SMALL BUT TANGIBLE LET THE FEASTING BEGIN

Olubukola Oluranti Babalola

Faculty of Natural and Agricultural Sciences

26 April 2018

Inaugural Lecture

Topic: Small but tangible let the feasting begin

Presented By

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MSc Microbiology, University of Ibadan

PhD Microbiology, University of Ibadan

Cert, Applied Dual-Use Biosecurity Education, University of Bradford, UK

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Professor of Microbial Biotechnology and

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Faculty of Natural and Agricultural Sciences

Musical interlude (The Old Rugged Cross)

Biographical

PROFESSOR OLUBUKOLA OLURANTI BABALOLA

Lecture Title: “Small but tangible let the feasting begin”

The Inaugural Lecturer, Professor Olubukola Oluranti BABALOLA was born on the 13th August, into the family of the late Pa Daniel Ademola and Mrs. Comfort Abosede Ademuyiwa, in the year 1970. She hails from Nigeria, West Africa. After her primary education at African Church Princess Girls’ School, she was educated at Methodist Girls’ High School, Yaba, Lagos. In her secondary school, she developed interest in science, most especially biology, the subject in which she had distinction at secondary school certificate level in the year 1987.

She holds a bachelor’s degree in microbiology from Ogun State University in the year 1992. This academic colossus of our time was exposed to the rudiments of good manufacturing practice (GMP), which embraces total quality control (TQC), and quality assurance. She became vast in the knowledge GMP and TQC, with proven research skills in Microbiology.

On being admitted to the premier University of Nigeria, this assiduous lady pursued a master’s degree, which she successfully completed. By choice, she proceeded to do her Ph.D. in Applied Microbiology. She worked on the biocontrol of the obligate parasitic weed, *Striga hermonthica,* at the International Institute of Tropical Agriculture, IITA, in Nigeria researching on how bacterial isolates could be used as an augment to trap crop effect in the suicidal germination of *Striga*. Not only had she worked on the microbiology of cultivated plants, at the plant–soil interface, she had also worked on microbes at the genomic level using biotechnological approaches, biotechnology software, and computational molecular biology methods.

During her PhD, she carried out part of her research in western Kenya. She based her *Striga* research in Kenya for scientific reasons: the place happens to have similar ecology to northern Nigeria in terms of *Striga* infestation; presence of a large, capable research system with a few qualified researchers already focusing on *Striga* biocontrol; access to a large area of *Striga* infestation, plus facilities designated for work on *Striga* control.

Besides, she was trained in the state-of-the art molecular techniques courtesy of Third World Academy of Science (TWAS). She can personally manage a laboratory because of her hands-on research training at Kenya Sugar Research Foundation (KESREF, 6 months) and, at the International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya (12 months). Additional fund was granted to her for commendable performance in ICIPE as a dissertation research internship scholar. She has a wealth of international experience, an asset acquired through on-the-job experience in standard international laboratories within and outside the shores of Africa. It may interest you to know that since 1993, she has been working with interdisciplinary teams, and of multicultural settings. She is bilingual; she speaks French and English, the two of which she passed with credit and distinction respectively in her West African Examination. December 2000.

So far, she had done two careers building postdoctoral researches. Previously at Weizmann Institute of Science, Rehovot, Israel (1 year, 9 months) courtesy of the Feinberg Graduate School postdoctoral fellowship and the International Atomic Energy Agency (IAEA) and at the Institute for Microbial Biotechnology and Metagenomics, University of the Western Cape, South Africa (2 years) to better her teaching and supervision capability in Molecular Biology and Biotechnology work in the school span area of Microbiology. Professor Olubukola Oluranti BABALOLA began her NWU academic career when she was appointed Senior Lecturer in September 2009, Associate professor in 2013 and Full Professor in January 2016. This resourceful lady was appointed Director of the Food Security and Safety Niche area (June 2015). Professor Olubukola Oluranti BABALOLA has solidified her reputation as the foremost scientist in the continent of Africa. As a seasoned administrator with people skill and flair she is the Vice President of the Organization for Women in Science for the Developing World (OWSD, 2016 to date).

Professor Olubukola Oluranti BABALOLA has research in collaboration with scientists such Dr Katherine M. Pappas, National and Kapodistrian University of Athens, Greece. Dr Claire Prigent Combaret, University Lyon 1, France**.** Prof Bernard R. Glick, University of Waterloo, Canada**.** Dr Paola Monica Talia, Instituto de Biotecnología, Argentina**.** Prof Gwyn A. Beattie, Iowa State University, Iowa, USA**.** Dr Stefan Marius, "Alexandru Ioan Cuza" University, Iasi, Romania**.** Prof Cristina Cruz, Universidade de Lisboa, Lisbon, Portugal.

Professor Olubukola Oluranti BABALOLA has received several Awards and Honours which include Governor's bursary for BSc (Hons), 1992; IITA Visiting Research Fellowship, July 1998 - December 2000; OWSD Doctoral fellowship January 2001 – November 2002; ICIPE Young Scientist Travel Award to South

Africa; IUBMB Travel aid to Paris; ICIPE 2002; NWU Rector's Award 2016 in recognition of International Leadership in Science as the Vice President of OWSD; Feinberg Graduate School postdoctoral fellowship to Israel July 2004 – August 2005; David and Lucile Packard Foundation grant to the University of California at Berkeley 22 June - 16 July 2005; IAEA Fellowship to Israel September 2005 – February 2006; NIST (USA) Junior Investigator Award to Antalya, Turkey; DBT-TWAS (2006, 12 months) Postdoctoral fellowship Award to New Delhi; UNCTAD Advanced laboratory training award to the University of Cape Town, South Africa, October 2006 – January 2007; University of the Western Cape NRF/UWC block grant to Banff, Canada 2008; OOU Senate Research grant 2008; NWU FAST research grant 2010, 2011; NRF UID73792 to Italy, 2010; NRF Rating 2012 C3; NWU Vice Chancellor's award for the Top 20 employees 2010; 2013, 2014, 2017; Merit Bonus 2010, 2011, 2012, 2013; University of Bradford, UK, Training Course Bursary, United States Department of State, Bioengagement Program 2012. IKS grant (IKS12102214311) July 2013- June 2014; South Africa /Argentina bilateral grant; Most productive NRF rated researcher Mafikeng campus, NWU 2014; Most productive female research, NWU, FAST, Mafikeng campus, 2014; ASLP Fellow 2015 to date; ASI Fellow 2016; SA-Romania bilateral; and UK / South Africa Researcher Links Mobility 2016 to mention but a few.

Professor Olubukola Oluranti BABALOLA is a productive scholar. She has to her credit 105 articles in peer-reviewed journals with over 1347 referenced on the Internet. She also has over 92 published abstracts, conference proceedings, monographs and technical report, as well as contributions to 16 chapters in Books.

Professor Olubukola Oluranti BABALOLA is an indefatigable member of many distinguished professional bodies including: The South African Council for Natural Scientific professions (SACNASP); The Royal Society of South Africa (RSSA); The South African Society for Microbiology (SASM); The South African Society for Biochemistry and Molecular Biology (SASBMB); The South African Women in Science and Engineering (SAWISE); The Science Advisory Board (SAB); American Society of Microbiology (ASM); The Southern African Research and Innovative Management Association (SARIMA); The South African Association of Women Graduates (SAAWG); The International Society for biosafety research (ISBR); The Organization for Women Scientists for the Developing World of which she is the Vice President (2016 to date).

In 1996, she met with, Professor Sunday Samson Babalola, a man whom she loves so much. They are happily married and blessed with two clever children Oluwatomisin Michella and Oluwatokesi Daniel.

Inaugural lectures

Each year the University hosts a series of inaugural lectures given by Professors or Chairs newly appointed by the University.

The speakers give an illuminating overview of their contribution to their field.

Inaugural lectures are free and open to the public. Anyone is welcome to attend. There is no need to book, just turn up at the door.

Small but tangible let the feasting begin

Psa_85:12 Yea, the LORD shall give *that which is* good; and our land shall yield her increase.

"Let food be thy medicine, and medicine be thy food."

Those are famous words from the ancient Greek physician Hippocrates, often called the father of Western medicine.

Salutation

The Vice-Chancellor and Principal

Vice-Principal and Deputy Vice-Chancellor

Registrar

Deputy Vice-Chancellors (Special Projects)

Executive Directors (Special Projects)

Other Principal Officers

Your Excellences

Executive Deans

Deputy Deans

Professors

Members of Campus Senate,

Directors of Government Departments

Academic Colleagues

Beloved Students

Campus Choir

Distinguished Guests

Ladies and Gentlemen.

Preamble

Blessed be the Lord of all wisdom that directs my path to study Microbiology. In the past I really wanted to study Medicine, but my matric score did not qualify for Medicine. Today, I may not have studied medicine in form of drug, but I have studied about sustenance in terms of Food. I therefore thank all my parents, teachers, lecturers, colleagues, students and many other people I have met on my way this far. Each of you has impacted to my knowledge today.

By the way, I never planned to have a doctorate degree talk less of being a Professor. However, I married someone who loves to be a Professor and therefore wants his family to be introduced as Prof and Dr (Mrs.) Babalola. He encouraged me to do my PhD and he got the form for me at the postgraduate school of the Premier University of Nigeria. I remember he told me to at least be a Dr if I cannot be a Professor as he is an academic and will be a Professor. I have no iota of regret that I did my doctorate and made academics a career.

In January 2012, while we gathered in my research laboratory to open the year with words of grace, God gave me the topic of my inaugural lecture. I could discern it and I keyed into it. Today is the actualization, blessed be the Lord!

I consider this lecture a unique one due to several reasons:

(1) First, this lecture is coming from a female scientist, first of its kind in FNAS, Mafikeng campus
(2) Secondly, I am the first female in my father's linage to see the wall of a university and consequently to be a professor hence be called to deliver an inaugural lecture.
(3) Thirdly, I hereby humbly present the first inaugural lecture from the Department of Microbiology.

Since joining the Department almost nine years ago, I have successfully produced 13 MSc graduates and 7 PhD holders.

Mr. Vice Chancellor, Sir, I receive this opportunity you have granted me in the rank of North-West University with thanks.

Introduction

Mr. Vice Chancellor, Sir, kindly permit me to familiarize this audience with a few the vocabularies for easier understanding of this inaugural lecture.

Vocabularies

Agricultural microbiology: is a branch of microbiology dealing with plant-associated microbes and plant and animal diseases. It also deals with the microbiology of soil fertility, such as microbial degradation of organic matter and soil nutrient transformations (https://en.wikipedia.org/wiki/Agricultural_microbiology).

Bacteria: more dominant group of microorganisms in the soil and equal to one half of the microbial biomass in soil.

Actinomycetes: intermediate group between bacteria and fungi. Numerous and widely distributed in soil.

Fungi: More numerous in surface layers of well-aerated and cultivated soils-dominant in acid soils.

Soil: is a complex mixture of minerals, water, air and organic matter on the direct surface of the earth that contains a vast array of organisms and acts as a natural means for the growth of terrestrial plants. Soils affect agricultural

output, water quality, and the global climate either directly or indirectly through its function as a means for plant growth, as well as water flow and nutrient recycling regulation (Delgado and Gomez, 2016). The soil is therefore vital to food production and the sustenance of food security.

Soil quality: is defined as the capacity of the soil to function (Karlen, 1997; Lehman et al., 2015). A healthy soil therefore, could function as an essential living system within an ecological unit, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health (Doran et al.1996; Lehman et al., 2015).

Soil biological properties: are crucial to agricultural productivity hence the importance of the study of plant-microbe interactions. The rate of decomposition is totally dependent on soil microbes, if the microbes on agricultural land are reduced, crop productivity will be affected because soil microbes are involved in various chemical processes which are directly related to availability of plant nutrients and influences soil physical properties.

Microbial inoculants: such as rhizobium, plant growth promoting rhizobacteria (PGPR) and arbuscular mycorrhizal fungi can be used as biofertilizers to improve soil nitrogen, phosphorus and potassium availability and uptake. Both bacteria and fungi inoculants show potentials for use in soil aggregate formation and stabilization and hence soil structure enhancement (Alori et al 2017). Rhizobacteria for examples helps in sequestration of iron, phosphate solubilization, nitrogen fixation as well as release of plant growth hormones into the soil thereby enhancing plant growth. Soil microbes are also involved in the nutrient cycling process.

What then are PGPR: The most abundant microorganisms found within the vicinity of the rhizosphere of plant roots are bacteria which occur in higher concentrations in the rhizosphere than in bulk soil due to exudates released by the plants which are used as sources of carbon and nutrients for microbial metabolism (Olanrewaju et al., 2017). These genera of bacteria which supports the growth and development of plants by either direct or indirect mechanisms are called PGPR**.** Figure 1 illustrates the different mechanisms of plant growth promotion by PGPR.

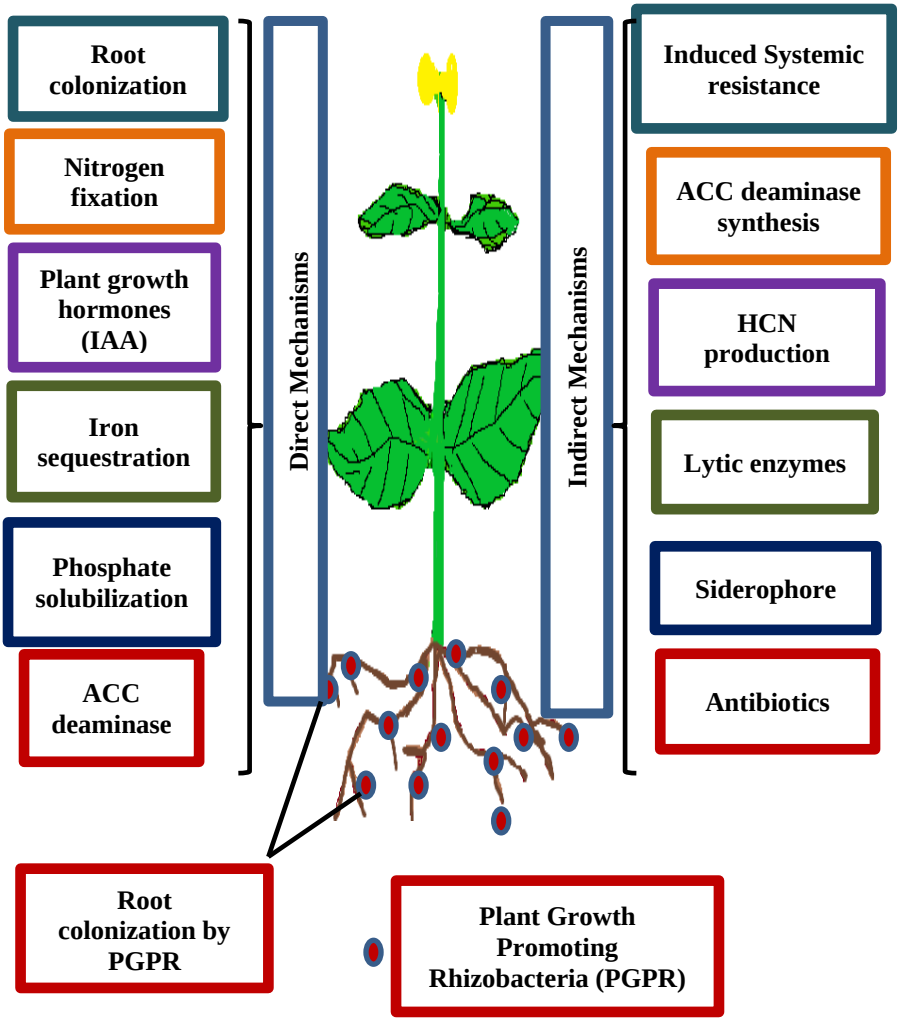

Figure 1: Graphic representation of the direct and indirect mechanisms of plant growth promotion by PGPR

Integrated pest management: (IPM) therefore, is the method of managing agricultural crops using various approaches to reduce incidence of pest below an economic threshold. It places emphasis on the interactions of pests, crops and the environment and different techniques to control their spread. IPM permits farmers to manage diseases, insects, weeds and other pests in a cost-effective and environmentally safe way. IPM has three major

components which are essential in the control of agricultural pests; prevention, monitoring and intervention as depicted in Figure 2.

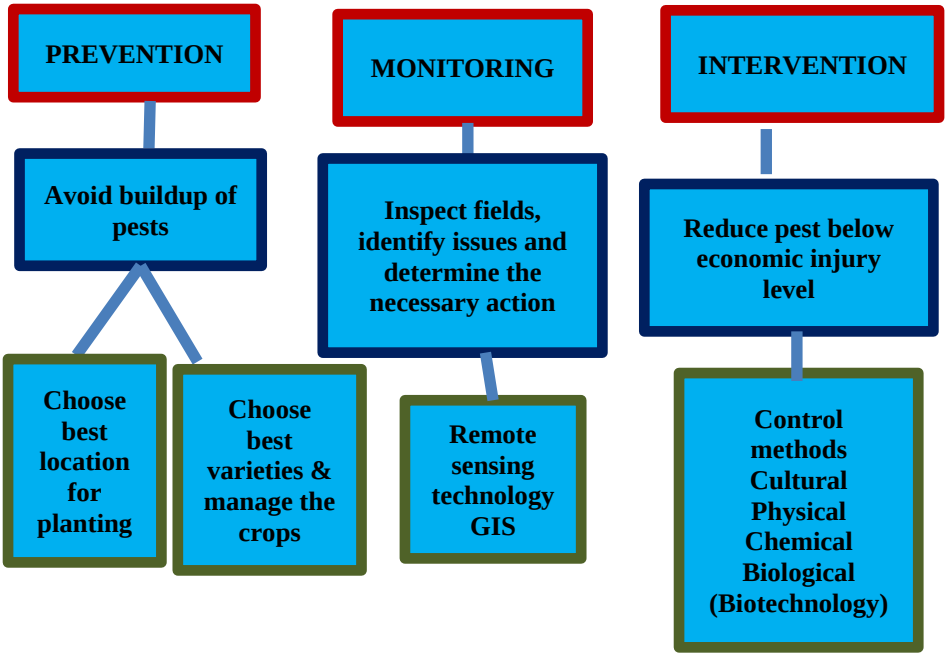

Figure 2: Components of Integrated Pest Management

Figure 3: Typical Farmer's Field

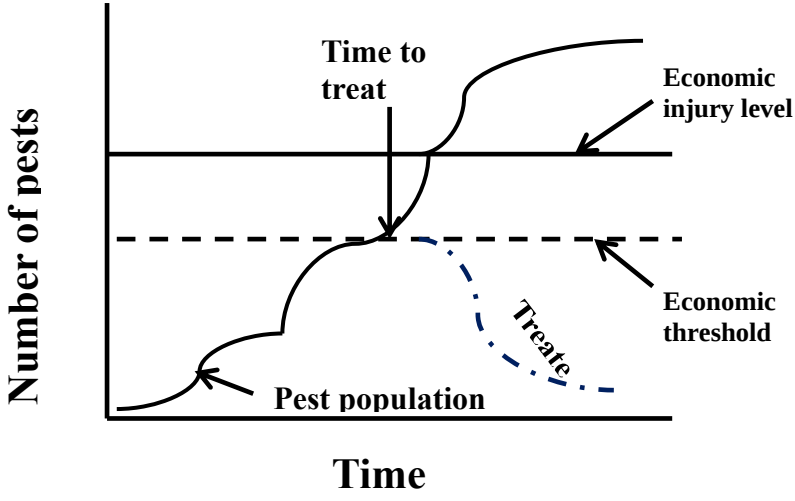

Figure 4: The economic threshold needs to be set below the economic injury level for an effective pest management

Why the Topic?

Babalola's accomplished research are in Food Security: subdivided into
[a] Parasitic weed management
[b] Plant health management {i} Plant protection and {ii} Food Safety
[c] Production of plant growth promoting rhizobacteria
[d]. Bioremediation of contaminated soil for sustainable food production

My contributions to Weed (*Striga hermonthica* [witchweed], *Orobanche aegyptiaca* [Egyptian broomrape], *Abutilon theophrasti* [velvet leaf], *Cassia obtusifolia* [sicklepod]) biocontrol:

Mr. Vice Chancellor, academic /nonacademic colleagues, students and distinguished ladies & gentlemen, many crops have closely related weeds with which they can hybridize. I validated the technology through the growth chamber and screen-house stages. My work contributes to partially overcome the need for high inoculum levels and the lack of sufficient virulence common to *Abutilon theophrasti* in the biological control of weed. Plants treated with *Colletotrichum coccodes* propagules and pectinase or cellulase had more

rapid and complete disease development. I also established that adding pectinase or cellulase did not increase the host range of the wild-type fungus (Babalola 2007a, 2010b, 2010c). Thus, suggesting that there might be value to transforming biocontrol agents to overproduce these enzymes, infection was not systemic, and fungus alone usually infects but rarely kills the *A. theophrasti* plants beyond the two-leaf stage. This is, to the best of my knowledge a pioneering research being, the first report that adding pectinase or cellulase to a fungus enhances weed control. The technology, though yet to be commercialized, lowers the amount of bioherbicide needed. The research was done during my career building postdoctoral fellowship at the Weizmann Institute of Science, Rehovot, Israel.

Striga hermonthica (a weed) is quite dangerous to food security and poverty alleviation. Many control methods in place could not reduce *Striga* to non-economic level. There is a clear need to augment chemical methods of their control with biological methods. *Striga* suicidal germination was analyzed using selected bacteria. Bacterial type significantly influenced the cowpea varieties with better performance over the non-inoculated control. Bacteria also promoted a significant increase in plant component with no deleterious effect on plant health. Ethylene released by the bacteria ranged from trace concentrations in *Pseudomonas* sp. to 210 nmoles/ 108 c. f. u. /ml in *Enterobacter sakazakii* 8MR5. One of my papers showed that varieties have differential responses to bacterial inocula because of the microbial activity and concluded that the isolates are safe for introduction into the rhizosphere during cowpea planting, as they are not deleterious to plant health. This includes collaborations in dealing with *Striga* at the International Institute for Tropical Agriculture, Nigeria and Kenya Agricultural Research Institute, Kenya.

Mr. Vice Chancellor, Sir, the award of 12-month research fellowship of the Organization for Women in Science for the Developing World as a doctoral scholar to the International Centre of Insect Physiology and Ecology in 2002 under the headship of Dr Ellie Onyango Osir, should be regarded as the building block of my Molecular studies. During the visit I tried to identify plant growth-promoting rhizobacteria (PGPR) in a shorter number of days as compared to several months of screenhouse trials, I used polymerase chain reaction (PCR) to amplify ACC deaminase gene from bacterial isolates I had previously examined in the screenhouse. I observed that each bacterial inoculation increased agronomic characteristics of maize, and the extent of growth enhancement differed between the isolates. *E. sakazakii* had the ability to stimulate plant growth, however in the PCR study; ACC deaminase was not amplified from this isolate, indicating that not all PGPR contain the enzyme ACC deaminase. In contrast, an ACC deaminase specific product

was amplified from *Pseudomonas sp*. and *Klebsiella oxytoca* (Babalola et al. 2003). My work is the first report of ACC deaminase in *K. oxytoca*. The use of soil bacteria as a biological strategy to control *Striga* is an attractive biocontrol approach, since enlisting nature's own agents and mechanisms to select for potential bacteria in the biological control of *Striga* would conserve the environment.

A single-authored review article of mine, collates several DNA molecular markers available for use in surveillance and investigation of food-borne outbreaks that were previously difficult to detect. The molecular detection methods reported are applicable to microbes from food, plant material, soil, and water (Babalola 2003). Babalola (2004), another single-authored review article, discussed standard molecular techniques (PCR, PFGE, RAPD, RFLPs, AFLPs, SSRs) for microbes. It provided insights into microbial identification, and the importance, economic relevance and the gains associated with the application of the techniques.

Inundative mycoherbicides have not been successful in weed control in row crops, probably due to evolutionary barriers, and adding virulence factors were considered essential. Exogenous addition of the products of various genes was used to ascertain synergy as a prelude to adding them transgenically. Improved mycoherbicidal activity of *Fusarium arthroporioides* (Babalola 2010a; Babalola 2010b) papers proved that cellulase-assisted mycoherbicide. *F. arthroporioides* is the most efficient. Transgenically over-expressing single "soft" genes (host lytic enzymes such as pectinase, cellulase, and expansins, or natural hormones such as IAA), or "hard" genes encoding toxins such as NEP1 and CP1, has enhanced virulence, but not enough. Gene stacking to obtain synergies among the various genes was also considered.

An aspect of my work (Babalola 2009) addresses the need to develop asporogenic mutant strains as researchers have identified that mycoherbicides must be restricted to the target weed. I established failsafe mechanisms to prevent spread and mitigate introgression of transgenic hypervirulent biocontrol fungi in the form of asporogenic deletion mutants of the transgenic hypervirulent fungi. Such asporogenic mutants would prevent the spread of the biocontrol agent and environmental persistence. Biosafety aspects were addressed by developing strategies to prevent organism spread as well as to render the transgenic biocontrol agents unfit to exist in the wild, as well as render any hybrid progeny unfit to exist in the wild. I have authored over 19 scientific papers on *Striga*, Orobanche, Abutilon and Cassia biological control.

The relationships of crop plant and *Striga* preconditioning period were assessed to assist in the determination and subsequent adoption of an appropriate preconditioning duration for biological control programmes (Babalola and Berner 2004). Since it was desirable to know the optimum preconditioning time, responses were considered under crop types. *Striga* can now be subjected to appropriate preconditioning amendments recommended in this research. Babalola et al (2004) investigated the indigenous rhizobacteria of *Striga*-infested maize and determined their potential for control of *Striga*. *K. oxytoca* was the major component of the total variation for *Striga* visual rating. *E. sakazakii* -treated plants supported the largest amount of emerged *Striga* (2.82 stems /pot) and the largest attached *Striga* (7.70 stem /pot). The result provided evidence that the application of any of these isolates could offer a better form of *Striga* biological control. Babalola et al (2007a) tested the effect of certain bacteria (able to induce *Striga* suicidal germination) on cowpea health. Bacterial type significantly influenced the cowpea varieties with better performance over the non-inoculated control. Bacteria promoted a significant increase in pod weight (±30.89%), fresh biomass (±24.22%), and improved pod number (±20.54%) and pod wall thickness (±7.33%) with no deleterious effect on plant health. Ethylene released by the bacteria ranged from trace concentrations in *Pseudomonas* sp. to 210 nmoles/ 108 c. f. u./ml in *E. sakazakii* 8MR5 (Babalola 2010a). This study establishes that varieties have differential responses to bacterial inocula because of the microbial activity and concluded that the isolates are safe for introduction into the rhizosphere during cowpea planting, as they are not deleterious to plant health.

The purpose of this development (Babalola 2007b) was to release germination stimulants into the rhizosphere, and thereby further induce the germination of *Striga* and consequently deplete the *Striga* seed bank when applied during trap cropping. In the screenhouse, the four bacterial isolates stimulated significant germination of *Striga*. This study demonstrates that there are some potential in certain rhizosphere bacteria to induce germination of *Striga* however the stimulatory action of the bacteria was much lower than could be recommended for *Striga* control without any other control method. Babalola and Odhiambo (2007) tested the hypothesis that an increased host root system will support higher numbers of *Striga* in the presence of potential stimulatory rhizobacteria with a view to developing effective biological control programs. The findings buttress that *K. oxytoca* '10mkr7' is a plant growth promoter and could stimulate *Striga* suicidal germination. Hence, there are good prospects for biological control of *Striga* using indigenous rhizosphere *K. oxytoca*. Evidence points toward *K. oxytoca* '10mkr7' rhizosphere competence and carrying capacity. Also observed are the facts that as plant

density increased, harvest index reduced and the proportion of plants without an ear increased.

My contributions to Actinomycetes studies:

The research entitled *Phylogenetic analysis of actinobacterial populations associated with Antarctic Dry Valley mineral soils* was conceptualized and conducted by me when I was a Postdoctoral fellow at the Institute for Microbial Biotechnology and Metagenomics, under the supervision of Prof. Don A. Cowan. This research was funded by National Research Foundation (South Africa) through IRDP programme for 3 years at the University of the Western Cape, Cape Town, South Africa.

As previously uncultured bacteria may represent an untapped source of genetic diversity, and ultimately novel bioactive metabolites. In this study, we assessed the diversity of actinobacteria in various mineral soil samples collected from Miers Valley in Antarctica by complementing traditional culture-based techniques with metagenomics. The molecular diversity of a metagenomic library was first assessed by amplified ribosomal DNA restriction analysis (ARDRA) of amplicons amplified using either actinobacterium- or streptomycete-specific primers. Secondly, the diversity of actinomycetes (both culturable and non-culturable) in Antarctic soils was assessed by phylogenetic methods using different bioinformatics tools. Phylogenetic analysis of clones generated with actinobacterium and streptomycete-specific PCR primers revealed that the majority of the phylotypes were most closely related to uncultured *Pseudonocardia* and *Nocardioides* species. Phylotypes most closely related to several rarer actinobacteria genera, including *Geodermatophilus, Modestobacter* and *Sporichthya*, were also identified (Babalola et al., 2009). While complementary culture dependent studies isolated several *Nocardia* and *Pseudonocardia* species, the majority of the cultured isolates (> 80%) were *Streptomyces* species. This research served as a platform for the isolation of novel species from Miers Valley with metagenomics providing a molecular 'snap-shot' of the phylotypic diversity in an environmental sample. This research findings were published in Environmental Microbiology with an impact factor of 5.395.

Rhizospheric soil samples were collected from different municipalities in Ngaka Modiri Molema district of North West Province. In this study, 341 strains of actinomycetes were isolated and screened for antibacterial activity against pathogenic bacteria. This revealed that 92 (27%) out of the 341 strains showed antagonistic activity against at least five of the eleven test

organisms (Adegboye and Babalola, 2013). Polyketide synthase (PKS) and non-ribosomal peptide synthetase (NRPS) pathways biosynthesize many biologically active compounds and exist widely in the genomes of actinomycetes. A PCR-based screening for the presence of genes associated with biosynthetic pathways can rapidly predict the isolates that have the potential to produce secondary metabolites. Therefore, in parallel with antimicrobial activity testing, the PCR-based approach to detect type I polyketide synthase (PKS-I), PKS-II and non-ribosomal peptide synthase (NRPS) genes were also carried out. Sixteen isolates (4.6%) were identified to have PKS-I gene positive strains, while the figures were 15.2% for PKS-II and 26% for NRPS gene (Adegboye and Babalola, 2015). Phylogenetic analysis of the nucleotide sequences from the amplified biosynthetic genes confirmed that the isolates form close phylogenetic relationship with known antibiotic producers. Based on similarity criteria of the 16S rDNA gene sequences, antibiotic producing actinomycete isolates were sorted into 12 genera: *Streptomyces*, *Actinomadura*, *Nocardiopsis*, *Promicromonospora*, *Nocardia*, *Arthrobacter*, *Pseudonocardia*, *Micrococcus*, *Nonomuraea*, *Rhodococcus*, *Streptosporangium* and *Saccharothrix*. These data indicated the considerable diversity of actinomycetes within the rhizosphere.

Analytical techniques continue to advance to allow the rapid elucidation of structures and make microbial products valuable components of modern drug discovery. The extraction of antimicrobial compounds from the cell free supernatant with equal volumes of different organic solvents resulted in antimicrobial activity against bacteria. These findings envisaged that the extraction method had a definite effect on the isolation of bioactive principles. In this study, the active solvent fractions from the crude extract of the actinomycete were subjected to GC-MS to establish the chemical components of these active fractions. The bioactive compounds identified include furosemide, phellopterin, 4,5-dihydroxyanthraquinone-2-carboxylic acid and milbemycin B. The compound 4,5-dihydroxyanthraquinone-2-carboxylic acid produced by NWU91 was not reported earlier from actinomycete. This study demonstrates the significance of actinomycetes in the rhizosphere and their potential for producing biologically active compounds and novel material for genetic manipulation or combinatorial biosynthesis. This project led to an Award of PhD to one of my postgraduate student, Dr Mobolaji Adegboye in 2015. She is currently a Post-Doctoral Fellow at the University.

We contributed to providing for the need to discover more environmentally friendly, cost effective antibiotic producing microbes. We have initially used various conventional ways to achieve that in 2007, using metagenomics. The soil-microbe interactions in mineral soils (Babalola et al 2009) citation is only

second to my other work. I took the lead role in the research and in the manuscript production. This is the work I was hired for as a Postdoctoral fellow (20 months) in Prof Don Cowan's laboratory. The metagenomics aspect unravels a molecular “snap-shot” of the phylotypic diversity in the McMurdo Dry Valleys, Eastern Antarctica, confirming that Antarctic Dry Valley desert soil harbours highly diverse actinobacterial communities and suggests that many of the phylotypes identified may represent novel, uncultured species (Babalola et al 2009). A discovery that has application to the identification of phylotypes of novel, uncultured species. We have undertaken sequencing of many, some of which have been deposited in NCBI databases (Accession numbers EU931044 to EU931109). This work has far reaching implications in pharmaceutical industries playing a major role in future antibiotic production.

Vice Chancellor, Sir, aside from the Actinomycetes work on mineral soils (Babalola *et al* 2009), our work on native Mahikeng soils in South Africa (Adegboye, et al. 2012) and other rhizospheric soils (Adegboye & Babalola 2013a) expand our knowledge on microbial survival irrespective of the prevailing environmental conditions. The Actinomycetes chapter in the Microbiology Book Series (Adegboye & Babalola 2013b) expatiates on their resourcefulness and enormous industrial worth. The discovery of Streptomycin from actinomycetes has been imperative to the exploration of this group as a source of novel bioactive compounds. These led to the award of a PhD degree, solely supervised by me to Mobolaji Felicia Adegboye, from this citadel of academic excellence in 2015.

I have presented my research to conference participants in many international, regional and national fora (Austria, Kuwait, Scotland, Belgium, Botswana, Canada, China, Egypt, Ethiopia, France, Finland, Greece, Germany, Israel, India, Italy, Japan, Kenya, Mauritius, Namibia, Netherlands, Nigeria, Portugal, Rwanda, South Africa, Turkey, Uganda, UK, USA, etc.), as a teaching and research scientist working at the plant-microbe and biocontrol interphase. The entire above mentioned have received several citations and have earned me invitation to join the rank of reviewers to several journals.

My contributions to Plant Health Management:

As part of academic citizenship responsibilities, graduated in this project are eight (8) master’s degree awarded to Kedibone Masenya in 2013, Ajilogba Caroline F in 2013, Modise Lorato M in 2013, Bumunang Emmanuel M. in 2013, Motsewabangwe K Raven in 2013, Oluseyi Samuel Olanrewaju 2016, Olalekan Ayodele Adedayo in 2016, Motlagomang Khantsi in 2016 with

distinction. In addition, was an award of a PhD in 2016 to Dr Ajilogba Caroline F.

Also graduated in the Plant Health project are Madyibi Lorato M 2010, Mokone Peter Ho 2011, Kodisang Seiphepo Lena 2011, Akindolire Muyiwa Ajoke 2011, Mogatianyane Keneilwe 2012, Esau Boipelo 2012, Gae Neo 2013, Kupi T 2013, Thebe Tumelo 2013, Rorisang Wendy Mmeno 2013, Adem Mohomud 2014, Mongadi Khomotso 2014, Mokgakane lindiwe 2014, Motete Tshoganyetso 2014, Serumula Ketshepile Beverly 2014, and Onkemetse Mosetlhe 2015).

In plant protection

Plant Growth Promoting Rhizobacteria increase agronomic characteristics of plant. Babalola (2010b) is a highly cited extensive review on PGPR with emphasis on their benefits to agriculture. Biotechnology in agriculture has implications for agricultural extension and advisory services (Babalola and Oladele 2011). There are both potentials and limitations in the field of biotechnology. The collection is a bird eye view for biotechnology stakeholders. Agricultural extension and advisory services need to explore the features of biotechnology if farmers in developing countries want to maximize benefits. Biofunctionalization of nanoparticle assisted mass spectrometry could serve as biosensors for rapid detection of plant associated bacteria (Ahmad et al. [IF: 6.409]). Similarly, the application of mass spectrometry as rapid detection tool in plant nematology (Ahmad & Babalola) was documented.

Integrated management strategies for tomato Fusarium wilt (Ajilogba & Babalola, 2013) caused by the fungal pathogens, *F. oxysporum* or *F. solani* is a devastating disease that affects many important food and vegetable crops and a major source of loss to farmers worldwide. Initial strategies developed to combat this devastating plant disease include the use of cultural, physical and chemical control. None of these strategies have been able to give the best results of completely ameliorating the situation except for the cultural method which is mainly preventive. A good knowledge of the nature, behavior and environmental conditions of growth of the disease agent is very important to controlling the disease development in that case. Biological control has been shown to be an environmentally friendly alternative. It makes use of rhizospheric and endophytic microorganisms that can survive and compete favorably well with the Fusarium wilt pathogen. They include PGPR such as *Bacillus* spp. and *Pseudomonas* spp. For PGPR to control or inhibit the growth of the Fusarium wilt pathogen, they make use of mechanisms such as

indole acetic acid production, siderophore production, phosphate solubilization, systemic resistance induction and antifungal volatile production among others. (Ajilogba, et al. 2013). These led to the award of a master's degree, solely supervised by me to Caroline Fadeke Ajilogba, in record time.

Babalola (2014) interrogated if nature makes provision for backups in the modification of soil bacterial community structures? It further showed that the changes observed as a result of forces and process interactions between released bacteria and indigenous microflora which encompass soil bacterial diversity, community structure, indigenous endorhizosphere microorganisms, molecular detection methodologies, and transgenic plants and microbes are largely transient. Studies on the variations in infectivity of indigenous rhizobial isolates of some soils (Ojo et al. 2014) suggested that cultivation of grain legume may require rhizobial inoculation for high productivity.

Also examined were phytodiversity conservation through evaluation of nematicidal properties of latex bearing plants against *Meloidogyne javanica* (Parihar et al., 2014) and the gas chromatography - mass spectrometry analysis and antibacterial activity of extracted Bluish-Green pigment from *Pseudomonas* sp. JJTBVK (KF836502) isolated from desert soil (Verma et al., 2015.). MALDI-TOF mass spectrometry was exampled as rapid detection technique in plant pathology for the identification of plant-associated (Ahmad et al 2012). In an allied case X-ray irradiation was exampled to generate Asporogenic mutants of *Alternaria cassiae* (Babalola 2009).

Diverse research was done including work on the construction of specific primers for rapid detection of South African exportable vegetable macergens (Aremu & Babalola 2015) and the classification and taxonomy of such vegetable macergens (Aremu & Babalola 2015). This work has far reaching implications in food industries playing a key role in food security and safety. The knowledge of genomic diversity within the macergens pathovars is necessary for host resistance disease-based management strategies for the plant breeders.

For horticultural crops development, the importance of fine chemicals production from microbial enzymes (Esuola et al., 2016a) were investigated. Nonetheless, in a recent finding the identification and characterization of a FAD-dependent putrescine N-hydroxylase (GorA) from *Gordonia rubripertincta* CWB2 (Esuola et al., 2016b) is the first diamine N-hydroxylatingmonooxygenase characterized with a physiological role in siderophore biosynthesis. GorA has an acceptance for diamines serving as substrates of N-hydroxylation or effectors turning GorA into an oxidase. More importantly its characterization seems to be the first among the known

diamine monooxygenases and thus allows a better view on these enzymes. Nitronate monooxygenase (NMOs) have a broad range of applications as they allow region selective N-hydroxylations and initiate siderophore (Greek: "iron carrier" very important in plant growth promoting bacteria) biosynthesis. They are being tapped as novel virulent mechanisms in microorganisms pathogenic to both animals and plants and are important in agriculture. Some common patterns with respect to activity and amino acid sequence have been identified. A link to hydroxamate type siderophore biosynthesis was demonstrated. The proven sequence motifs together with activity data will allow a proper annotation of respective enzymes. Overall, this study has contributed to the available pool of NMOs; particularly, GorA has a biosynthetic role in the production of hydroxamate metallophores for a vibrant and environmentally-safe mobilization of industrially important metal. The project led to the award of PhD degree to Oluwakemi Catherine Esuola in 2016 and was jointly supervised by myself, Prof M Schlomann along with Dr Dirk Tischler of the Technical University Bergakademie Freiberg, Freiberg, Germany. Dr. Esuola is a researcher at the National Horticultural Research Institute (NIHORT), Ibadan.

gorA, a gene encoding for GorA, a microbial NMO has been discovered from the genome of the *Gordonia rubripertincta* CWB2. GorA has been cloned and overexpressed in a suitable microbial host *Escherichia coli* DH5α and *E. coli* BL21 (DE3) (pLysS) respectively. GorA is active in the presence of a range of primary diamines. The apparent $V_{max,}$ $K_{m,}$ and k_{cat} of the NADPH oxidation is 310 $\pm$ 0.01 nmol min^{-1} mg^{-1}, 361 $\pm$ 0.1 µM and 0.27 s^{-1} respectively whereas the hydroxylation assay showed GorA with an apparent $V_{max,}$ K_m and k_{cat} of 246 $\pm$ 0.01 nmol min^{-1} mg^{-1}, 737 $\pm$ 0.1 µM, and 0.21 s^{-1} respectively.

In Food Safety

Whilst consumption may occur throughout the year, production and processing of fruits is seasonal. This necessitates storage and blending of the juices to produce uniform products. Microbiological quality control study of some processed fruit juices (Babalola et al., 2011) indicated that the bacteria are fruit borne rather than contaminants from air, water and utensils alone. Pertaining to issues of resistance of pathogens to antimicrobial agents (Adegboye et al., 2012), the taxonomy and ecology of antibiotic producing Actinomycetes were reported. When evaluated the antibiotic biosynthetic potential of Actinomycete isolates to produce antimicrobial agents shows that PCR-based approach using degenerative primers to screen for the presence of biosynthetic gene clusters responsible for the biosynthesis of bioactive secondary metabolites, is an effective approach for discovering diverse antibiotics from actinomycetes (Adegboye & Babalola 2015). The detection

and molecular characterization of antibiotic-resistant *S. aureus* from milk in the North-West Province, South Africa (Akindolire et al., 2015) was a good example. The technique also finds usefulness in the assay for thermostable bacterial bioflocculant produced by Cobetia spp. isolated from Algoa Bay, South Africa (Ugbenyen et al., 2012) and in E. coli, a beneficial bug, but a dynamic threat to public health (Okoh et al., 2012). Babalola (2010) summarized the beneficial bacteria of agricultural importance making it a reference point for others in the field, hence it has been cited over 321 times all over the world.

Biofunctionalization of nanoparticle assisted mass spectrometry as biosensors for rapid detection of plant associated bacteria is a trilateral research between South Africa, India and Taiwan. The work (Ahmad et al., 2012, IF: 6.409). This collaborative and multidisciplinary study proved that even at low concentrations, bacteria can be directly detected without morphological, molecular and biochemical test. The application of MALDI-TOF MS as biosensor to detect rhizospheric soil and root bacteria is rapid and highly sensitive. Besides, it could be widely used for the detection of beneficially important plant associated bacteria in environmental samples. Our work established that rapid bacterial detection ionization/enrichment technique using IgG functionalized Pt NPs assisted MALDI-TOF MS could successfully explore *B. thuringiensis* and *B. subtilis* from carrot.

Curiosity is the mother of inventions. An overview of what I have observed in my research career points strongly to nature self-balancing. This was examined as a single-authored work (Babalola 2014). It is noteworthy from my work that nature makes provision for backups in the modification of soil bacterial community structures. The work expands our understanding of the factors influencing bio-inoculant modification of bacterial community structure in the colonization of the rhizosphere that is essential for improved establishment of biocontrol agents.

Aremu and Babalola (2015a, IF: 2.035) suggest that there might be value in having specific primers for rapid detection of macergens in perishables before they are exported as compared to classical methods of detection, in the sense that the entire assay is fast, reliable, cost effective and no taxonomist is required before the identification is complete. This can be employed in analyzing and monitoring plant materials for macergens invasion in a quarantine section of the agricultural sector of a country before importation and exportation of these plants.

Prior to the work (Aremu and Babalola 2015b, IF: 4.165), not one article investigated vegetable macergens. For this work, I was involved in collection

of data, drafting of the manuscript, revising it critically, the general student supervision etc. as declared in the article. The work expands our knowledge that some scientific method like MLSA used for classification have limitation of single locus analysis. Thus, a proper classification is imperative. This information is useful to plant breeders, farmers, and legislators to ensure quick and effective disease diagnosis and management, to avoid unnecessary destruction of economically valuable crops. My work contributes to partially overcome the unreliable classification of macergens. These led to the award of a PhD degree, solely supervised by me to Bukola Rhoda Aremu, from this citadel of academic excellence in 2016. Also graduated in Food Safety research is Ajoke M Akindolire, MSc 2014.

The Protea-South Africa bilateral collaborative work "Handbook for *Azospirillum*. Technical Issues and Protocols" (Vacheron et al., 2015) is about everything practical a biology learner needs and would always want to know about *Azospirillum* sp. but could be afraid to ask. I contributed the aspect on alleviation of abiotic stress in Plants by *Azospirillum*.

My contributions to Bioremediation and Sustainable Technologies:

Mr. Vice Chancellor, Sir, industrialization and technological advancement have led to increased amounts of toxic substances being released into the aquatic and terrestrial environment, thus increasing the burden on the environment. These contaminants have long-term adverse effects on the environment, and public health. The buildup of these pollutants, especially heavy metals, in the environment is a major global health concern as these metals are not degradable.

The driving force of South African economy is the mining industry and contributes significantly to the gross domestic product of the country. The mining industries are famous for production of gold, diamond, chromite ore, platinum, palladium, rhodium, ruthenium, osmium, manganese nickel and vanadium (Aka and Babalola 2016). However, mining operations generates copious quantities of wastes that contain high concentrations of heavy metals. This has impacted negatively on the environment causing destruction and alteration of the ecosystem (Ayangbenro and Babalola, 2017). They accumulate in agricultural soils threatening food security and safety. The heavy metals are absorbed by plants and may be taken up by animals and humans through consumption of contaminated food or drinking water (Tak et al., 2013).

In a bid to remediate agricultural land contaminated with mine waste, Ndeddy Aka and Babalola (2016), evaluated the effects of three heavy metal resistant bacterial strains isolated from mine tailings on the accumulation of heavy metals by *Brassica juncea*. We observed that these bacterial isolates (*Pseudomonas aeruginosa* KP717554, *Alcaligenes faecalis* KP717561, and *Bacillus subtilis* KP717559) exhibited plant growth promoting properties that boost plant defense mechanisms against fungal pathogens. These heavy metal resistant isolates were found to possess indole acetic acid, hydrogen cyanide, ammonia and phosphate solubilization properties (Table 1) these properties are known to improve crop production (Table 1).

In like manner, inoculation of *B. juncea* seeds with the bacteria strains improved seed germination, seedling vigor, plant height, and root length compared to the inoculated seeds in the presence of heavy metals tested (Cd, Cr and Ni). Generally, there were significant increase in growth of *B. juncea* inoculated with bacteria strains in the presence of heavy metals (Table 2). The isolates also resulted in corresponding increase in heavy metal accumulation in the shoot and root tissues. In the absence of bacterial inoculant, the quantity of metal accumulated by plants was significantly less. It is possible that low available heavy metals in soils limited the amount of heavy metals accumulated by plants. The study showed that inoculating heavy metal accumulating plant species with suitable metal tolerant-plant growth promoting bacteria can be used to enhance the efficiency of phytoextraction. The bacterial strains enhanced the translocation of heavy metals from roots to shoots thus increasing the removal of heavy metals from contaminated environment (Ndeddy Aka and Babalola, 2016).

Table 1. Plant growth promoting properties of metal tolerant bacteria strains

Bacterial Isolate	NH_3 production	Catalase activity	Phosphorus solubilization	IAA production	HCN production
Alcaligenes faecalis	+	+	+	+	-
Bacillus subtilis	+	+	+	+	+
Pseudomonas aeruginosa	+	+	+	+	+

Source: Ndeddy Aka and Babalola (2016).

Table 2. Heavy metal concentrations in *Brassica juncea* tissues after 45 days of sowing

Treatment	Root (mg/kg DW)	Shoot (mg/kg DW)	BCF	TF
Cd^{2+}	369.3 ±8.4[a]	118.6 ± 20.4[e]	3.7± 0.01	0.32±0.01
A. faecalis + Cd^{2+}	689.5 ±11.6[b]	135.4 ± 16.9[c]	6.9 ±0.02	0.20± 0.04
Ni^{2+}	289.2 ± 6.7[c]	146.5 ±31.1[b]	2.9 ± 0.09	0.16± 0.12
B. subtilis + Ni^{2+}	451.1 ±41.2[d]	227.2 ± 10.9[d]	4.5± 0.02	0.19± 0.02
Cr^{6+}	272.6 ±24.9[e]	155.7 ± 6.2[f]	2.7 ± 0.3	0.57± 0.31
P. aeruginosa + Cr^{6+}	556.3 ±26.5[f]	339.2 ± 5.4[a]	3.7 ± 0.02	0.61± 0.02

All the values are mean of three replicates ± SE. BCFD = Bioconcentration factor, TFD= Translocation factor. DW = dry weight. Data of columns indexed by the same letter are not significantly different according to Fisher's protected LSD test ($p < 0.05$). Source: Ndeddy Aka and Babalola (2016).

In another study, Ndeddy Aka and Babalola (2017) isolated and characterized heavy metal resistant bacterial isolates from mine tailings in order to access their tolerance to different concentrations of heavy metals. We isolated eleven bacterial strain that showed different tolerance to multi-metal system. Different parameters such as temperature, pH, and salt concentration were tested on bacteria growth in the presence of heavy metals. Optimum growth temperature in the presence of heavy metals were found to between 35-37˚C and between pH 7.5-8.5and tolerant to different concentrations of heavy metals.

Bacterial cells are capable of bioaccumulation which is the ability to build up heavy metal ions in both particulate as well as insoluble forms and their byproducts (Ojuederie and Babalola 2017). The most essential constituents in such bacteria cells having ion sequestration capability is exopolysaccharides. The bioaccumulating potential of the isolates were also tested to evaluate metal uptake by each organism. These bacterial isolates have different metal uptake potential towards each metal ion and we observed that most species have high preference for chromium and nickel than for cadmium (Table 3). This is due to the toxic effect of cadmium ions on bacteria cell. The amplification of heavy metal resistant genes in the bacteria species revealed

the presence of chromium resistant genes *ChrA* in *Bacillus cereus*, *ChrB* in *Proteus mirabilis.* Cadmium resistant gene *cadA* were found to be present in *Pseudomonas aeruginosa, Bacillus pumilus, P. mirabilis, B. safensis,* and *B. subtilis* while nickel resistant gene *nccA* were detected in *P. mirabilis, B. subtilis, Alcaligenes faecalis,* and *Bacillus* sp. These isolates have potential in remediating heavy metal polluted environment.

Table 3. The percentage bioaccumulating potential of isolated bacteria species

Isolate	Metal salt	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Alcaligenes faecalis	$CdCl_2$	35.5	48.7	72.4	61.8	52.5	31.6	28.9
Bacillus pumilus	$CdCl_2$	22.1	38.9	40.5	39.1	38.3	35.8	34.5
Bacillus sp	$CdCl_2$	16.3	29.7	22.8	21.6	21.2	20.2	16.8
Bacillus cereus	$K_2Cr_2O_7$	14.2	15.3	16.7	9.3	7.5	7.3	6.9
Bacillus safensis	$K_2Cr_2O_7$	28.3	29.7	33.9	16.7	14.3	13.6	9.4
Pseudomonas aeruginosa	$K_2Cr_2O_7$	56.8	64.3	68.7	45.4	38.7	38.4	37.9
Proteus mirabilis	$NiCl_2$	48.0	47.6	49.2	45.5	45.1	24.8	24.8
Bacillus subtilis	$NiCl_2$	21.4	51.3	69.8	46.7	45.9	40.2	40.1
Bacillus cereus	$NiCl_2$	15.8	23.6	32.3	24.4	16.1	12.7	11.5

Source: Ndeddy Aka and Babalola (2017).

We also studied the role of *Bacillus weihenstephanensis* in nitrate removal from contaminated wastewaters using small scale bioreactor (Seenivasagan et al., 2017). Most ground water, the source of drinking water, is contaminated with nitrate and nitrogen compounds. Nitrate is highly water soluble posing a serious health challenge and causing ecological disturbances such as eutrophication of rivers and deterioration of water sources (Fernández-Nava et al., 2010). The high nitrate, phosphate and nitrogen contamination in ground water may be due to enormous application of nitrogenous fertilizers, organic manures, industrial effluents, and human and animal wastes. Our results showed that the bioreactor was able to reduce nitrate by 80% after 156 hours. The remaining nitrate was removed by using coagulants of different concentrations. In various lime concentration applied to the bacterial treated water, 0.5 mg/L lime concentration was found to be more effective in removal of nitrate, nitrite and ammonium.

An attempt was made to remove the remaining concentration of nitrate using chemical coagulants alum and lime. The removal of microbial biomass was

also significant. The use of bacterial cultures before chemical treatment was not only useful in reducing nitrate but also the bacterial biomass was useful for the attachment of chemical coagulants and quicker precipitation. This may be due to negative charge of cell wall. Since, the bacterial cell wall possesses negative charge they would bind on surface of the calcium. Hence, the bacterial rate was decreased in the coagulant treatment. Similar mechanisms occurred in removal of nitrite and ammonium.
It is noteworthy that academically, the bioremediation project led to two MSc qualifications awrded to Ms Sebogodi Keletso M 2013, and Mr Ndeddy Aka R J., 2016, and the PhD qualification of Dr Muibat Omotola Fashola in 2016. Also graduated in the Bioremediation project are, Chukwuneme Chinenyenwa Fortune 2014 and the closure by Ayangbenro Ayansina. Graduated in the Soil metagenomics project are Julius Leumo Kgosiemang 2017, Ditshipi Peter Taukobong 2017.

The way forward

My team future research direction is vividly to build on research around Plant Growth Promoting Rhizobacteria (PGPR) especially within an international context. This is the era of sustainable agriculture and we clamor for environmentally friendly means of increasing plant yield without damaging the environment. I foresee enhancing the PGPR yet being conscious of biosafety regulations because of the risk of transgenes from transgenic microorganisms to the non-targets in the environment. I aim to continuously groom postgraduate students (capacity building) in the field of Molecular Plant-Microbe Interactions. You will agree with me that the planned project has immense potential vibrant development considering the relevance to agriculture.

After substantial field trials on biofertilizers and their formulation if all works well there is high possibility of commercializing the research product for the benefit of mankind. This will help in combating the long-standing problems of food insecurity; in this aspect I envisage industrial application and patent. I so much look forward to that.

Recommendations

Mr. Vice Chancellor, Sir, based on my experience over the years and as a researcher, I wish to humbly make the following recommendations:

Plant Health Management: The world is already experiencing a global food crisis and it has been estimated that at least 50% more food is required by 2050 to feed approximately 9 billion people. A future of food shortage has been predicted due to several biotic and abiotic factors. Achieving the attainable yield of crops entail proper management of yield-limiting factors of the growing environment. Drought-stress, genetic factors, diseases, weeds and allelopathy are some growth-limiting factors of plants. Over the years, we have employed microorganisms for drought-stress control, weed control and as biofertilizers thereby promoting plant growth. Given the recent concerns over climate change, land use and decline in agricultural work force, food security is a priority for all nations of the world. More funds and programmes are therefore encouraged for this extremely key area of research to forestall starvation.

Bioremediation: Due to its toxic effects, pollution by heavy metals is a major threat to all forms of life. Bulks of chemical waste are generated from conventional remediation methods and this is highly uneconomical. Employing microorganisms for this purpose is however eco-friendly and more economical. Microbes possess several mechanisms of metal sequestration that hold greater metal biosorption capacities eliminating or recovering metals and metalloids from solutions with the aid of their biomass and components. More attention should therefore be given to this area of research to keep these metals in check.

Standard greenhouse: The existing greenhouses are becoming inadequate to contain our expansion. There is need for a standard greenhouse and screenhouse for extension of laboratory studies on plants before field trials/research. Bacteria complexes in soil, especially those involved in the nitrogen cycle. The complexity of soil bacteria required studying them in their natural habitats as well as in cultures. The use of laboratory methods exclusively, e.g., isolation, pure culture, and bacteriological media, could not establish real soil microbiology issues. Soil microbiology is an independent science that should be carried out under conditions as near nature as possible, "in the soil itself."

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Conclusion

Today, I have presented my academic sermon. Mr. Vice Chancellor, Sir, I now proceed to lay claim, formally, to my professorship of Microbial Biotechnology, North-West University.

Thank you **all** for your presence and attention.

Now unto the King eternal, *immortal, invisible*, the only wise God, be honour and glory for ever and ever. Amen.

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