate 7b: *Aspergillus niger*

Plates 7a and 7b: Colony and microscopic morphology of efficient bioremediator of Asa River sediment (**Fawole**, *et. al*., 2017).

Ahamefule, **Fawole** and Eifediyi (2015) examined the response of spent auto-engine oil contaminated soil to amendments using maize as a test crop. It was observed that the auto-engine oil contamination of soil increased the total hydrocarbon content of the soils but the organic materials used as amendments hastened the remediation of the soil. Toxicity of the spent auto-engine oil to maize seed germination was observed and above 1% concentration organic amendments results in significant increase in hydrocarbon degrading microorganisms in the soils.

Olowonihi and **Fawole** (2011) investigated the potential of arbuscular mycorrhizal fungi (AMF) indigenous to southern Guinea Savannah zone of Nigeria, *Scutellospora reticulata* and *Glomus pansihalos* to enhance the phytoremediation of alfisol contaminated with aluminum and manganese, cropped with cowpea. Both *S.reticulata* and *G.pansihalos* significantly reduced Al (F5, 21 = 791.4, $P<0.05$) and Mn (F, 5, 21 = 286; $P<0.05$) contents of soil polluted with the metals. *S. reticulate* showed a significantly higher remediating ability than the *Glomus pansihalos.* Soil properties were observed to have a significant impact on bioremediation by AM Fungi.

Vice-Chancellor Sir, many agricultural wastes and industrial wastes have the tendency to pollute our environment. Pollutants have significant negative impacts on the environment, vegetation, livestock and humans. However, the natural existence of the unseen life in soil and the transformation activities of these microbes ensure the removal of toxic substances from the environment. They may be metabolised into non-toxic products by extensive bio-degradation or removed via bioremediation processes. The pollutants respond to different microbial enzymes at optimum conditions for efficient transformation. Enzymes involved in bioremediation include hydrolases, dehalogenases, proteases and lipases. These have shown great potentials in degradation of aliphatic and aromatic hydrocarbons, pesticides and other agro-chemicals. Knowledge of the best conditions for production of microbial enzymes is essential to equip the scientists for manipulation of these micro-organisms for effective degradation processes. I was involved in some microbial enzyme studies. The effects of varying cultural conditions were assessed for the production of pectic enzymes in a strain of *Aspergillus niger* isolated from decaying orange fruit. Polygalacturonase and pectinmethylesterase were found to be inducible by polygalacturonic acid and pectin in the medium respectively. Ammonium sulphate was the best nitrogen source for the production of both enzymes. Temperature and pH were found to have marked effects on the enzyme production with best conditions being 40^{0}C and pH 5 respectively. Surface culture technique gave appreciable enzyme yield while agitation had an inhibitory effect on enzyme production (**Fawole** and Odunfa, 2003).

Alori and **Fawole,** (2017) wrote a review titled "MicrobialInoculants-Assisted Phytoremediation for Sustainable Soil Management". The mechanisms of microbial inoculants in phytoremediation of polluted Soil were reported. Microbial inoculants can improve pollutant removal through various mechanisms. Some have the potential to produce metal chelating siderophores, which could improve metal bioavailability. Moreover, they produce biosurfactants (rhamnolipids) that can enhance the solubility of poor water-soluble organic compounds and the mobility of heavy metals. Formation of biofilm is another mechanism by which microbial inoculants assist plantsin remediation of polluted soils. In addition, these microbes can transform metals into bioavailable and soluble forms through the action of organic acids, biomethylation, and redox processes. Diverse soil microbes have the ability to secrete plant hormones such as indole-3-acetic acid (IAA), cytokinins, gibberellins (GAs) and certain volatiles which promote plant growth by altering root architecture. The microbial plant growth stimulatory actions result from the manipulation of the complex and balanced network of plant hormones that are directly responsible for growth and root formation.

Contributions in other Areas of Agricultural Microbiology

I will like to speak briefly on my contributions in other areas of Agricultural Microbiology. Some soil borne micro-organisms infect seeds and cause diseases in growing plants. Seeds in soil stimulate the germination of microbial propagates. Ahmed, Balogun, **Fawole**, Fabiyi…*et al*. (2016) examined fifteen soybean cultivars in five locations of Guinea savannah agro-ecology of Nigeria for seed borne fungi. The predominant seed borne fungi encountered were *Fusarium* species and *Penicillium* species. The cotyledons of the seeds were found to be most active sites of infection. The study established the need for seed health testing before distribution of seeds to farmers. Balogun, Odeyemi and **Fawole** (2005) isolated and identified some pathogenic fungi from diseased fruits, stems and leaves of pepper plant. Fungi associated with the diseased plant were *Penicillium digitatum, Aspergillus flavus*, *Aspergillus niger* and *Verticillium* species. Pathogenicity tests revealed that *Verticillium* species was the causal organism of the wilting and drying off in the field of the pepper plant.

Verticillium species are usually soil borne fungi that infect plants through the roots. They grow up in water conducting tissues and result in wilt due to water stress. Effects of fungi on germinability and cowpea seedling health were determined using seedling symptoms test by **Fawole**, Ahmed and Balogun (2005).The virulent fungal isolates were screened for production of cell wall degrading enzymes. The four fungal species tested reduced germination rate of the cowpea varieties used in the study. Cellulases and pectinases were produced by pathogenic fungi and the symptoms observed include seed rot, chlorotic leaf development and stunted growth.

Ahmed, **Fawole** and Balogun (2006) also carried out a component analysis of seeds for seed mycoflora of four cultivars of cowpea and reported that the cotyledon was the most infected component of the seed. Embryo components of seeds from the four cowpea varieties were also infected by fungi. This resulted in significant reduction in percentage germination of seeds. The study highlighted the importance of seed health testing in preventing spread of fungal pathogens on the field as relatively healthy looking seeds had deep seated infections.

Fawole, Ahmed and Adetunji (2010) carried out a component plating study to detect the seed mycoflora of four maize varieties (SUWAN IESR, DMR ESR, ACR 97 STR, ACR 97 TZLC). The pathogenicity of fungal isolates was determined. The major site of infection in all the maize varieties was the cotyledon. The embryo components of seeds from the four varieties were all infected by fungi which was the probable reason for the low percentage germination of seeds. Relatively healthy looking seeds were found to have deep seated infections highlighting the importance of seed healthy testing in prevention of fungal pathogens on the field.

Balogun, Amoo, Oyedunmade and **Fawole** (2007) reported that the pre-emergence inoculation of sorghum plants gave 42% yield loss compared to 12% loss in plants inoculated 28 days after germination based on dry root weight. The need for fungicidal seed treatments before planting was again established with results obtained in this study. The treatments will prevent infections by pathogenic forms of unseen life in soil.

Odunfa and **Komolafe** (1989) investigated the nutritional characteristics of *staphylococcus* species from fermenting African locust bean (*Parkia biglobosa*) *Staphylococcus xylosus* (55%), *staphylococcus saprophyticus* (33%), *staphylococcus* hominis (11%), were isolated from the fermenting African locust bean. Many amino acids including methionine, leucine, alamine and glycine stimulated the growth of the bacteria.

Odunfa, **Komolafe** and Ekunsanmi (1987) also studied the effects of chemical preservatives on the microorganisms isolated from fermenting African locust beans. Sodium benzoate, sodium metabisulphite and sodium chloride inhibited the growth of staphylococcus and Bacillus species isolated from the fermenting locust beans. The levels of sodium benzoate and sodium metabisulphite required to inhibit the growth of these organisms were above acceptable levels in food. Thus, sodium chloride was recommended for use in preservation of locust beans.

I started my career in the Microbiology Unit of the Nigerian Stored Products Research Institute, Ibadan office in 1990. My love for the activities of microorganisms in storage was ignited and this has continued to be an area of interest for me. I returned to the institute in 2010 on sabbatical leave and collaborated with scientists in the Institute to carry out studies on reduction of post-harvest losses that result from microbial activities. A number of microorganisms that cause field to store infections are of soil origin. I will speak briefly on some of my research activities at NSPRI. I worked with a team of scientist to study the effects of hydrophilic plasticizers on the quality and storability of oranges with Chitosan films, Adetunji, **Fawole**, Arowora, Adetunji…*et al.*(2013a). These films plasticized with hydrophilic compounds extended the shelf life of oranges effectively. The effects of edible coatings of CMC and cornstarch on cucumber fruits stored at ambient temperature were also examined by Adetunji, Arowora, **Fawole** and Adetunji (2013a).It was observed that the shelf life of cucumber could be extended for 7 weeks in the evaporative cooling system. The mucilage of cactus plant was also found to be effective in extending the shelf life of carrots when used as coating (Adetunji, Arowora, **Fawole** and Adetunji, 2013b). A survey was conducted to investigate consumer perception and preference of edible coatings on fruits in Ilorin West Local Government Area of Kwara State. The majority of the respondents (95.7%) would prefer to buy packed fresh cut fruits coated with edible coatings if the National Food and Drug Agency will publicly declare and approve it (Adetunji, Oyebamiji, **Fawole** and Olatilewa, 2014). Adetunji, **Fawole**, Arowora, Nwaubani…*et al.,* 2013b) developed two different coatings from corn starch and CMC each mixed with *Moringa oleifera* extracts and tested their effects on quality and storability of orange fruits. The corn starch- Moringa coating was more effective than CMC-Moringa coating for storability of orange fruits though both coatings were found to be capable of extending the shelf life of orange fruits. The effect of *Aloe vera* as an edible coating on pineapple fruits was also examined (Adetunji, **Fawole**, Arowora Nwaubani...e*t al.*, 2012). The storability of pineapple fruits was extended by 7 Weeks. It was concluded that *Aloevera* gel could serve as an alternative to post harvest chemical treatments. Bamidele, **Fawole** and Balogun (2023) carried out the molecular characterization of bacteria associated with some fruits and vegetables isolates. DNA extractions and nucleotide sequences were made. Alignment and construction of phylogenetic trees were then performed. Good yield and Pure DNA extracts were obtained and the primers used were found to be useful for bacterial identification.

My Efforts in Community Service

I was appointed as the first female Sub-Dean of the Faculty of Agriculture, University of Ilorin in 2006. This office gave me an opportunity to interact more closely with many students and staff in the Faculty. I was able to counsel many weak students and some students who came into the field of Agriculture without passion for the course, because they could not get admission into other courses of their choice. Some even came in with low self-esteem and battered ego from spending few years studying another course and not being in good standing. In my interactions with such students, I made them see the prospects in having a career in agriculture and a number of them are successful Agricultural Scientists today.

I was appointed as an Assistant Director of the Centre for International Education of the University in 2010. I had the opportunity of receiving International Students and helping them settle into our University. I interacted with students from Benin Republic, Cameroon, Togo, Sierra Leone and others nationals.

I also coordinated exchange programme for students between Kenyetta University, Kenya and University of Ilorin for many years. Some of the Kenyetta University graduates were so delighted to see me when I attended a conference in Nairobi, Kenya some years after. They mobilized to welcome and celebrate me, emphasizing that I was a good ambassador of the University of Ilorin.

I was elected as President of my Cooperative Society in the University from 2010 to 2013. I led the Pacesetters Cooperative to build a standard female hostel for students on the University Campus. I served the Department of Agronomy as Ag. Head of Department from 2015 to 2017, was the Chairperson of the University Guest House Management Board from 2019-2022 and currently I serve as the Dean, Faculty of Agriculture.

I won the prestigious and highly competitive Fellowship of the African Women in Agricultural Research and Development (AWARD) in 2015. The Fellowship exposed me to more community based activities. I brought together a team of female agricultural scientists in my Faculty after completion of the 2-year AWARD fellowship. This group was inaugurated as Unilorin Chapter of NiWARD in 2018. The group formed research teams to find solutions to problems in the community with a gender responsive focus. Capacity building programs were started in the Faculty. I was involved in organizing and coordination of a mentoring workshop for female Agricultural Scientists in the University of Ilorin and a number of mentors who were in attendance were encouraged to give formal mentoring to female scientists in the Faculty. Over the years, I have been invited to many secondary schools to give career talks. I am passionate about getting young ones interested in Agriculture and exposing them to different aspects which will guide them in choosing careers that will ensure agricultural and economic development in the nation. I have also invited secondary school students from different schools to the University community for career talk.'

Plate 8a: Some members of Nigerian Women in Agricultural Research for development and my AWARD Mentor, Prof. O.A. Omotesho

Plate 8b: Students and teachers of a secondary school after a career talk at the University of Ilorin

Plate 9: Participants at the opening session of the NiWARD mentoring workshop organized for Faculty of Agriculture staff with the then Vice-Chancellor Prof. Sulyman Age Abdulkareem.

Vice-Chancellor Sir, I worked with other members of Unilorin NiWARD to carry out some social activities in University neighboring communities. In collaboration with Nigerian Stored Products Research Institute (NSPRI), the vegetable basket for prolonged storage of vegetables was introduced for adoption. I was elected as the National President of NiWARD during 2020 Annual General Meeting of the organization. I have been coordinating the activities of the association since then till date, making sure the light lit by the AWARD Fellowship keeps burning in all regions of Nigeria.

Plate 10a: Stakeholders meeting at Sentu, Kwara State for NiWARD-NSPRI project

Plate 10b: NiWARD members women Vegetable Farmers at Sentu, Kwara State

Plate 10c: NiWARD members with women Vegetable farmers at Amoyo, Kwara State

I also had the opportunity of contributing to the progress of my State. I was a member of Ekiti State Economic Advisory Council from 2007 to 2008 and later the Ekiti State Economic Development Council (2008-2010). The advisory council put together by the then military administrator of the State, General Adetunji Olurin, developed a road map that was submitted to the in-coming democratically elected Governor of the State. The Advisory Council was later inaugurated as a Development Council to help in the implementation of policies in the document.

On the National level, I am currently a member of the Academic Advisory Council of the Nigerian Institute for Policy and Strategic Studies, Kuru.

Plate 11: At the inauguration of Academic Advisory Council of the Nigerian Institute for Policy and Strategic Studies, Kuru on 15th December, 2022.

Conclusion

There is great diversity in the microbial life of soil ranging from the beneficial saprophytic forms to the detrimental pathogenic ones. Soil is a rich store house for micro-flora of great economic value in industries. The unseen life in soil plays very significant roles in the maintenance of soil health. Healthy soils are important for healthy plant growth, livestock and human nutrition. The key roles of soil microbes in transforming nutrient elements to forms that are readily available for plant use cannot be overemphasized. They also play very important role in biodegradation, helping to rid the soil of naturally occurring and synthetic compounds that would otherwise be sources of contamination and pollution. Soil micro-organisms are also known to play key roles in determination of the atmospheric concentrations of greenhouse gases and as such have a great influence on climate change. The interactions of soil microbes with other living organisms in soil ecosystem are very significant. The knowledge of the existence of the unseen life in soil has helped in the world of biotechnology for biocontrol, biofertilisation, bioremediation and mitigation of climate change for protection of crops, improved agricultural productivity and food security. I declare boldly that without the existence of the microbial life in soil, there is no life. The unseen life in soil, though strangers to man in structure, are indeed intimate in activities and roles.

Vice-Chancellor Sir, the greatest motivation I have over the years is from the Almighty God who has sustained, strengthened and guided me through my career path. My faith in the Lord Jesus Christ has kept me going from strength to strength. I have been motivated to continue growing as a teacher and a researcher in the University by the outcome of my efforts over the years. Feedback from students that I have trained and the successes they have been recording have been a source of motivation for me. My husband, Prof. Adegboyega Fawole of the Department of Obstetrics and Gynaecology and our dear children have also been so supportive over the years. My husband was raised in an academic environment and as a medical practitioner and a University teacher/researcher he has an understanding of how involving the job of a scientist can be. He gave me all the support needed, encouragement in challenging times and helping hands in caring for our children when they were younger. Our Children made parenting a pleasurable experience for us. Striking a balance between career and family was not difficult for me. In taking decisions, my family was always my first consideration but because I have supportive loved ones, my career did not suffer.

The AWARD fellowship gave me room for personal development and as such I have been inspired and motivated by many AWARD trainings I received. The AWARD Mentoring Orientation Workshop (Kenya, 2015), the Scientific Skills Course (Ghana, 2015) and the Women Leadership and Management Training (Ghana, 2016) prepared me for more action as a teacher and researcher. I learnt to be visible, to be assertive, to see issues through the gender lens and to write grant winning proposals and internationally acceptable scientific papers. The financial support given for international conference attendance and paper presentation in Bloemfontein, South Africa in 2016 was also a motivation for me. The three month AWARD Advanced Science Training that I had at Bayer Crop Science, Morrisville, North Carolina, USA from March to June, 2017 prepared me for more in-depth research activities.

Since I got the chair of Soil Microbiology in 2017, my desire has been that more female agricultural scientists will rise to the professorial cadre in my Faculty through hard work and focus. This is already happening as four female full Professors and a number of Readers have since been announced. A gender balance will enhance development in Agricultural research. I plan to continue working with the Unilorin NiWARD chapter to encourage upcoming ones and organise more capacity building programmes. I also aspire to reach out to more communities around the University to proffer solutions to problems faced by women farmers. I look forward to starting an NGO that will be a platform for reaching the “girl child” for career mentoring and the female farmers for enhanced food security and improved economic power.

Recommendations

The importance of the intimate strangers in soil has been presented in this lecture. Preservation of soil will come with appreciation of its components and the impact of human activities. I would, therefore, like to make the following recommendations:

i. soil must be seen by the government and the people as a natural resource to be protected, maintained and enhanced;
ii. there should be public awareness campaigns through mass media to educate Nigerians on the roles of soil microbes in maintenance of soil health and the need to check negative impact of human activities on soil environment;
iii. environmental education should be taught in schools to educate children early on the impact of human activities on soil microbes and the dangers of climate change;
iv. governments and farming communities should invest in climate-smart agriculture practices to promote soil health and fertility while also sequestering carbon and decreasing greenhouse gas emissions;
v. afforestation should be encouraged in our communities for a healthy soil ecosystem;
vi. farmers should be encouraged to practice conservation agriculture for preservation of soil biodiversity- crop rotation, cover cropping, reduced tillage, mulching;
vii. organic farming practices should be encouraged through the use of eco-friendly soil amendments to enhance soil fertility for improved crop productivity and soil health should be promoted while the use of eco-friendly pesticides for the protection of crops from pests without damaging the soil and the intimate strangers or unseen life in it should be encouraged;
viii. provision of world class equipment and facilities for the study of soil microorganisms in our laboratories;
ix. establishment of a stock culture collection centre and database for indigenous soil microorganisms, in the Faculty of Agriculture, university of Ilorin;
x. the University can generate income from production of organic fertilisers from composting of wastes; and
xi. the University should support the Soil Science Unit in the Faculty of Agriculture in celebration of the annual World Soil Day , 5th December as it will be an avenue for sensitising the University and neighboring communities on why and how soil health should be maintained.

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My children: Dr. Adetayo Fawole, Mr. Sogo and Mrs. Tolu Owolabi, Mr. Oluwatosin Fawole, for being wonderful and trainable, for understanding and adapting to the busy schedules of parents in academia and to my beautiful grandchildren: Oluwapelumi and Oluwasemilore, you are a blessing to my life.

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