UNIVERSITY OF PORT HARCOURT

THE ROOT AND THE MEDIA: THE USE OF PHYSIOLOGICAL PROCESSES AS INDICATORS OF ENVIRONMENTAL CHANGE

An Inaugural Lecture

By

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DEDICATION

I AM THAT I AM is His name.
He is a God that acts in totality, not in part.
He is holistic to bring about the wholesomeness of every individual.
He has long arms that stretch from every part of the universe to the other parts and still continues till eternity.
No one can hide from Him.
I'm better off rooted in Him, and to Him be all the glory!

Also to my grand children

- Chibuchi - Brilliance
- Mpulunma - Virtue
- Ebubedike - Victor
- Esomchi - Grace

APPRECIATION

I appreciate the world's greatest parents; my father late Chief Josiah Nwekeh Nwosu (Chimereze 1 of Ndashi Etche) and my mum, Mrs Victoria Njinalu Nwosu. I owe them gratitude for a successful career. They laid the foundation for me to succeed. Abraham Lincoln said '*All that I am or hope to be, I owe to my angel mother,* (and I add, my disciplinarian and Teacher father) …… *No man is poor who has a godly mother'*. They named me Love, and they loved me like no other! I am their first child.

My precious daughters, Engr (Mrs) Ugochi Ugonna Hart, Nkiruka and Chidobe Akonye and my beloved son, Engr Sopirinye Victor Hart are divinely sent. May the blessing of the Lord, like the dew of Hermon, rest upon you and your generations. You've always stood solidly behind me.

I love my siblings. Each one of them has given me special support. Mr Chidi Nwosu, Mrs Irene O. Adiele (I-Nma), Mr. Godspower Okechukwu Nwosu, late Mrs Mercy Ebere Nwokugha, Mr Chinwendu U. Nwosu, Dr (Mrs) Gloria N. Iwhiwhu, Mrs Beauty N. Louis-Kayode, Mrs Chioma Mbanahia, Engr Mr Azubuike B. Nwosu, Mr Diploma C. Nwosu, Mrs Nnenne U. Amadi, Mr Obinna Nwosu, Evang Chimuanya S. Nwosu, Ord Gift N. Nwosu, Mrs Chibunma G. Justice, Miss Joy U. Nwosu, Miss Confidence U. Nwosu and Mr Amanze C. Nwosu.

There is an in-law that sticks closer than a brother. He is Barr Ikem Adiele whose advice and guidance, I have always cherished. Another in-law doubles as a friend and with her husband, it is a duo. They are Rtd AIG Stephen Hart and his dear wife, Rtd CP Meg Hart. Mr Akahmbari J. Nwordu (O'Jay) has been like a senior brother to me; I won't forget his mentorship and vision in Secondary School and University. I also thank Dem Emeka (Mr Chukwuemeka Linus), Engr Monday Nwanyanwu, Mr Samuel Choko, Sir John E. Egbule, Rtd Major Paul C. Akonye and his amiable wife - Dr Mrs. Angela Akonye, Mr Samuel Iyke Nwosu, Dr N. G. Ekeh, Barr A. P. M. Mbazigwe, Mrs Grace Ohanuna, Mr Sam Nwokugha, Mr Kingsley Amadi, Rev Enoch Justice, Pst. Pius Mbanahia for all their kindness to me.

I am immensely grateful to Prof F. A. Onofeghara who supervised all my projects (B. Sc., M.Sc. Ph.D) and ignited a passion and the enthusiasm in me to anchor my work in Plant Physiology boosting my drive for Stress Physiology. It was a privilege that I grew under his tutelage and I count myself fortunate to be nursed by his rich knowledge in science. I cherished his advice which he usually gave me in a godly, fatherly and friendly way. He is late but his legacies live on. He had a dogged belief in Jesus Christ, which he taught and preached. He was a great mentor. He believed in pragmatism (the essence of multitasking) and the principle to deliver on mandate, something I had to imbibe to measure up to the workloads of being a mother, a student and an academic staff. It is my fervent wish that my students would imbibe some of these nuggets if not all, to add to what they already have.

Emeritus Professor S. N. Okiwelu deserves a special applause for the role he played in instigating my career networks both at SPDC to use their facilities for my Ph.D research (refrigerated centrifuge) and as a mentor for IFS (International Foundation for Science, Sweden) grants. He is among other qualities reputed to facilitate academic relationships within the Faculty of Science, reaching out to the wider university community as Dean. He has what I may call 'people skill' with a lot of positive impact on many staff. When the Department of Geology lacked staff to teach a course that related to Botany, he asked me to handle it. That course was Palaeontology.

I am also indebted to other lecturers: Professor P. D. S. Kinako, Professor G. C. Clerk, Late Professor A. E. Arinze, Professor B. E. Okoli, Late Dr C. B Powell, Dr B. H. R. Wilcox, Dr S.K. Irwin (my Academic Adviser), Dr D. O. Ezeala, L. Dr Enu-

Kwesi, Dr M. A. Rana, for all their labour of love in knowledge impartation. They exuded passion, lighted us up as students and as superiors. The rigorous laboratory exercises for every course that I took is memorable. The lacunae created by the exit of these generations of lecturers from our academic institutions must be filled.

Help, advice and information came from many quarters and it is a special pleasure to acknowledge the assistance of all my colleagues whether living, late, young or new: Prof C. I. Umechuruba, Prof D.I. Anyanwu, Prof B. L. Nyananyo. late Prof E. N. Elenwo, Prof A, E. Ataga, Dr S.I. Mensah and Dr J. O. Amakiri, Prof B. C. Ndukwu, Prof J.O. Osuji, Prof G. C. Obute, Prof (Mrs) E.O. Nwachukwu, Prof I. O. Agbagwa, Dr F.B. G. Tanee, Dr (Mrs) J. U. Agogbua, Dr E. B. Ochekwu, Dr B. A. Nwauzoma, Dr N. L. Edwin-Wosu, Dr P. O. Eremrena, Dr S. M. Sunday, Dr C. Wahua, Dr Albert Ejikeme, Dr (Mrs) G.I. Ugiomoh, Mrs B. A. Odogwu, Mr Kalu Okonwu, Mrs C. G. Ikechi-Nwogu and Miss J. Ukomadu. I cannot forget the laboratory staff for providing technical assistance and plant house facilities: Mr J. Opayemi, Mr C. Nnubia, Late Mr Onoshakpor and Mr B. C. Ordu, Mr Japhet Onwuegbu, Mr Kweka N. Deeduah, Mr C. Nwizug.

My Faculty in Science and Agriculture (in part) and the entire University are all hereby acknowledged for their wonderful works of cohesion and adhesion in relating to me since 1977 first, as a student and later as academic staff. I am so fond of UNIPORT Alumni especially the class 81 set.

It gives me pleasure to recognize my friends in my youth and adulthood – Rev Dr Sister Caroline Mbonu, Prof Mrs Chinyere Ohiri-Aniche, Prof R. E. Amakoroma, Engr Alfred Amadi and his dear wife, Mrs Chinyere Amadi, Dr (Mrs) Christmas Otokunefor, Dr Eze Orduwa, Dr Mrs Elsie Hamadina, Dr (Mrs.) Adaba T. Ibim, Mr Hanson Aniefiok, Mrs Florence Manda, Prof. Julie Umukoro, Mr. (Bro) Charles Ndubuisi Oguguo

My sincere thanks are especially due to all my primary and secondary school teachers who made learning incredibly exciting. All the classroom scenes are ever fresh in my memory.

My heartfelt appreciation goes to my Etche Brothers and Sisters (Ogbako Etche, Uniport Branch) ably mentored by Prof S. N. Maduagwu and Prof Ozo-Mekuri Ndimele, the Vice Chancellor of Ignatius Ajuru University of Education.

Neighbours are the ‘first responders’. They all practice what Jesus said ‘Love your neighbor as yourself’ Mk 12:31, Matt 22:39. I want to express my thanks to all my neighbours, old and new – Dr I. U. Mbeledogu our courseware tutor, late Mr. Maduafokwa, Dr Jones Ayuwo and his dear wife, Dr Mrs. Felicia Ayuwo, Professor Mike O. Onyekonwu, Dr Aziagba, Prof E. C. Nduka, Prof and Dr Mrs F. Ugiomoh, Mr. Mbachu, Professor A. N. Gbosi and his dear wife, Anty Peggy, Professor O. Akaranta, Professor J. U. Okoli and his wife, Professor Wumi Iledare, Professor O. A. Ejele and his dear wife, Prof Mrs. P.E. Ejele.

I ask God to bless my OSC family, Ecclesiastical and all the Chaplains – His Grace, Most Reverend, Archbishop I. C. O. Kattey, Rev G. O. Kalu, Rev Peterson Nwidoobee, Ven S. C. Opara, Rev Dr E. W. Udo, Rev Kelechi Timothy Francis, Rev Canon S.T. Nbete, Rev F. A. Iduma, Prof E. G. Akpokodje, Dr Chibuike Eze Nwafor, Mrs Data Briggs, Mrs Flora Iyagba, Martha Brierley as well as the Student Christian Movement (SCM) and the Full Gospel Business Men’s Fellowship International (FGBMFI). You have stood and withstood and I gained so much in our fellowships.

My origin in Christianity began in St James Anglican Church, Ndashi Etche where the seed (The Word) was sown by the special grace of God. I thank Rt Rev Okechukwu Precious Nwala (JP) – Bishop of Etche Diocese, late Samuel Umenwa Amadi, Emeronye, Francis O. Nwakacha, Rev Light Oparanozie, Rev Chuks Moronu for their labours of love, I am indebted to my academic children who are certainly cherished for their dedication to research; Prof Gabriel Osuagwu, Prof Umunagbu S. Offor – Dean, Vocational and Technical Faculty, IAUOE, Dr Tanee, Franklin, B. G. (Assoc Prof), Dr Peter Eremrena, Mr Onwudiwe, Ifeanyi Alo, Dr Ogbuehi, Hyginus Chikaodi, Dr Mrs Ugiomoh, Ifeoma Gladys, Mr Oji, Oji Okorie, Mr Numonde Davidson, Mr Chinedu Ikechukwu Emelife, Mr Susinya Habila, Mr Josiah Muonam Ikuli, Rev Dr Isirima Chekwa Ben, Mr Kalu Okonwu, Mr Samuel Onyeyirim, Mrs Queen Menuchim and Mrs Georginia Egbunefu.

I thank the Vice Chancellor, Professor Ndowa E. S. Lale for the approval of the date and presentation of this Inaugural Lecture.

Finally, I thank God.

1 Lord, enthroned in heav'nly splendor,
first-begotten from the dead,
Thou alone, our strong Defender,
liftest up Thy people's head.
Hallelujah! Hallelujah!
Jesus, true and living Bread!

2 Prince of Life, for us Thou livest,
by Thy body souls are healed;
Prince of Peace, Thy peace Thou livest,
by Thy blood is pardon sealed.
Hallelujah! Hallelujah!
Word of God in flesh revealed.

3 Paschal Lamb! Thine off'ring finished
once for all when Thou wast slain,
in its fullness undiminished
shall forevermore remain.

Hallelujah! Hallelujah!
Cleansing souls from ev'ry stain.

4 Great High Priest of our profession,
through the oil Thou ent'redst in;
by Thy mighty intercession
grace and mercy Thou dost win.
Hallelujah! Hallelujah!
Only sacrifice for sin.

5 Life-imparting heav'nly Manna,
stricken Rock, with streaming side,
heav'n and earth with loud hosanna
worship Thee, the Lamb who died.
Hallelujah! Hallelujah!
Ris'n, ascended, glorified!

Source: Hymns to the Living God #192
Author: George Hugh Bourne

ORDER OF PROCEEDING

2.45P.M. GUESTS ARE SEATED

3.00P.M. ACADEMIC PROCESSION BEGINS

The procession shall enter the Ebitimi Banigo Auditorium, University Park, and the Congregation shall stand as the procession enters the hall in the following order:

ACADEMIC OFFICER
PROFESSORS
DEANS OF FACULTIES/SCHOOL
DEAN, SCHOOL OF GRADUATE STUDIES
PROVOST, COLLEGE OF HEALTH SCIENCES
ORATOR
LECTURER
REGISTRAR
DEPUTY VICE-CHANCELLOR [ACADEMIC]
DEPUTY VICE-CHANCELLOR [ADMINISTRATION]
VICE CHANCELLOR

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

THE VICE CHANCELLOR‘S OPENING REMARKS.

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

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

THE INAUGURAL LECTURE

The Registrar shall rise, cap and invite the Orator, Prof. Ebi R. Amakoromo to introduce the Lecturer.

The Orator shall then rise, cap and introduce the Lecturer, and resume her seat.

The Lecturer shall remain standing during the Introduction. The Lecturer shall step on the rostrum, cap and deliver her Inaugural Lecture. After the lectures, she shall step towards the Vice-Chancellor, cap and deliver a copy of the Inaugural Lecture to the Vice-Chancellor and resume her seat. The Vice-Chancellor shall present the document to the Registrar.

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

THE VICE-CHANCELLOR'S CLOSING REMARKS.
The Vice-Chancellor shall then rise, cap and make his Closing Remarks. The Congregation shall rise for the University of Port Harcourt Anthem and remain standing as the Academic [Honour] Procession retreats in the following order:

VICE CHANCELLOR
DEPUTY VICE-CHANCELLOR [ADMINISTRATION]
DEPUTY VICE-CHANCELLOR [ACADEMIC]
REGISTRAR
LECTURER
ORATOR
PROVOST, COLLEGE OF HEALTH SCIENCES
DEAN, SCHOOL OF GRADUATE STUDIES
DEANS OF FACULTIES/SCHOOL
PROFESSORS
ACADEMIC OFFICER

PROTOCOLS

The Vice Chancellor

Past Vice Chancellors

Deputy Vice Chancellors (Admin and Academic)

Members of the Governing Council

Principal Officers of the University

Provost, College of Health Sciences

Dean, Faculty of Science

Deans of other Faculties

Distinguished Professors

Directors of Institutes and Units

Heads of Department

Visiting Academics and Colleagues

Captains of Industries

Cherished Friends

Unique Students

Members of the Press

Distinguished Ladies and Gentlemen

1. INTRODUCTION

I am grateful to the Vice Chancellor for giving me the opportunity to fulfill this noble tradition- to give my inaugural lecture, and I thank you all for finding time to come to the 144th Inaugural lecture on what I may call a harvest of my research contributions summarily framed in the title '**The Root and the Media: The Use of Physiological Processes as Indicators of Environmental Change'.** I consider this lecture as an avenue to extend the communication of my expertise in my subject area to the University and a wider community.. My job in this lecture is to synthesize the physiology of the root and how it harnesses the manifestation of the entire plant in the environment. The root initially experiences and signals the change in the soil medium– water (drought or flooding), salinity and soil pollution.

Let me briefly mention my forebears in my Department who have vibrantly enthused us with their academic achievements and research interests. The late Professor Francis A. Onofeghara who delivered the 3rd Inaugural lecture in the year 1986 titled 'Botany in Human Affairs' in this university was the first in the Department. He is a well-known and accomplished academic, a professional who has raised the profile of higher learning of the University of Port Harcourt, Faculty of Science and the Department of Plant Science and Biotechnology. Others are Prof. P. D. S. Kinako, Prof. B. E. Okoli, Prof. B. L. Nyananyo, late Prof. A. E. Arinze, Prof. D.I. Anyanwu, Prof. B. C. Ndukwu, Prof. J.O. Osuji, Prof. A, E. Ataga. Their areas of expertise are indicative of the import and impact that Plant Science and Biotechnology has had in our society. I am proud to say that I am a UniPorT product in that I obtained my B.Sc., M.Sc., and Ph.D. from the this institution. Having accredited programmes in other institutions, I stand to be corrected if I say that my Department, Plant Science and Biotechnology is more starstudded than others. In fact, we set the pace and others follow as shown by the fact that we were the first to change our name from Botany; to Plant Science and Biotechnology and then, others followed. It is not the long distances that others travelled to get a degree that counts but the quality of education one obtains. The first Dean of the Faculty of Science, Prof S. N. Okiwelu reflected during the 25th anniversary celebration of the Faculty that in his tenure, *"the Faculty was a mini Universitas"* meaning a conglomeration of academics from almost every part of the world (US, UK, Europe, Canada, Asia, India, other countries in Africa). My academic adviser (Dr. (Mrs.) S.K. Irwin) was a Canadian and she sometimes paid me a surprising visit in my hostel. I have not forgotten the nuggets of time management and practical observations in Biology she inspired in me. While she lectured in Biological Sciences, her husband lectured in the School of Chemical Sciences. On a wider scale in the University, I remember scholars like Prof. Kimse Okoko, late Prof. Claude Ake, and late Dr. Chukwumerije, who handled our GES lectures which were loaded with nationalistic ideals embellished with a social taste for Marxism. Indeed, all our lecturers were thoroughly baked intellectuals and they gave us well-rounded education to excel in the modern world, whether expatriate or home-based. The pioneer Dean of theSchool of Biological Sciences, Prof F. A. Onofeghara captured his experience thus: '…. *staff development was aimed at attracting high caliber staff … staff development was aimed at recruiting first degree graduates and training them locally and abroad to obtain their doctoral degrees'*. They laid a solid, strong and purposeful foundation in the Faculty, the importance of which cannot be overemphasized. The legacies have remained with us till today. *There are only two lasting bequests* (gifts) *we can hope to give our children; one of these is roots, the other, wings* – W. Hodding Carter II. They gave us all; to remember where home is and to practice what has been taught us no matter where we find ourselves.

In plant physiology, we study the integration of all the functions and the structure of the plant that manifest in the growth,productive potential and end of that plant. The study of plant physiology is useful to the service of man due to vital processes and functions of plants for man's needs. As Bidwell (1974) put it, '*plant physiology is the study of the processes of how plants carry out their life processes; of how and why each plant performs these processes in a peculiar way. It is the study of the organization and operation of the processes in the plant that order its development and behaviour*'. Physiological principles are founded in chemistry, physics, and mathematics. It provides the fundamental basis about the working plant, and working of plants. The truth about plant physiology has far-reaching relationships to our anthropoliticosocial and spiritual well-being.

Images of Plant Physiology

Although, plant physiology as a discipline is rooted in basic knowledge and research, most of the things we see and touch have their roots in plant physiology.

- The images of plant physiology could be seen in the use of the Earth's green screen (i.e. chlorophyll) in the maximization of light harvesting scheme and subsequent energy conversion and carbon dioxide ($CO_{2)}$ reduction mechanisms, all because of the knowledge of photosynthesis, growth, and stomatal physiology. This underlies the innate creativity in plants for high productivity. This is the entry point to crop production (Plate 1).

Plate 1. Crop Growth
(Source: https://pospitips.files.wordpress.com/2016/08/agriculture-nigeria-e1468769335599.jpg)

- The dynamics of nutrient recycling is embodied in the study of absorption, transport, transpiration, stomatal physiology, and storage. Such knowledge is applied in environmental practices to mitigate pollution, to establish parks and gardens, to regenerate the environment, to improve aesthetics in human sociology and psychiatry- since natural environments restore sanity. Phytoremediation, i.e. the science of using plants to remedy polluted environment is predicated on physiological attributes of absorption, transpiration, translocation, metabolism, and root exudates (Plate 2). Various remediation techniques such as phytoextraction (sometimes called phytoaccumulation), phytodegradation, rhizodegradation, phytovolatilization, phytostabilisation (sometimes called phytosequestration), and phytohydraulics are all based on plant physiological processes.

Plate 2. Phytoremediation -using plant roots to clean polluted water (Source:http://4.bp.blogspot.com/_Cwb4CmLtXM/S6rMrRc2sNI/AAAAAAAAACQ/eryAFslWtv0/s1600/root%2Bsystem.jpg).

- The study of plants' organization in time and space (i.e. tropic and nastic growth), the seasons of planting and harvest for each crop, crop value improvement and suitability, the timing of flowering, fruiting and tuberization (such as photoperiodism, vernalisation) has impacted the farming systems significantly (Plate 3).

Plate 3. Farming systems

(Source: http://www.fao.org/zhc/farming-systems-that-save-and-grow-in-pictures/en/?%2525253butm_campaign=buffer&%2525253butm_source=twitter.com&%252525 3butm_medium=social).

- By studying the plant survival in extreme environmental conditions (Plate 4), plant physiologists have maximized yields by relieving limitations on plant growth and/or modifying the environment thereby achieving optimum crop performance.

Plate 4. Wilting plants (a) in drought soil (Source: https://extension.umd.edu/growit/wilting-drought-or-waterlogged-soil). (b) in waterlogged soil (Source: https://pixabay.com/en/photos/soil/).

- Knowledge of growth phenomenon in plants or its parts has helped man to use plant roots to control erosion, to improve soil texture and fertility (Plate 5), while the plant leaves intercept rainfall and act as wind breaks.

Plate 5. Plant root types used to mitigate soil erosion a. (Source: https://asknature.org/strategy/root-systems-control-erosion/#jp-carousel-7764bbb). b. (Source: https://www.pinterest.com/pin/465841155178222233).

- In seed germination studies, plant physiology has contributed to many pre-sowing treatments that man has used to improve either the emergence of germinated seeds from the soil or vigor and seedling establishments (Plate 6). In the brewery industries, the malting quality of cereals is revealed by the germination activity of the seeds. Dormancy studies have also served man in the improvement of germination of seeds and its storage conditions especially in horticultural crops and forest or tree species that are to be multiplied.

Plate 6. A kidney bean germinating into a seedling (Source: http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html)

- The discovery and study of plant hormones such as auxins, gibberellins, cytokinins, ethylene and abscissic acid, has improved agricultural practices. Based on various and different aspects of plant physiology, these hormones are either used for modification of plant growth and development (Plate 7), or as herbicides.

Plate 7. Gibberellins hormone treatment test on grapes (a.) untreated grapes (b.) treated grapes
(Source: http://www2.nsysu.edu.tw/Bio/images/commen/plant-horm10303.pdf)

- Various applications of tissue culture lend beautiful images (Plate 8) and expressions in the following ways:
  - micropropagation (clonal multiplication of meristems in culture);
  - virus elimination (culture of small meristems which are virus-free);
  - embryo rescue (culture of developing embryos which cannot develop further after fertilization);
  - *in vitro* fertilization (fertilization of pollen and egg cell in culture to obviate incompatibility barriers);
  - germplasm storage and transport (shelf storage of genetic resources at defined conditions and transport of same);
  - callus regeneration (induction of callus from explants of leaf, petiole, stem, roots, storage organs or from immature meristematic tissues such as immature embryos,

inflorescences, intercalary meristems, immature leaf base and root meristems);

- o mutation and mutant selection (application of mutagens to cultures of protoplasts, cells, callus, and organs followed by isolation and screening);
- o soma-clonal variation regenerants (selection of phenotypes which have desirable characters from a population in culture);
- o secondary plant products and metabolites for medicinal purposes (provision of larger quantities in shorter duration);
- o protoplast fusion (combination of two different protoplasts in such a way that their genomes can fuse together).

Plate 8. Tissue cultured plantlets
(Source: https://www.dreamstime.com/stock-photos-plant-tissue-culture laboratory image 39985483)

- Studies of mineral nutrition and water absorption have led to the discovery of essential nutrient elements, fertilizer formulation and applications (Plate 9). This is the origin of hydroponic farming. In space stations (and probably submarines), suitable conditions in the aerospace are created which are called CELSS i.e. Controlled Ecological / Environmental Life Support System. Thus, that plant life can be supported in such a system far away from the earth. In greenhouses today, hydroponics and controlled environment agriculture is fast becoming a common sight in urban cities and environments considered hostile to grow plants.

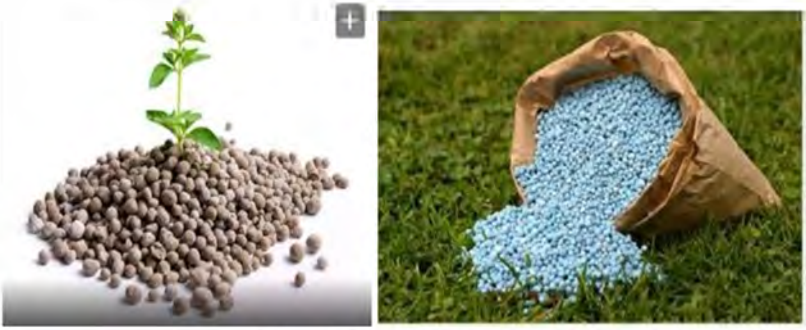


Plate 9. Fertilizer granules
(Source:
http://www.istockphoto.com/photos/fertilizer?excludenudity=true&sort=mostpopular&mediatyp e=photography&phrase=fertilizer).

- Studies on the synthesis of primary and secondary plant products is associated with assimilate partitioning from source to sink, and translocation of solutes. The deluge of such products ranges from simple carbohydrates to drugs (Plate 10) such as narcotics.

Plate 10. Secondary plant products from medicinal plants.
(Source: https://www.shutterstock.com/search/drug+plant)

Vice Chancellor, Sir, I do not regret reading Botany or pitching my tent in plant physiology, because I am full of gratitude to late Prof Francis A. Onofeghara who mentored me in my early years and groomed me to specialize in plant physiology. I have realized that it is not the course that one reads that matters in life but how a person can horn his talent to serve humanity. Please permit me to sing the first stanza of the song in the appreciation page.

Lord, enthroned in heav'nly
splendor, first-begotten from
the dead, Thou alone, our
strong Defender, liftest up
Thy people's head.
Hallelujah! Hallelujah!
Jesus, true and living Bread!

2.0 THE ROOT STRUCTURE AND FUNCTION

Box 1. Functions of roots

- Support / Anchorage – the shoot is firmly held up by the roots to withstand the vicissitudes of the environment such as rain, wind, flood, and man. Stilt roots of mangrove trees shield and stem the tidal waves. Prop roots of maize and gigantic trees give extra support to the plant.
- Absorption /Conduction – the roots absorb water and mineral nutrients to sustain the plant.
- Nutrition – parasitic plants have roots known as haustoria (haustorium-singular) with which they use to absorb nutrients and water from their hosts. An example is the mistletoes, semi-parasitic angiosperms that attack cola, cocoa, pepper fruit, local pear, citrus.

- Propagation – perpetuation of plants such as Asparagus are done using their roots.
- Respiration/Aeration – mangrove breathing roots (pneumatophores), aerenchyma formation in hydrophytes and flooded plants enable intake of oxygen to sustain the plants.
- Storage - the root serves as a storage organ in many plants such as cassava, carrot, and potatoes
- Synthesis of metabolites- the roots of plants are involved in enzymes, vitamins, and hormones formation.

The root system is of two types namely, the taproot and fibrous roots. The functions of the root are many (see Box 1), depicting the various specializations of the root, but the beautiful array of the shoot on the earth's surface surpasses other functions. For the plant to express itself, it must be rooted in a medium, which can take different forms – soil, water and air. So, the vegetation in our environment, the crops in our farms, the hydroponic/ aeroponic gardens in our greenhouses, the plantlets in the test tubes in our tissue culture laboratories are all rooted in one form of medium or the other. A medium lacking in nutrients will cause plants to show deficiency symptoms due mainly to the fact that the role played by that nutrient cannot be substituted by another nutrient, and note that it is what the root absorbs that the plant uses.

The internal structures of the monocot and dicot roots differ (Fig. 1), though the basic building plan of enclosing the vascular bundle within an endodermis remains. With glaringly absent pith in dicots, the fingerlike projections of the xylem form arcs or hollows and the phloem is situated between the fingers. The xylem bundles which range from 2-6 (diarch to hexarch) could be polyarch in some plants. The activities of the pericycle give rise to the formation of lateral roots (from cells opposite to the protoxylem), cork cambium. Secondary growth occurs in dicot roots. With prominent pith, the vascular bundles (xylem and phloem) of monocots alternate, and are arranged in a circular fashion, and are polyarch. Onion is an exception with hexarch constitution.

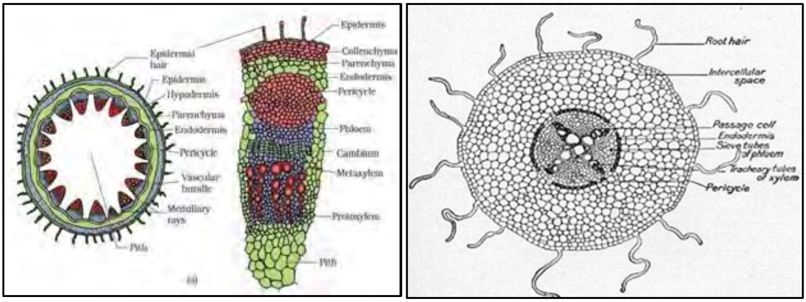


Fig. 1. Transverse section of (a) monocot (Source: http://www.askiitians.com/biology/anatomy-of-flowering-plants/internal-structure-of-stemsroots andeaves.html#Internal%20Structure%20Of%20Typical%20Dicotyledon%20Root).
(b) dicot roots (Source: https://www.pinterest.com/pin/360921357607917605/?lp=true).

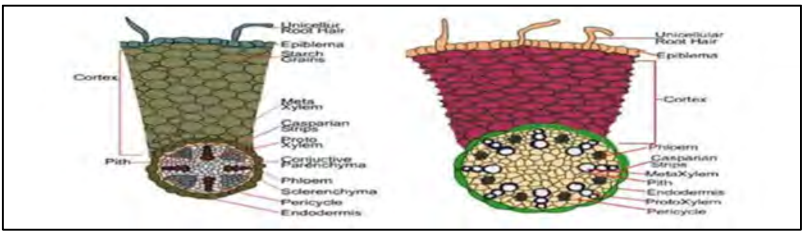


Fig 2. The transverse section of (a.) dicot roots showing a tetrarch condition, (b.) monocot root showing polyarchy condition (Source: http://vle.du.ac.in/mod/book/print.php?id=11896&chapterid=23615)

The root is a system. This means that it is composed of a group of related parts that work together as a whole unit for a particular (common) purpose according to Longman dictionary of contemporary English (year). It has distinct morphological (i.e. matured zone, elongating zone and the tip covered with a cap) and anatomical features (Fig 2) from the shoot system. It is the subterranean / underground part of the tree / plant hidden and unseen in the soil where it serves the function of anchorage, in fact the American-Chinese architect, I.M. Pei once said that '*a lasting architecture has to have roots*'. The root is admirably designed for absorption with:

- the branching of the roots that ensures that a vast area of the soil can be accessed for water absorption;
- the presence of the root cap which safeguard against injury to the delicate parts of the root during its downward sojourn through the soil, and
- a higher surface volume ratio to achieve an abundant development of root hairs. This is thus an adaptation for increasing the absorbing surface of the root for water and minerals.

The internal structure of the root reveals that numerous pili known as root hairs protrude from the root surface, known as the piliferous layer (epiblema). Roots do not have epidermis because a 'dermis' is a protective covering that disallows permeation of substances. What a root has is an endodermis situated after the cortex that regulates the entry of water and mineral elements. The endodermal cells are overlaid with a suberin material tangentially (known as Casparian strip named after Caspari, who discovered it), hence water / minerals must pass through the semi-permeable membrane of the endodermal cells before it gets to the xylem for the upward irrigation of the stem to the leaves. The xylem and phloem (i.e. the vascular bundles) are arranged radially inside the stele for efficient water movement. Water molecules move through both the apoplast and symplast from the root hair, epidermal cells and cortex. But from the endodermis and xylem, the movement is symplastic. Mineral ions are also absorbed passively by differences in chemical and electrochemical potential facilitated through a channel or actively using energy by adenosine triphosphate (ATP) hydrolysis to drive the transport of molecules up the gradient of concentration. This can be achieved using the ion pumps or ion gradients. The latter could take the form of a symport, uniport or antiport in absorption. This signifies the importance of the root to the plant (i.e. its growth, establishment, productivity, senescence). If the root cannot mine for nutrients, the plant growth is undermined. Marcus Garvey once said that '*a people without the knowledge of their past history, origin and culture is like a tree without roots*'. The root is the first organ that accesses the soil media, where the realms and recesses are dark, obstructed by sand particles but it continues to grow and branch out uninhibited by the gravitational response and directed by statoliths that initiate the secretion of hormones.

Deep Calleth Deep

The root architecture may be extensive or intensive or both, depending on the type of plant and of course the environment. The root relationship with that of shoot is significant in the survival and competitive ability of the plant. In quantitative terms for example, root lengths (Fig. 3) of stressed cassava plants remained restricted (50% reduction in root growth rate) within the experimental protocols, the magnitude (-10 to -40 bars) and duration (1 to 7 days) of stress notwithstanding. This resulted to precipitous decline in relative growth ratio (RGR) and net assimilation rate (NAR) indicative of the susceptibility of the young cassava plants under water stress (Nwosu and Onofeghara, 1992). Roots as the wicking system provide the water and the nutrients the plant needs. Root and shoot growth balance is measured by the root/shoot ratio and any imbalance increases the task on the roots. The root generally exceeds the shoot in terms of surface area and extent.

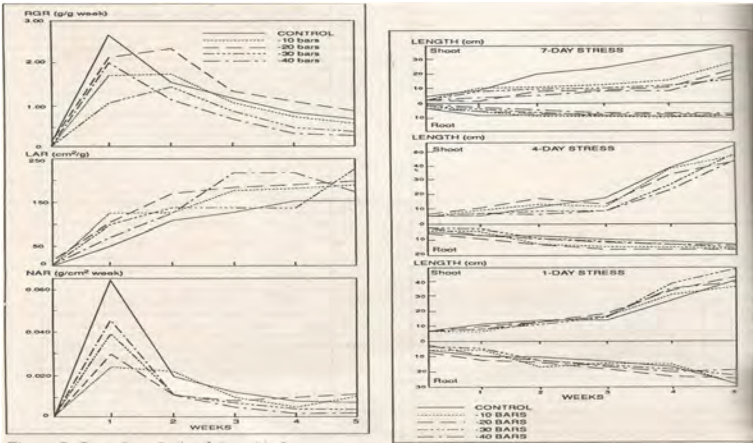


Fig 3. Growth analysis of cassava roots under water stress (a.) growth analysis of day-old plants stressed for 1 day, (b.) Shoot and root behavior under stress (Source Nwosu and Onofeghara, 1992).

The inability of the root to sustain the growth of the entire plant could therefore be hampered by the following:

i) Presence of soil water and porosity of the medium for capillary movement: Since water movement is from a point of higher water potential (Ψ) to lower Ψ, when soil is dry, the rate of water movement slows down considerably i.e. a total sectional area available for flow decreases with moisture content and the root absorption declines.

ii) Rooting characteristics and root integrity: The absorption rates of roots vary depending on the size of rooting systems, length of roots, and number of root hairs. The root integrity may be compromised with root diseases.

iii) Temperature: Viscosity of water decreases with temperature (twice as high at 0ºC as at 25ºC). Therefore, there is a decreased rate of movement from soil water to root and through root cells.

iv) Osmotic characteristics of the root medium: During physiological drought, plant roots are incapable of extraction of water molecules from the medium. In saline medium, the roots require extra energy to extract water as well as solutes (active absorption). This movement against gradient slows growth which gradually stops with a resultant mortality.

v) Internal resistance to water transport: resistance within plants to water movements may occur in the soil or within the plant with a resultant absorption lag. Whenever appreciable transpiration occurs, the absorption of water usually lags behind transpiration. Such absorption lags occur even in well-watered soils.

3.0 THE MEDIA

Table 1: Comparison of plant root and news media

	ROOT MEDIA	NEWS MEDIA
a	Manipulate positively or negatively by scientists	Same by press
b	Polluted by oil, effluents, wastes	Polluted by junk news
c	Stressed by unfavourable conditions	Stifled and suppressed by the government, and sometimes journalists are attacked
d	Masses depend on it to create and increase crop yield	Masses depend on it to feed their mind and intellect

I am not referring to the news media. The phrase ‘social media’ is now a household chant and has become so powerful that reputable media houses including those owned by the government, have step-up their finesse to maintain their superiority and authenticity. A few contrasts however, cannot be left unnoticed (see Table 1). The media are the storehouses of information. The environment is a mega medium and has several media i.e. living and nonliving, and the root has access to all. On the soil medium, the root establishes the plant as mesophyte, xerophyte, and halophyte; in water medium, the plant grows as a hydrophyte while plants rooted in living tissues are parasites. The characteristics of the surrounding environment determine to a large extent the optimization, minimization and maximization of resources to meet the needs of the plant. The expression of the plant is the resultant effect of the medium in which it is growing. How do you prove this at least physiologically? So that it can help us to manage food security, minimize environmental impact, restore environmental integrity, and preserve or conserve biodiversity.

The Soil Medium

Composition of the soil in Fig 4 corresponds to the solid, liquid and gaseous phases with the last two ever changing. The parent material of any soil originates from the lithospheric composition from which the nutrient elements are derived.

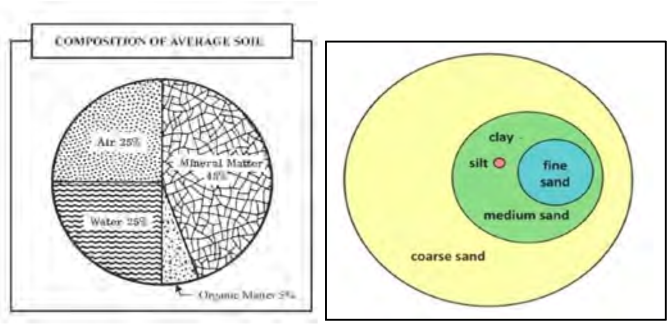


Fig. 4. (a)Soil composition((Source: http://myimsservices.com/docs/Soil%20Properties%20-%20Topic_Notes[1].pdf)(b) Comparative size of sands, silt and clay in soil (Source: http://www.prescriptionsoilanalysis.com/).

The texture of the soil depends on the quantity of the size of the mineral particles (such as clay, silt, and sand – fine, medium and coarse) and which has consequences on the pore size thus affecting aeration, capillarity (such as the water-holding capacity, and drainage). Organic matter (OM) content (which include living and dead residues of plant and animals at different stages of decomposition by microorganisms which finally form humus) is located at the upper soil surface. The amount of OM varies with climatic conditions and drainage, less OM are predominant in dry soils of warm climate than in wet soils of cool climate and gives colour to the soil (http://www.ext.colostate.edu/mg/gardennotes/214.pdf).

Water exists according to the forces that affect its bulk displacement. Water in the soil macropores, subject to the force of gravity pulls water down the soil profile. Such percolation drains the soil in 2-3 days without which the filled-up pores deprive most upland plants of air. This is gravitational water and is not available to the plant and plant growth is usually poor (Nwosu 1984). Capillary water exists in the micropores held by capillary forces (adhesion and cohesion) as the true soil solution and available for absorption by the roots. Hygroscopic water is bound tenaciously to the colloidal soil particles and is not available for root absorption. The atmospheric air aerates the soil such that while nitrogen (N_2) has similar amount, oxygen (O_2) is less and carbon dioxide (CO_2) is more in the soil than that of the atmosphere. Other gases are oxides of nitrogen, ethylene, methane and other volatile organic compounds. The dynamics of O_2 and CO_2 concentration are controlled by respiration of microorganisms, roots and soil fauna, chemical reactions, and autotroph assimilation for CO_2 (Glinski and Stepniewski, 1986).

Different soil types exist. Soil is the orthodox growth medium for plants. Soil fertility involves three aspects – chemical (i.e. richness of nutrient elements), biological (i.e. bacteria, fungi, protozoa, insects, worms) and structural (i.e. soil constituents that confer tilth). It is the ability of a soil to support plant growth and development. Summary of the roles of various nutrient elements (Table 2) mined by the roots indicates that it is not just the quantity available to the plant that counts but the quality also.

Table 2. Functions and Deficiency Symptoms of Macronutrients (Hopkins and Huner (2008)

S/ N	Nutrient Element	Functions	Deficiency Symptoms
1	Nitrogen **(N)** *Absorbed as* NO_3^- Mobile and redistributed	Present in all cells and needed for protein and chlorophyll formation. Many other organic compounds such as coenzymes, amino acids, nucleic acids contain nitrogen. They are used by the plants for chemical defenses.	Stunting, chlorosis, slow maturity, abscission, and thin stems.

2	Phosphorus **(P)** *Absorbed from the soil medium as the monovalent* H_2PO_4 *and divalent* HPO_4^{2}*phosphate ion.* Mobile and redistributed	Involved in energy reactions and transfer. It is contained in molecules such as nucleic acids, sugar phosphates, nucleotides, phospholipids and certain enzymes. Important in cell division, reproduction, photosynthesis, carbohydrate (sugar and starch) synthesis and transport.	Stunting, necrotic spots, dark green or purple green in some crops. Distorted fruit shape and poor seed development.
3	Potassium **(K)** *Absorbed from the soil medium as* K^+ Mobile and redistributed	A biologically versatile cation in living systems. Functions in carbohydrate metabolism and translocation, enzyme activity, protein synthesis and osmotic balance.	Growth retardation, yellowing of leaves, necrosis, disease susceptibility.
4	Calcium**(Ca)** *Absorbed from the soil medium as* Ca^+ Not mobile	The middle lamella which cements adjacent primary cell walls contains calcium pectate while calcium oxalate is found in vacuoles and the phosphatidic salts are found in membranes. Activation of amylase and ATPase enzymes.	Meristem death and deformed young leaves. Stunting, Chlorotic to necrotic leaf margins, rotted end of fruits.

5	Magnesium **(Mg)** *Absorbed from the soil medium as Mg^{2+}* Mobile and redistributed	As a chlorophyll constituent, Mg is important in photosynthesis. Also functions importantly in enzyme activities, phosphorylation and ribosome functions.	Interveinal chlorosis, stunting, shortened internodes, early abscission and lack of flowering.
6	Sulphur**(S)** *Absorbed from the soil medium as the SO^{2+}* Not mobile	Incorporated into cystine, cysteine and methionine amino acids; also in biotin, thiamine and coenzyme A. Protein structure is maintained by disulphide bridges (-S-S-) while sulphydryl groups (-SH) have an important role in determining the active centre of enzyme.	Chlorosis – uniform yellowing of leaves, low protein in plants, low yields. Decreased oil content in oil-producing crops

4.0 ENVIRONMENTAL CHANGE AND THE SOIL MEDIUM

Box 2: Key Indicators of Environmental Change

KEY INDICATORS

1. CLIMATE CHANGE – CO_2 and greenhouse gas emission intensitie
2. OZONE LAYER - ozone depleting substances
3. AIR QUALITY – SO_x and NO_x emission intensities
4. WASTE GENERATION – municipal waste generation intensities
5. FRESHWATER QUALITY – waste water treatment connection rate
6. FRESHWATER RESOURCES – intensity of use of water resources
7. FOREST RESOURCES – intensity of use of forest resources
8. FISH RESOURCES – intensity of use of fish resources
9. ENERGY RESOURCES – intensity of energy use
10. BIODIVERSITY – threatened species

The Organization for Economic Development and Cooperation (OECD) in 2008 enumerated the key global environmental indicators and their associated indicators (Box 2). The first five indicators dealt with pollution issues while the rest are natural resources of concern. The soil medium is one factor binding all the indicators; hence the soil ultimately is the impact receptor. Many environmental changes create extremes of environmental parameters that impose stressful conditions in plants. Franklin D. Roosevelt, the 32nd President of the United States said '*A nation that destroys its soils destroys itself. Forests are the lungs of our land, purifying the air and giving fresh strength to our people*'.

Vice Chancellor, Sir, in this lecture, an overview of approaches will be discussed and some specific studies will be described. Questions in our minds will address: presence and magnitude of environmental changes, the cause of the environmental changes and, whether the environmental changes are greater than natural variability. Water stress is among the disruptions in the dynamics of the soil that affect plant growth. When there is no water, drought ensues posing a great risk to plant growth. There will also be a limitation to the introduction of new crops into such soils. Food security may then be hampered. Reduction on the impact of drought is minimized more by soils with large available water capacity than in those that have less. One of the properties of the soil medium is the capacity to store and gradually release moisture slowly to the plants.

5.0 THE PHYSIOLOGICAL INDICATORS

There are two basic ways of resisting or dealing with stress if the plant is not susceptible to it. They are avoidance and tolerance mechanisms (Fig 5). By avoidance, the plants develop a kind of escape mechanism from stress. This mechanism shields the plant from experiencing the adverse presence of the stress in the environment, thus, the impact of the stress on the plant is reduced. Mechanisms of tolerance enable the plant to develop the capability to overcome the adversity, even when the stressful impacts have changed the physiological conditions within the plant (or cell). Consequently, the plant functions normally despite the presence of the stress internally and externally. For example, a 12-day-old cassava plants placed under water stress of -4.0MPa resulted to a water potential of -2.57MPa within the tissues after 7 days. This is an index of adversity given the fact that under normal conditions, the tissue-water potential is -0.84MPa. Thus, if the cassava plants function normally under such dehydrating conditions, the plants are tolerant to water deficit.

Therefore, focusing on the study of plants physiology, development and survival, helps to explain their geographic distribution (why some plants are found in certain areas and not in others), ability to provide information for breeding of cultivars that can resist stress and their performance along environmental gradients (due to climate change).

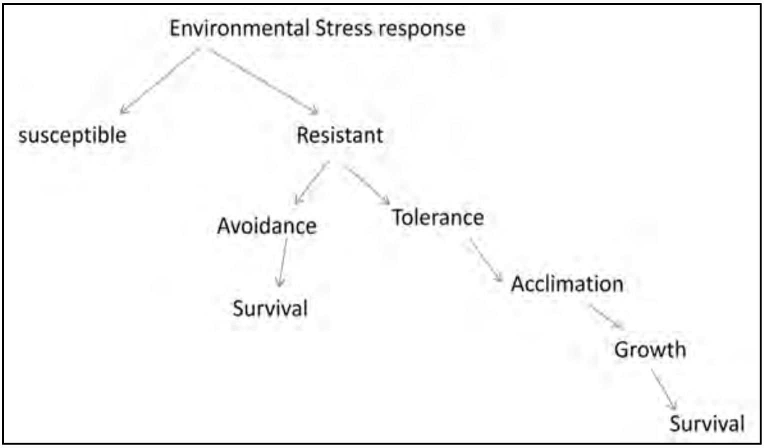


Fig. 5: Environmental responses by plants (*source: Hopkins W.G., Hüner N.P.A., 2008*). Redrawn.

Importance of physiological processes as indicators of environmental change is based on the following (Dixit, Kingston and Charles, 1992):

- ✓ They have effects on integrity of species
- ✓ They are the drivers of primary productivity and logically secondary and tertiary productivity in ecosystems.
- ✓ They are used for monitoring. The sensitivity of physiological functions and rapidity in response to environmental change make them amenable as reliable and effective indicators.
- ✓ Trends and changes in functions depict or reveal the status of environment or gradients. Physiological processes therefore have narrow optima and tolerances for many environmental variables which make them exceptionally useful in quantifying environmental characteristics to a high degree of certainty. These can be used to develop a proxy tool of simpler parameters.

- ✓ They create a good model of sustainability because they have a fine balance sheet of input and output based on a framework of structure and function.
- ✓ They produce toxic compounds with extreme stress as indicators of environmental stresses.

Our studies revealed that the first physiological change in plants is growth. Everyone notices the phenomena of growth in all living things. We define growth as irreversible increase in the size, weight, or area of the plant. It is the easiest indicator. Beginning from seed germination to the subsequent growth, development and ultimate yield of the plant, the reports are consistent with the following pattern: (a.) Sigmoid trends: under normal conditions, plant growth curves are sigmoidal. Deviations from the norm are instigated by environmental variables such as water deficits, temperature extremes, and salinity changes. (b.) Plant Productivity: is an index of control of the regime of environmental stress. One key indicator in our clime is the increase in the cyanide content of cassava. In our work with water stress and crude oil pollution, cassava leaves and tubers had higher cyanide. Reports of Nwosu and Onofeghara (1994); Akonye and Osuagwu, (1998), Akonye**,** (2000), Akonye and Owhonda (2006) attest to cyanide (HCN) increase in cassava as the environmental changes became greater than the natural variability. Cassava products, such as garri, fufu, tapioca, cassava flour, are consumed on a daily basis and it is quite safe because of the processing it undergoes to rid it of the cyanide which exists mostly as the bound glycoside (Conn and Butler, 1969). Moreover, only individuals with iodine deficiencies suffer cyanide toxicity especially when food is in short supply and in areas with high or constant social unrests, instability and war (Nicolau, 2016), which reduce the processing time. The periods when people desire to 'make quick money', reduction in processing time can also lead to high amounts of cyanide in the cassava products.

Cyanide is a powerful, quick-acting, poisonous toxic gas that induces asphyxiation when inhaled. It induces its effects in the pulmonary system (Polton, 1983). During respiration, cytochrome c oxidase (found in the mitochondria of mammals - humans and other warm-blooded animals) is inhibited by cyanide (CN^-). This thus disrupts the normal manner of oxygen absorption by the tissues from the blood. It is for this reason that plants (Table 3) that contain cyanogenic glucosides are considered dangerous for human consumption in their raw forms. Other inhibitors of cytochrome c oxidase are carbon monoxide (forms carboxyhaemoglobin in the red blood cell) and azide (N_3^-).

Table 2. Examples of plants containing cyanogenic glycosides

Glycoside	Sugar	Aglycone	Occurrence
Linamarin	D-Glucose	α-Hydroxyisobutyronitrile (acetone cyanohydrin)	*Linum usitatissimum*, *Phaseolus lunatus*, *Trifolium repens*, *Lotus* sp.
Lotaustralin	D-Glucose	α-Hydroxy-α-methyl butyronitrile (methyl ethyl ketone cyanohydrin)	(See linamarin)
Acacipetalin	D-Glucose	β-Dimethyl-α-hydroxyacrylonitrile	*Acacia* sp. (South African)
Prunasin	D-Glucose	D-Mandelonitrile	*Prunus* sp., many Rosaceae, *Eucalyptus* sp.
Sambunigrin	D-Glucose	L-Mandelonitrile	*Sambucus nigra*, *Acacia* sp. (Australian)
Amygdalin	Gentiobiose	D-Mandelonitrile	*Prunus* sp.
Vicianin	Vicianose	D-Mandelonitrile	*Vicia angustifolia* and other *Vicia*
Dhurrin	D-Glucose	L-*p*-Hydroxymandelonitrile	*Sorghum* sp.
Taxiphyllin	D-Glucose	D-*p*-Hydroxymandelonitrile	*Taxus* sp.
Zierin	D-Glucose	*m*-Hydroxymandelonitrile	*Zieria laevigata*
Gynocardin	D-Glucose	Gynocardinonitrile	*Gynocardia odorata*, *Pangium edule*

Source: Beevers (1976)

Cassava tubers may be sweet or bitter and so the range of cyanogens is wide, about 15-400 mg/kg (Nartey, 1978). We need to screen some of the elite cassava varieties before they are introduced, but the bottleneck is the technique that will detect HCN in very small samples is complicated and sophisticated. However, the picrate test (Harborne, 1972) is a general available field method while the linamarase-based test (Nambisan and Sunderasan, 1984) is more sensitive for such studies. The HCN in cassava exists as the glycoside, linamarin and lautostralin (Fig. 6) with valine and isoleucine amino acids as their precursors respectively (Butler and Conn, 1964). Linamarin occurs 90% of the total glycoside in cassava. The HCN is liberated from the bound form as linamarin, as glucosidic cyanide by the enzyme, the linamarase enzyme. It is imperative to devise assay tools that are sensitive and low-cost which ensure that safe products are delivered to the consumers especially when processing bitter varieties.

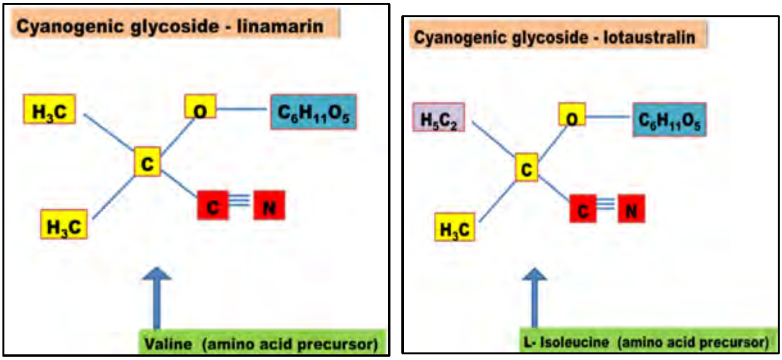


Fig. 6: Cyanogenic glycoside: (a.) Linamarin with the precursor valine, (b.) Lotaustralin with the precursor L-isoleucine.

The linamarin, when acted upon by the linamarase enzyme yields acetone, D-glucose and HCN. While the lautostralin, when acted upon by the same enzyme, yields 2-butanone, D-glucose and HCN (Fig. 7).

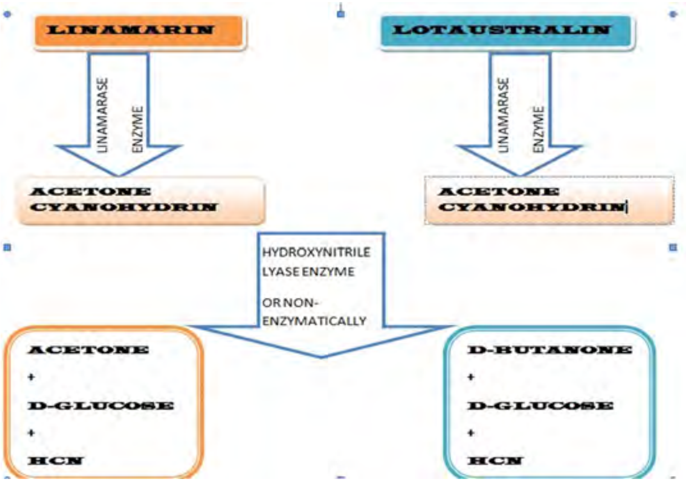


Fig. 7: Sequence of breakdown of cassava cyanogens.

From our study, we found that one reason for the adverse effect on the toxicity of cassava may be the linamarase enzyme involved in the cyanide metabolism. The linamarase enzyme activities cassava varieties (Table 3) also gave progressive decline as water stress dehydrated the plants.

Treatment	Local variety			TMS 50395		
	During stress	Rewatering for 7 days	Rewatering for 14 days	During stress	Rewatering for 7 days	Rewatering for 14 days
Control	0.066±.009	0.087±.003	0.084±.004	0.129±.025	0.121±.000	0.124±.011
Mild stress	0.071±.003	0.070±.007	0.083±.004	0.132±.022	0.123±.006	0.082±.008
Moderate stress	0.065±.003	0.086±.006	0.080±.001	0.113±.006	0.049±.010	0.066±.016
Severe stress	0.049±.005	0.062±.006	0.061±.008	0.083±.008	0.037±.001	0.035±.005
Very severe stress	0.039±.006	0.054±.001	0.053±.005	0.051±.003	0.075±.005	0.045±.007

Table 3: Changes in specific activity of cassava linamarase (mole HCN/mg protein/min) at various water stress levels and during re-watering.

Occurrence of water stress in the natural environment can severely increase the quantity of cyanide, whether in the glucosidic or in the free form (Figs. 8 and 9). This ultimately leads to higher toxicity of cassava varieties grown in such environments. Nwosu and Onofeghara (1994) found that water stress caused 66.7% increase of the total cyanide levels in the local cassava variety while one of the Tropical Manihot Series (TMS 5039) had 83.3%. This is so considerably high that even when the stressed plants were returned to normal relative water content (RWC) or rehydrated, the persistence in magnitude and trend was still maintained. More importantly glucosidic components were ca. 50% of the total. That stressed plants continued to accumulate significantly more cyanide than plants stressed at lower water deficits, this indicated that the metabolic machinery of the plants have been adversely affected.

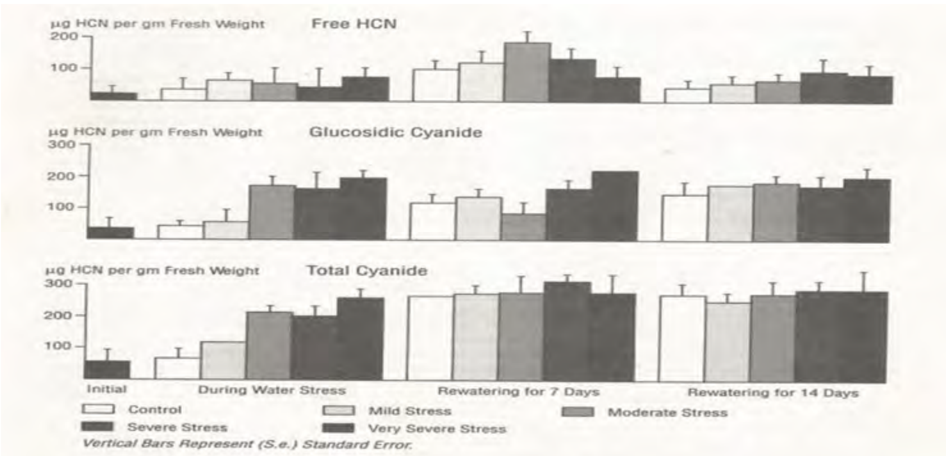


Fig. 8: Cyanide Potential of Local Cassava during water stress- Nwosu and Onofeghara (1994).

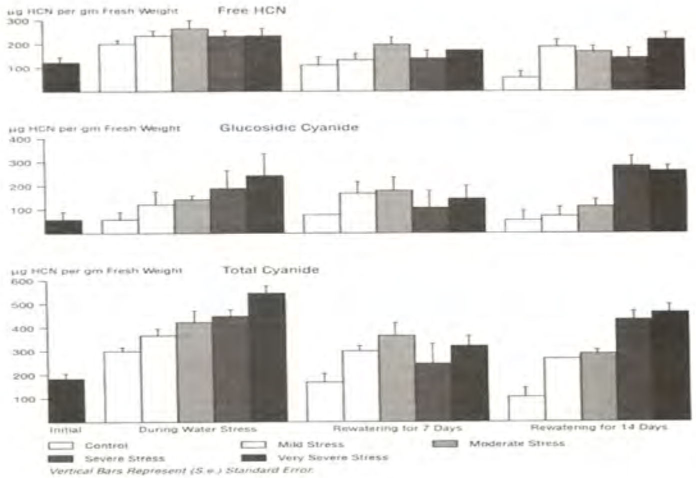


Fig 9. Cyanide Potential of TMS 50395 Cassava during water stress - Nwosu and Onofeghara (1994)

Different varieties differed in their intensity in cyanide accumulation. We showed that the ‘tolerant TMS 30572 maintained a consistent level of cyanide. Even field trials corroborated the laboratory findings as reported by Akonye and Osuagwu (1998). In addition, different varieties, such as TMS 30572, TMS 4(2)1425, Local, TMS 50207, at different stages of growth (young, tuberization and maturity stages) exhibited remarkable cyanide potentials (Table 4).

Table 4. Cyanide potential of irrigated and non-irrigated 4 cassava varieties

Sample	Cassava varieties	IRRIGATED TREATMENT				NON-IRRIGATED REATMENTS			
		FC	CG	CH	TC	FC	CG	CH	TC
Leaf	TMS 4(2)1425	3. 64±0.17	1.10±0.16	1.84±0.21	6.57±0.16	4.83±0.28	2.96±0.5	1.70±0.19	9.59±0.51
	TMS 305572	4.43±0.13	0.65±0.09	1.01±0.48	6.09±0.11	3.87±0.03	1.03±0.16	2.84±0.07	7.73±0.04
	TMS 50207	7.68±0.19	1.60±0.53	0.83±0.19	10.14±0.54	5.30±0.26	0.99±0.18	6.93±0.90	12.22±0.65
	Local	7.63±0.80	18.14±0.35	6.29±0.36	32.17±0.11	18.78±0.35	9.48±0.68	3.83±1.14	32.06±1.29
Root	TMS 4(2)1425	0.40 ±0.07	0.12±0.02	0.30±0.12	0.82±0.07	0.84±0.04	0.72±0.00	0.27±0.04	1.83±0.16
	TMS 305572	0.6 ±0.01	0.25±0.05	0.18±0.05	1.02±0.05	0.45±0.01	0.06±0.05	0.11±0.01	0.82±0.07
	TMS 50207	0.72±0.01	0.47±0.07	0.26±0.05	1.45±0.03	1.35±0.02	0.16±0.05	0.31±0.05	1.84±0.16
	Local	0.99±0.02	0.12±0.07	0.20±0.05	1.11±0.04	1.00±0.07	0.14±0.01	0.14±0.01	1.28±0.05

Table 5 Cyanogenic potential (mg/g dry wt) of irrigated and non-irrigated cassava varieties at maturity stage

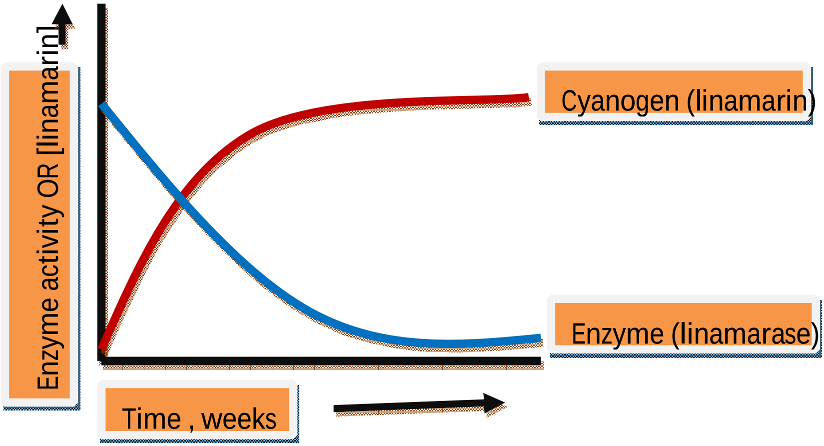
Sample	Cassava varieties	IRRIGATED TREATMENT				NON-IRRIGATED REATMENTS			
		FC	CG	CH	TC	FC	CG	CH	TC
Leaf	TMS 4(2)1425	2. 96±0.03	1.49±0.02	1.49±0.02	5.92±0.06	4.41±0.07	2.21±0.5	1.24±0.02	8.10±0.06
	TMS 305572	4.43±0.13	0.65±0.09	1.01±0.48	6.09±0.11	3.87±0.03	1.03±0.16	2.84±0.07	7.73±0.04
	TMS 50207	6.72±0.06	0.68±0.01	0.95±0. 05	8.34±0.02	3.83±0.11	1.96±0.28	1.45±0.05	7.23±0.22
	Local	4.12±0.11	2.54±0.01	2.59±0.01	8.03±0.03	10.20±0.02	2.55±0.01	2.551±0.01	15.30±0.03
Root	TMS 4(2)1425	0.27 ±0.01	0.12±0.02	0.28±0.01	0.67±0.01	0.59±0.01	0.30±0.01	0.14±0.01	1.03±0.02
	TMS 305572	0.41 ±0.01	0.18±0.01	0.13±0.02	0.72±0.02	0.29±0.01	0.14±0.00	0.14±0.01	0.57±0.00
	TMS 50207	0.44±0.001	0.13±0.00	0.11±0.01	0.68±0.01	0.59±0.01	0.29±0.03	0.24±0.03	1.57±0.07
	Local	0.69±0.02	0.14±0.01	0.16±0.02	0.99±0.01	1.60±0.07	0.15±0.01	0.15±0.01	1.14±0.01

FC = Free HCN; CG = Cynoglucoside; CH = Cyanohydrin; TC = Total Cyanide

Classification of cassava into bitter and sweet is dependent on the root content, not the leaf content. Generally, the leaves have higher cyanide contents than the roots. Of all the varieties tested, the sweet cassava variety accumulated the greatest amount in the leaves than in the roots. The root of the sweet cassava restrictively controlled how much cyanide sunk into it from the leaves. Cassava plants have the inherent deposition of cyanide in its underground storage organ.

The relationship between these two phenomena was attributed to cause and effect (Fig 10). Since glucosidic cyanide is a substrate of linamarase, it is obvious that suppression of the enzyme during dehydration led to the accumulation of the cyanogens. Upon alleviation of the environmental stress, the retardation in the enzyme activity persisted which continued to cause the lofty cyanide accumulation. Thus, the enzyme inhibition could contribute to or cause a higher cyanide concentration under stress. The implications of these findings relate to the fact that severe stresses raise the toxic level of cassava and consequently its products. Instigation of water stress could be caused by physiological drought, flooding, excess application of fertilizers, herbicides, and pollution.

The ISTRC award certificate was based on this research. It appeared in the IFS news.



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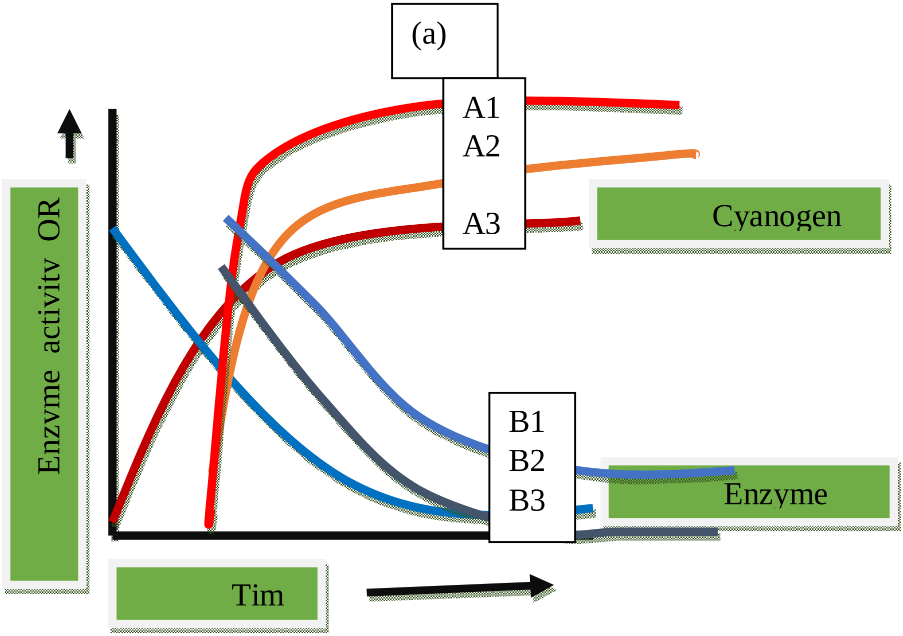

Fig. 10: (a)The relationship between the enzyme activity and linamarin accumulation

(b) Highlights between DIFFERENT Cassava VARIETIES in the relationships between the enzyme activity and linamarin accumulation

With larger proportion of bound cyanide, accompanied by suppressed linamarase activity, detoxification methods need to be more rigorous for roots / tubers from cassava plants that have experienced prolonged dry spells, a common situation in the tropics. Critical preparation steps that enhance detoxification of cyanides are soaking, drying, frying, grating, and cooking. We recommend that food safety regulators such as National Agency for Food and Drug Administration and Control) (NAFDAC) need to emphasize and reemphasize on these issues to ingrain the safety concerns of the Nigerian community and the world at large. There is need to upgrade the value we build around the products of cassava.

We also found that different cassava varieties exhibited different linamarase activities. For instance, the elite variety (TMS 50395) resulted to a lower level of glucosidic cyanide than that of the local variety in which the level of enzyme retardation reflected in a higher proportion of the bound cyanide than the free HCN. It is imperative to breed varieties that have low cyanogens with higher linamarase activity (Fig 10). Variety A1B3 will be at the extreme of toxicity while variety A3B1 will possess the lowest cyanogens and in addition, the detoxification process will be faster.

Oil pollution is a common phenomenon in the oil producing regions in Nigeria. For instance, in Rivers State (Fig 11), Akonye and Owhonda (2006) showed that there is a relationship between the impact history of different sites and the cyanide concentration of the tubers depending on the residence time of the crude oil pollutant.

Fig 11. Maps of (a)Nigeria and (b)Rivers State showing sampling locations (Source: http://www.maplandia.com/nigeria/rivers/obioakp/portharcourt/http://www.nigeriagalleria.com/Nigeria/States_Nigeria/Rivers/Rivers_Sta te.html)

a b

The sites were chosen according to the previous occurrence (i.e. the history) of oil pollution. They were Umuechem (18 months), Khana I (5 years), Khana II (8 years) and Eleme (10 years). The relationship between cyanide concentration and the residence time of crude oil pollutant in the soil where the cassava was grown showed that high cyanide concentration was recorded in sites with recent pollution and *vice versa*. Cassava plants grown at a control site where there had not been oil pollution, located at Rumueme (OBALGA) gave low cyanide content. The alteration in the soil quality (Fig 12) due to oil pollution was observed to be more reduced in conductivity and nitrate than pH, and total organic matter, while the total hydrocarbon elevated the cyanide accumulation, a condition that calls for caution in crude oil spillage in agrarian communities.

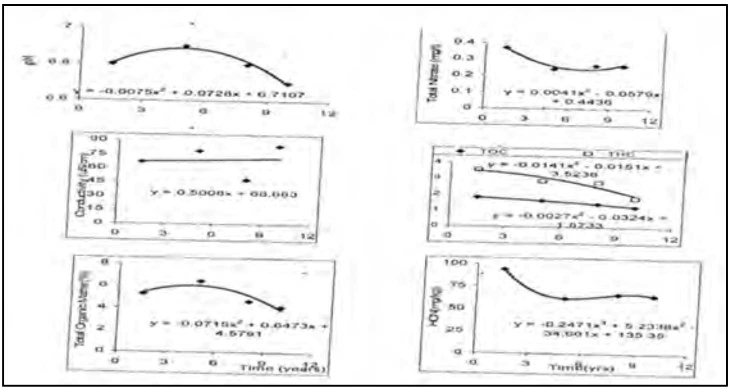

Fig 12. Physicochemical parameters of the soils indicating the cumulative trends over the years.

The International Institute for Tropical Agriculture (IITA) reported the pattern of adoption and diffusion of cassava varieties (Bentley *et al*, 2017) in four regions in Nigeria (Table 5). Although Rivers and Bayelsa were excluded from that survey, the report showed that farmers favoured processing traits such as season and age, while the preferred agronomic traits were high yielding, with many big roots, early maturing, durable (i.e. stay well underground, for at least two years), tolerate poor soils, are cattle resistant, not watery, and drought-resistant (especially in the Northern parts of Nigeria).

Table 5. Trait preferences by women and men in Nigeria (Source: http://www.iita.org/wp-content/uploads/2017/Cassava_farmers_preferences_monograph.pdf

Community	Women	Men
Southwest	Easy to peel Processing High yielding Early maturing	High yielding Early maturing Storable underground Controls weeds Ready market
North	Easy to peel High yielding Nontoxic Storable underground Processing	Early maturing Insect resistant High yielding Access to market
South-south	Easy to peel High yielding Stays well underground Processing	High yielding Stays well underground Tolerates poor soils Early maturing
Southeast	Early maturing Easy to peel Storable underground Big roots (high yielding)	Fast maturing High yielding Less starch Drought resistant

Overall there is need to upgrade the value we build around the products of cassava. This will involve the choice of cassava variety, the agricultural practices, the degree of rigour placed into the processing methods and the determination of final products by the end-users. The raw unprocessed cassava (fresh or dry) is consumed by ruminants; the semi –processed *tapioca* is eaten as snacks, and the completely processed *garri* and flour is eaten as *eba* or *fufu* or further used for bakery.

Tolerance and Adaptation

Assimilate partitioning (Fig13) during growth serves two purposes. According to Nwosu and Onofeghara (1991), one way is to overcome the environmental stress through osmotic adjustment by the production of compatible solutes such as sucrose as is the case with cassava. In other crops, other compatible solutes such as proline, betain and many other quartenary ammonium compounds (QACs) are produced as osmoprotectants and have been shown to detoxify reactive oxygen species, stabilize enzymes/proteins and protect membrane integrity (Gill and Tuteja, 2010). Our results clearly open the possibility of genetically engineering (i.e. overexpressing the genes for the key enzymes which allow synthesis of required compatible solutes) cassava plants with concomitant improved stress tolerance.

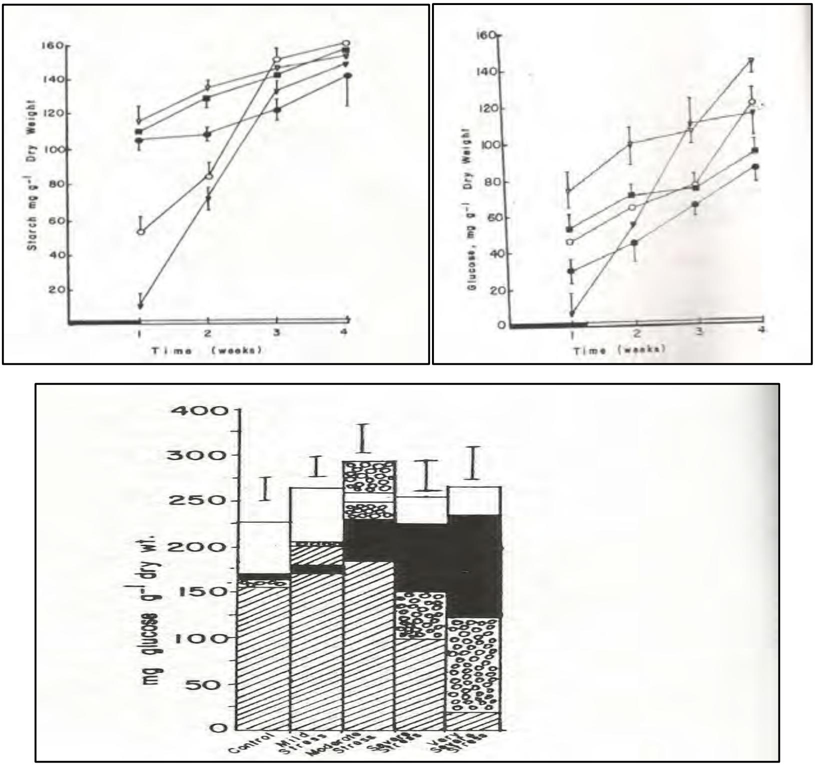

Fig. 13: Carbohydrate content of TMS 30572 (a) starch content of cassava variety 30572 during water stress and influence of the various water stress levels on rehydration, (b) Soluble sugar concentrations of cassava variety 30572 during water stress and influence of influence of the various water stress levels on rehydration, and (c) Total carbohydrate of cassava variety 30572

under water stress and after rehydration for one week, 2weeks and 3 weeks.

The other is to manage the sink and source relationship. In the first case we found that the increased soluble sugar fractions were used for osmotic adjustments necessary for the seedling survival under water stress. Varietal factors indicated sensitivity responses. Some breeding programs have redesigned the source-sink capacities of some crops by reducing the sink strength of non-harvestable portions of crops and thus directed the photoassimilate to the economic and consumable part. For instance, breeding dwarf varieties of cereals with large economic yield has reduced photoassimilate demand by stems with a consequent increase in floret numbers set and grain size (Patrick, Wardlaw and Offler, 2016).

GROWTH AND PRODUCTIVITY

When a seed is planted, it germinates and the root or the radical is the first organ to emerge from the seed. Although the manner of seedling emergence may be epigeal or hypogeal, it germinates and grows into a plant which in turn passes through many stages from seedling to juvenile form to a mature plant. At this point, the plant begins to produce flowers to enable fertilization to produce seed. Thereafter, senescence may set in depending on the life cycle (annual, biennial, or perennial nature. The outward manifestation that interests man could be anything from seed to shoots, flowers or root because these mediate his economic transformation apart from his immediate satiation.

In the environment, the soil profile within which the seed germinates is associated with varying temperature amplitudes due to varied insolation, soil structure and season, hence the extent to which the the seed coat interacts with the environment external to it becomes pertinent (Ellis, Cowell, Roberto and Summerfield, 1986). Seed coats regulated thermal time accumulated in *Sphenostylis* *stenocarpa* (Akonye and Ohiri, 1999a) and we were able to develop equations for the prediction of median germination percentage following differences in seed coat constitution.

$$\text{For alba } Ct_{50} = \frac{1 - Y_b}{330 - 0.3(\text{duration})}\ \text{hr}; \quad \text{For magnum, } Ct_{50} = \frac{(1 - Y_r)}{1820 - 46.38(\text{duration})}\ \text{hr}$$

Long thermal durations lowered radicle elongation rates, the degree of temperature notwithstanding the waxy seed coats adapted better it served to prevent solute leakage during imbibitions even at varying water potentials (Akonye and Ohiri, 1999b). Fecundity rates are dependent on seedling establishment and the main reason why there is biodiversity loss may not be unconnected to poor adaptation to climate change.

Growth is an intrinsic process in every living thing. Many of us will remember MR NIGER-D in our first Biology lessons back in secondary school in the seventies. There are other characteristics of living things. Physiologically growth is defined as an irreversible increase in size and the measurement of size taken at different dimensions (Akonye and Nwauzoma, 2003). That notwithstanding, it is irreversible. When there is no more growth, the size of the plant remains constant over time. It is only growth quantification in terms of rate that will reveal the kinetics of growth at any time. Growth usually follows a sigmoid curve, the phases of which are lag, log or exponential, the declining and stationary phases (Fig 14). The log phase is very important in determining the productivity of the plant and it follows a compound interest law, in which there is a continuous reinvestment of the dry matter (photosynthates) with time into the initial dry matter which increases as time increases the output per unit input. This depends in part, on the material acquisition by the roots, and then the rate of photosynthesis. Competition is focused on the acquisition of these resources with other plants growing in the same vicinity. However, as the plant continues growth, changes take place in what is described as development. Developmental growth can be likened to diversification in business. This is what the plant does on hitting the critical mass after expansion. The upper arm of the sigmoid growth reflects the extent of the environmental resistance and is proportionately related to the size of the plant, the dry matter acquired (Nwosu and Onofeghara, 1989). This represents the productivity or yield of the plant for which most researches are geared. Productivity can be increased through technological inputs which can be adapted to suit our farmers especially in the area of cost because of most farmers' unwillingness to integrate new ways into farming (Offor and Akonye, 2006; Offor, Akonye and Agbagwa, 2009). One of the cost effective measures is the application of leaf extracts to crops. Using the leaf extracts of *Senna alata*, (Agbagwa, Onofeghara and Akonye, 2002) there was an overall promotory effect on many growth indices (height, leaf area and dry weight). Plant growth is economical in resource acquisition, management, and accumulation of metabolites.

Many simulation studies take into account growth duration, rate and environmental resistance. Therefore, analyses of plant growth that decompose into the contributions of source, partitioning and accumulation fall into these categories.

- Physiological and metabolic organization,
- Investing in plants for high productivity,
- Assessment of plants for productivity,
- Augmentation (especially with fertilizers) for productivity, and
- Amenability to technology application.

  Growth performance assessments are baseline data to provide future modeling of plants for cultivation in different environments. Generally, crops with longer durations of growth yield better than short duration crops and there are examples.

Some results however, showed that many indices of physiological integrity were affected, and culminated in less growth and development, and inevitably poor yield (Nwosu, 1992; Nwosu and Onofeghara, 1989, 1991). Such notable parameters are: pigment quantities (Fig 15), ATPase, chloroplast metabolism, and mitochondrial metabolism (MDH, SDH GDH dehydrogenases).

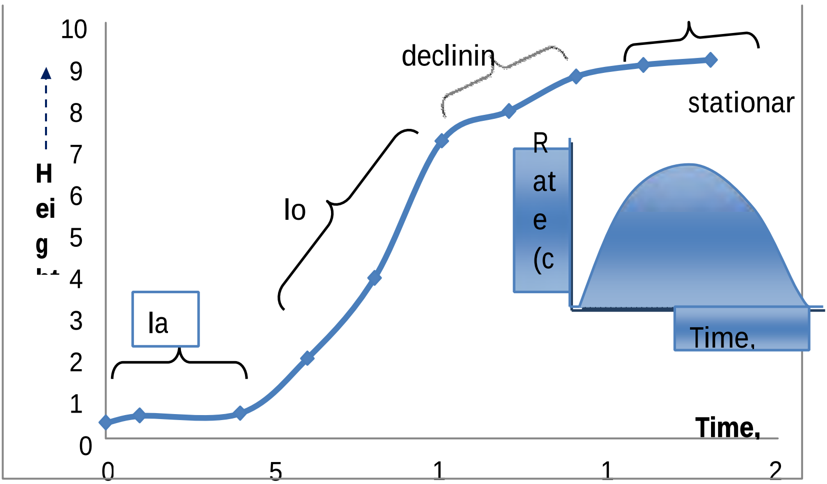

Fig. 14: Pattern of growth of *Capsicum frutescens* (chilli pepper) watered at a regime of twice in 3 days. Inset: An idealized growth rate.

Screening protocols during breeding need to take cognizance of duration and intensity of stress as this has caused unwarranted production of varieties that are not suitable to some environments. Sometimes the plants may show **elastic** or **plastic** responses depending on the extent of stress

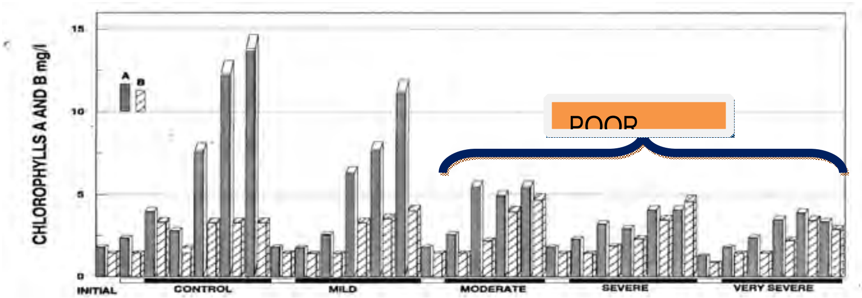

Fig 15. Accumulation of Chlorophylls a and b in water stressed cassava

THE RHIZOSPHERE

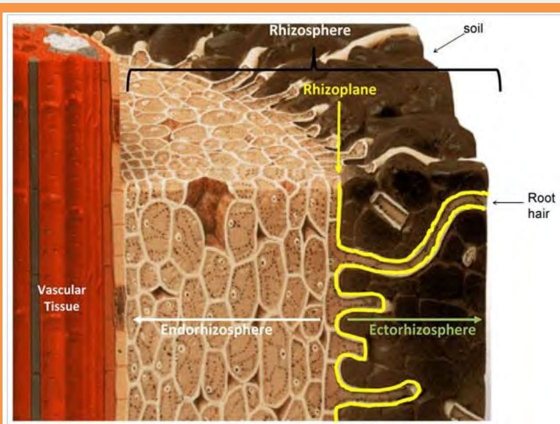

Fig.16:Different Rhizosphere zones

https://www.nature.com/scitable/knowledge/library/the-rhizosphere-roots-soil-and-

At the soil-root interface is the rhizosphere- this is the atmosphere around the root where it has influence. The term was first used by Lorenz Hitner in 1904 comprising of 3 three zones namely: endorhizosphere, rhizoplane and ectorhizosphere as shown in Fig 16. It is characterized by the presence of biological components such as the microflora (bacteria, fungi, algae, soil viruses), protozoa, nematodes, worms, earthworms, millipedes, centipedes, insects, mites, snails, small animals which mineralize organic matter and fix nitrogen (symbiotic and assymbiotic). The presence of root exudates such as photoassimilates (carbohydrates, organic acids, phenolic compounds), sloughed cells of the root cap, nitrogen compounds, inorganic ions, and enzymes perform various functions (Lines-Kelly, 2005). These functions contribute to the soil respiration since they are substrates for the biological community that shapes a characteristic and distinct ecological setting imperative, vital and fundamental to root proliferation, elongation, and absorptive capacities. Other functions include but not limited to:

- Moisturization of the rhizosphere due to their hydrophilic properties
- Stimulation of growth of micorganisms vital to the optimum physiological performance of the plant with simultaneous inhibition and deterrent of pathogenic organisms
- Acquisition of nutrients and retention by chelation and formation of ligands with nutrient elements thus avoiding excessive ion absorption
- Secretion of allelopathic chemical that inhibit the growth, survival and proliferation of target surrounding plants which may otherwise be harmful to either the root or shoot or the entire plant.
- Maintenance of a differential of physicochemical properties (pH, EC, diffusion rates of gases especially O_2, CO_2, N_2, VOCs) in the micro-environment of the rhizosphere with that of the macro-environment in the soil.
- Protection of the piliferous layer with mucigel complex
- Improvement of the tilth property and soil aggregate stabilization for increased fertility of the surrounding soil.

SOILLESS GROWING MEDIA

Determination of nutrient elements necessary for plant growth by two German botanists Julius von Sachs and Wilhelm Knop in the years 1859-65 led to the discovery of hydroculture. This method, now called hydroponics has various advantages as it obviates the use of orthodox soil thus making it amenable to reuse the water in the system over and over again with the key focus being to control the nutrition of the plant. Yields are higher and stable as diseases and pests are eliminated resulting in healthier plants except for pathogens that thrive in humid conditions. However, different plants require different nutrient compositions without which plant mortality occurs. Use of nutrient solution alone could just be any of the following - static, continuous flow or aeroponics. Other variants are the nutrient film technique, intermittent sub-irrigation, root misting, and membrane systems (Berry and Knight, 1997). But the need for plant roots to attach to a substrate would involve inclusion of solids, usually inert. Thus, we can have sand culture, gravel culture, rockwool culture.

Media for hydroponics have many substrates viz clay pellets, glass wastes (growstones), coconut coir (coco peat), perlite, rice hulls, pumice, vermiculite, sand, gravel, wood fibre (from wood residues, sawdust, barks), sheep wool, rockwool, brick shards, peat moss (Spomer, Berry and Tibbitts, 1997). Different nutrient solutions have been compounded and they basically are composed of 17 essential elements for most plants. They are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine, and nickel (Salisbury and Ross, 1994). Only carbon and oxygen are obtained from the atmosphere while the growth medium provides the others. Some other elements are considered beneficial due mostly to the fact that they stimulate plant growth, modify, or compensate the toxicity of other elements. In some cases, they function in certain aspects where the specificity of essential nutrients is less obvious. They are sodium, silicon, vanadium, selenium, cobalt, aluminum, and iodine among others. The roles of the macronutrient elements have been presented in Table 1.

Formulation of nutrient solution is considered one of the most important determining factors of yield and quality which depends on the crop requirement. The challenges of maintaining appropriate pH as required by different plants, although the variations slightly differ and the maintenance of a dynamic stability of the electrical conductivity as the plant root absorbs the elements have proved to be more critical than temperature control. Oxygenation of the nutrient medium in a static set up requires constant aeration but positioning of seedling roots by avoiding complete immersion enables adequate root respiration for plant survival (Trejo-Telléz & Gómez Merino, 2012). Recirculation and reuse of nutrient solutions helps to reduce the environmental impact of dumping the effluents on soils with its attendant consequences of causing increased salinity of the surrounding soils. It is therefore imperative to apply the 3Rs (i.e. reduce, recycle, reuse) in environmental management in hydroponic effluent. This can be achieved by managing nutrients by mass balance in such a way that the elements that are quickly absorbed are replenished with the appropriate refill solutions. Based on the rapidity of absorption, essential nutrients are classified into 3 groups. While group 1 elements (N, P, K, Mn) are rapidly absorbed in a matter of hours, the rate of absorption by group 2 elements is moderate and those of group 3 are slowly absorbed, often accumulating in solution (Bugbee, 2004).

Ongoing research with *Telfairia occidentalis* (Plate 11) and *Oryza sativa* is geared towards integration and adoption of the hydroponic systems with replicable improvisations for good productivity by local farmers. To this end, the cost reduction is attractive when compared with open field agriculture. The versatility of hydroponic technology lends it the appropriateness for production in any given space. It has proven to be an efficient means of food production from village, backyard, garden to high-tech space stations.

Plate 11: Hydroponic cultivation of *T. occidentalis* (a.) mature pod, (b-c) Seedlings growing on soil medium, (d-h) seedlings growing in a hydroponics medium

Other advantages of hydroponics include but not limited to: employment generation, water conservation, energy generation, improvement in the quality of life and reduction in competing demands for land especially in urban areas. Hydroponic effluents (Plate 12) have proven to be useful in soils with low fertility as residual nutrients augment and supplement those lacking in the soil. The effluents can be applied to open field agriculture, in plantations, lawns and hedges for flourishing and productive vegetation.

Plate 12. Usefulness of hydroponic effluen

Hydroponic Industry constraints are many as captured by Carruthers (2002), but few of them stand out:

– Grower cooperation to ensure production volumes, adequate grading and market interest in industry output;
– A retreat from the amateurism that characterizes a new or emerging industry, that is, use of substandard equipment and a reluctance to invest/embrace a commercial scale of production;
– Promotion to shift public opinion away from an image of backyard marijuana production and a high chemical input or unnatural systems;
– Attention to a constantly shifting and evermore sophisticated market, including one that is starting to demand the low

chemical, sustainably produced product that is the industry's strength. Product branding may be one way of capturing this market;

- Industry education and training at a grass roots level of production is important. This might include education on climate control, crop environmental requirements, and IPM programs within greenhouses;
- Fulltime professional industry leadership to drive the industry from a strategic position, including formulation and resourcing of an industry strategic plan.

SOIL POLLUTION AND PHYTOREMEDIATION

The presence of man-made (xenobiotic) chemicals principally from industrial activities, acid precipitates, radioactive fallouts, agricultural chemicals in quantities higher than the normal range or out-of-place changes in the natural soil environment causes contamination or pollution of the soil. The resultant health risk and ecological imbalance are of great concerns. These hazards stem from the fact that they have the following undesirable properties:

- Persistence – they are non-biodegradable or at best very slowly degraded by environmental agents or metabolic activities,
- Bioaccumulate: they have the tendency to accumulate in biological systems,
- High lipophilicity and low hydrophobicity.

Oil pollution (from the petroleum industry) is the key environmental issue in the Niger Delta region of Nigeria, the theatre of oil exploration. The report from Amnesty International states thus '*Royal Dutch Shell and the Italian multinational oil giant ENI have admitted to more than 550 oil spills in the Niger Delta last year, according to an Amnesty International analysis of the companies'*

latest figures. By contrast, on average, there were only 10 spills a year across the whole of Europe between 1971 and 2011'. "These figures are seriously alarming. ENI has clearly lost control over its operations in the Niger Delta. And despite all its promises, Shell has made no progress on tackling oil spills," said Audrey Gaughran, Amnesty International's Global Issues Director. "In any other country, this would be a national emergency. In Nigeria it appears to be standard operating procedure for the oil industry. The human cost is horrific – people living with pollution every day of their lives."
https://www.amnesty.org/en/latest/news/2015/03/hundredsof-oil-spills-continue-to-blight-niger-delta/ (accessed Oct 2017). Shell reported 204 Niger Delta spills in 2014 while ENI, which operates in a smaller area, reported a staggering 349 spills (Fig. 17).

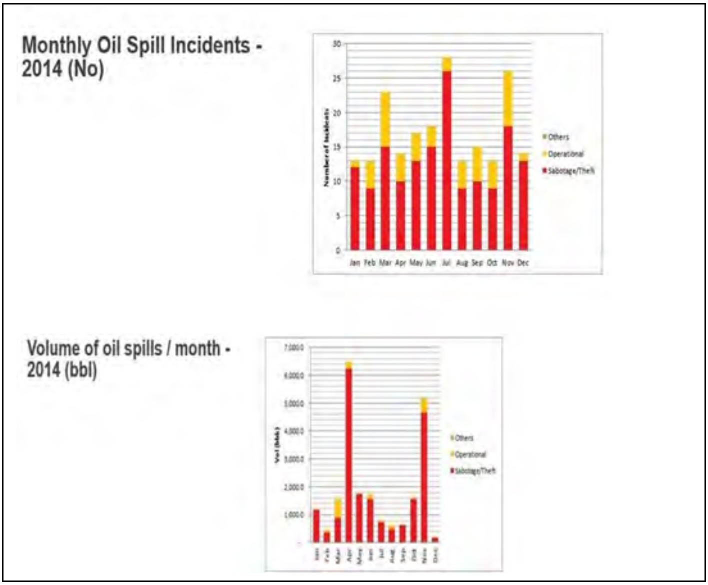

Fig 17. Oil spill (a)incidence (b) monthly spills by SPDC
(Source:http://www.shell.com.ng/sustainability/environment/oil-spills.html. accessed Oct 2017)

Oil pollution damage to plants (Fig. 18) ranges from depressing primary production at the ecosystem level (Kinako, 1981), to the individual plant involving tissue maceration and cellular injury (Amakiri and Onofeghara, 1983) and even causing genetic effects (El-Bakatoushi, 2011). Depletion (Chindah et al., 2008) of the large (5,000 to 8,580 km²) expanses of mangrove forests (Nwilo and Badejo, 2007) is a major concern. Increased toxicity of mangrove soils to *R. racemosa* increases the establishment of a non-native invasive species of palm, *Nypa fruticans*, which quickly colonizes the area. The *Nipa Palm Utilization Project* of the Nigerian Conservation Foundation, 1996. Retrieved May 21, 2007. Archived March 11, 2007, at the Wayback Machine. https://en.wikipedia.org/wiki/Environmental_issues_in_the_Niger_Delta

Fig 18. Effect of oil pollution on vegetation
(Source: UNEP)

Pollutants have been the target for remediation to restore the soil medium, water, or air to normal. A medium that is polluted requires clean-up. It could require a physical, or chemical or biological cleaning. Phytoremediation which is a form of bioremediation has emerged as an effective remedial measure in crude oil polluted soils.

Vice Chancellor, Sir, various plants have shown potentials for phytoremediation of crude oil and their degree of effectiveness is indicated in Table 6 below but this is dependent on the following factors:

- ✓ Type of plant species – root development was a critical factor with nodulated roots ranking higher than non-nodulated roots. Profuse branching is an added advantage given the rhizospheric activities generated.
- ✓ Concentration of pollutants – this determines the precedence of different types of cleaning. Highly concentrated amounts pollutants will require evacuation for treatment in a bioreactor before going ahead with phytoremediation.
- ✓ Amount and type of amendment – amendments are usually organic and the functions of organic matter in a soil will apply. It is apparent from the studies we have conducted that no particular amendment can suffice in satisfying all the conditions required detoxification of pollutant.
- ✓ Duration of pollutant in the soil – longer durations of volatile pollutants attrite easily while others decompose with microbial attacks following secretion of induced enzymes. Others however remain recalcitrant accumulating in the upper echelon of the food pyramid.
- ✓ Soil properties – physical properties of aeration, temperature, water-holding capacity improve the conditions necessary for biochemical reactions needed to degrade the pollutants

Table 6. Plants used for phytoremediation

S/N	Plant species	Reference
1.	*Vigna unguiculata*	Tanee and Akonye, 2008; Akonye and Onwudiwe, 2004); Offor and Akonye (2006)
2.	*Abelmoschus esculentus*	Akonye and Onwudiwe, 2004
3.	*Zea mays*	Akonye and Onwudiwe, 2004; Offor and Akonye (2006); Isirima, Ezekiel, Iyagba and Akonye (2010)
4.	*Manihot esculenta*	Akonye and Onwudiwe, 2004, Eremrena, and Akonye (2013); Habila, Akonye, Oruwari, Salako, and Olukanmi (2011).
5.	*Azonopus compressus*	Akonye and Onwudiwe, 2004; Ogbuehi and Akonye (2007)
6.	*Telfairia occidentalis*	Offor, Onwugbuta, Enyi and Akonye (2009)
7	*Arachis hypogea*	Akonye and Onwudiwe, 2004

DEGREE OF PARITY RESTORATION WITH AMENDMENTS

Some amendments have shown promise for increased degradation of crude oil during phytoremediation

- Sawdust - Akonye and Onwudiwe, 2004; Akonye and Onwudiwe, 2007
  - Improved aeration and soil respiration, soaked up the oil
- *Chromolaena odorata leaves*
  - Acted as a nutrient amendment due to its fast decomposition, increase organic matter of the soil
- *Centrosperma pubescens* - Eremrena, and Akonye (2013)
  - As with *Chromolaena sp*

- Rumen-based organic Mulch – (Isirima, Ezekiel Iyagba and Akonye (2010).
    - Provided microbial populations to the rhizosphere biology
- Bacterial consortium of *Pseudomonas* and *Bacillus*- Habila, Akonye, Oruwari, Salako, and Olukanmi, (2011).
    - Provided microbial populations to the rhizosphere biology
- *Calopogonium mucunoides* - Ogbuehi and Akonye (2007)
    - In addition to the functions of *Chromolaena sp,* it improves the C/N ratio
- NPK - Ogbuehi and Akonye (2007)
    - Provides nutrients for plants and bacteria, improves C/N ratio

Some amendments, using sawdust; *Chromolaena odorata leaves*; *Centrosperma pubescens* and NPK; Rumen-based organic Mulch (Isirima et al., 2010); and bacterial consortium (Habila et al., 2011), have shown promise for increased degradation of crude oil during phytoremediation.

LEVEL OF TOXICITY DECLINE IN PHYTOREMEDIATED SOILS

- LEAD – Akonye and Onwudiwe, 2007
- THC
- ZINC – Ogbuehi and Akonye, 2008a
- CHROMIUM - Ogbuehi and Akonye, 2008a
- Nitrogen Ogbuehi and Akonye, 2008b

	Table 7. Sustainable Development Goals (SDG) (UN SDG, 2015)
Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all at all ages
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5	Achieve gender equality and empower all women and girls
Goal 6	Ensure availability and sustainable management of water and sanitation for all
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

What we as a nation want as regards agriculture, is for agriculture to contribute significantly to Nigeria's GDP, and contribute to the goal 2 of the UN sustainable development goal as highlighted in Table 7. Productivity can be increased either by increasing the number of plants i.e. population of plants or by increasing the output of each plant. Hence physiologically, we can manage the environment where the plant is growing, taking into cognizance the light, temperature, soil, gases, water, pollutants, nutrients. This integrates how the plant abstracts the resources, the vicissitudes of stresses and increasing its performance within and with other plants. One has only to look at the subsistence agriculture to see the impact of lack of meeting point of indices of productivity efficiency. Therefore, government has to choose between using the teeming population which requires large land space (favourable in the North, because the competing need for land in the South is very high). Or government has the alternative to adopt technology to increase yield per plant. On our part as researchers, the recommend the Framework for African Agricultural Productivity as shown in Fig19.

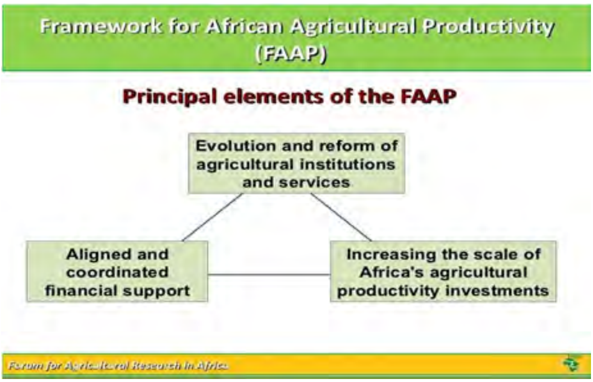

Fig 19. Paradigm for increased productivity
(Source: https://image.slidesharecdn.com/irene-111208142640-phpapp02/95/enhancing-capacity-forafrican-agricultural-research-conceptual-framework-models-and-lessons-11728.jpg?cb=1339507772) .

What works and what does not work in growth and subsequent yield patterns displayed by plants and crops has been the concern of plant scientists over the years. This has plunged us into the argument between conventional breeding of organism and genetically modified organisms (GMOs). The FAO defines GMOs as those organisms that have been modified by the application of recombinant DNA technology or genetic engineering, a technique used for altering a living organism's genetic material (http://www.fao.org/docrep/015/i2490e/i2490e04d.pdf). The arguments in favour of GMOs are that of increased food supply with consequent reduction and probably eradication of hunger in poor and developing countries since such crops are resistant or tolerant to diseases, pests and environmental stresses better than non-transgenic counterparts. Thus, the issue of climate change, competition for arable lands and the concomitant population growth is addressed. GMOs enhance the understanding of the biology and physiology of plants. Many crops such as cassava, tomato, banana, cotton, soybean, cotton, and coffee were genetically improved. The basis however, for objection to GMOs are that toxins and allergens may be introduced to food, which may result in a drastic alteration of nutritional components of crops, the preponderance of impinging on the biodiversity. Although Nigerians have called GMOs the 'Monsato Poison', the Biosafety Bill which was hurried passed should input stringent risk assessment and firm regulatory system orchestrated by the National Biosafety Management Agency. A note of explanation is that there is a difference between hybrids which are derived from conventional methods of breeding and selection, and it involves moving genetic materials from a related species into another related species – something closer to nature. For example, crossbreeding plantain with long fingers with those with high iron content just so that the hybrid will have both traits. GMOs however are derived by moving the genetic material of interest from an unrelated organism to a target species. For example, introducing genetic material from a bacterium into corn. The end game however, is prosperity for the individual that translates to the prosperity of the nation.

CONCLUDING REMARKS

The soil is the orthodox medium for plant growth. When polluted or rendered unusable by whatever means as orchestrated by various mechanisms, plant growth and yields suffers. The UNEP Report has shown the red flags of difficult and prolonged periods of soil restoration of polluted soil (UNEP 2011). The Ogoni clean-up exercise is just a beginning, however, there is need to clean up other impacted sites in the oil region, the industrial regions and the infested ammunition-riddled enclaves of the North-Eastern Nigeria by Boko Haram.

There are other media for plant growth (as shown in the exhibitions). These can be employed in what is known as Controlled Environment Agriculture (CEA), which implies that the environmental control that impinge on the plant can be maximized for increased productivity and minimize the unfavourable factors. In plant physiological studies, appropriate and adequate controls are superimposed on every treatment to interpret / bring out the truth of what goes on in the plant.

In the interim, I implore the government to seriously consider the flagrant distortion and abuse of the plant growth medium on which the ecological foundation stands – the soil. It is the nexus for driving and managing agricultural productivity, and hence prosperity.

Roots are rugged in their interaction with the growth medium for water absorption and sequestration of nutrients. Availability of water and nutrients determine the optimal functioning of the root for supply to the shoots and hence determine to a significant extent the manifestation in the shoot and indeed the whole plant. When the soil medium is polluted, the root absorption capacity is impaired leading to deficits in the shoot and hence improper functioning of the entire plant. Food production is of utmost importance. It is a goal that we must reach in tandem with the UN sustainable development goal.

I am rooted in Christ and built up in Him (Colosians 2:7). He is the offspring and root of Jesse (Isaiah 11:10) and we are the branches. Without Him, we can do nothing (John 15:5).

Thank again for listening.

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CITATION ON

PROFESSOR LOVE AKAJA AKONYE
B.Sc, M.Sc, Ph.D. (UPH)

Mr. Vice-Chancellor Sir, I feel honoured and delighted to read the citation on this erudite scholar, outstanding mentor, former Dean of Faculty of Agriculture and my friend, Prof. (Mrs.) Love Akaja **AKONYE**.

Prof. Love **AKONYE** was born on 11th November 1958 in Ndashi-Etche, Rivers State, to the late Chief Josiah Nwekeh Nwosu and Mrs. Victoria Njinalu Nwosu. She is the first in the family of 19 children. Prof. Love was greatly influenced by her grandmother, whom she lived with while her parents travelled across Rivers State to teach in the mission schools they were posted to.

Education

On attainment of school age, Love attended State School Ndashi-Etche where she obtained her First School Leaving Certificate (FSLC) in 1972. True to the saying that teachers' children do well in school, she passed the FSLC with Distinction. As a scholastically energetic child, her father, then a headmaster, provided the books and much to the surprise of her male classmates, she could read aloud correctly and confidently. She became a vibrant role model to her siblings and many others.

Mr Vice Chancellor Sir, at Etche Girls Secondary School, Umuola Etche, she passed WASC with Grade I (1976) despite the plight of not having consistent teaching. She proceeded to the University of Port Harcourt and graduated in 1981 with a Second Class (Upper Division) degree in Botany. She was the best graduating student in her department. She was a Demonstrator in Department of Biological Sciences, University of Maiduguri, during her service year in Borno State (1981/82). Prof. Akonye joined the staff of the Department of Botany, University of Port Harcourt in 1982, becoming the first graduate of the University to take up appointment in the Department.

Having a keen interest in academics, she proceeded to graduate studies in the same university and obtained an M.Sc in Plant Physiology in 1985 and Ph.D. in Botany in 1992.

Academic and Administrative Experience

Prof. Akonye grew through the ranks of academia by dint of hard work and rose to the rank of Professor in 2009. She has served in various positions in the University and beyond the confines of the University.

She has a firm combo of devotion to duty, forthrightness and self-discipline with which she served as Departmental Time-Table Officer (1997-1999), Hall Warden (1997-2000), Environmental Adviser to SPDC (2001/2002), Chairman and Member of Review Panels for Environmental Impact Assessment (EIA) with the Federal Ministry of Environment (2002-2006). Faculty Representative in Senate (2004-2005), Ag. HOD, Plant Science and Biotechnology (2005-2008) Associate Dean, Faculty of Science (2005-2008), Member, Governing Council, Paul University, Awka (2014 - date) and Dean, Faculty of Agriculture (2011 – 2014).

She worked arduously during her tenure as Ag. HOD and the department got full accreditation by National Universities Commission (NUC). She also played a major role in the establishment of a tissue culture laboratory and production of a spreadsheet to calculate the CGPA of students effectively. She led the NUC Resource Verification Exercise for the change of name from Department of Botany to Department of Plant Science and Biotechnology. Her achievements as Dean, Faculty of Agriculture include: the establishment of reputable Faculty journal (AJATE), signing an MOU with Rivers State Sustainable Development Agency (RSSDA), an affiliate of Songhai Farms and implementation of INTRA ACP Academic Mobility of the European Commission.

She served as Chairman, Documentation/Technical Subcommittee, 25th Anniversary Planning Committee of Faculty of Science and Secretary ASUU, Uniport Branch. She has been External Examiner to three universities, member, Governing Council, Paul University, Awka, Visiting Professor, Ignatius Ajuru University of Education, Port Harcourt, member, Ad Hoc Accreditation Team to University of Ibadan, Ibadan, and University of Lagos, LASU, SRCOE and External Assessor to University of Botswana and Enugu State University of Science and Technology and University of Lagos (UNILAG).

Prof. Akonye has over 40 publications, including 4 books. She has supervised eight M.Sc and five Ph.D. Theses, as well as many B.Sc dissertations. She has attended several national and international academic, leadership and management courses and conferences. The recent ones include the Middle East Agribusiness Exhibition And Seminar – AGRAme (2012), Dubai, United Arab Emirates and the 3rd RUFORUM Biennial Conference held in Entebbe, Uganda (2012) and Plant Biology, USA (2015).

She is a member of several professional bodies and affiliate associations including Biotechnology Society of Nigeria (BSN), Botanical Society of Nigeria (BOSON), and International Society for Tropical Root Crops (ISTRC)..

Awards and Honours

Prof. Akonye has received many awards, honors and prizes. These include:

- Overall Best Graduating Student (Government Girls' Secondary School, Umuola Etche) 1976/77
- Federal Government of Nigeria Scholarship Award (1982/83),
- University of Port Harcourt Scholarship Award and Rivers State Government Scholarship Award (1978-1980),
- Dean's List as an Undergraduate (1979 – 1981)
- Best Graduating Student in Botany, Class of 1981
- International Foundation for Science (IFS), Stockholm, Sweden (1987-1990; 1991-1994).
- The Donald Plucknett Best Paper Award (1991) by the International Society for Tropical Root Crops (ISTRC)
- First female Master of Science botanist by Rivers State Women Education (1987).
- Award of Excellence as Hall Warden by Student Union Government (SUG) Uniport (1998/99).
- Man O' War Merit Award as recognition for an Immense contribution towards the upliftment and growth of Man O' War Uniport Command (1999)
- Certificate of Honour by UPH Foundation Class '81 Silver Jubilee Award in recognition of being the First Female Associate Dean, Faculty of Science, UPH
- Award of Excellence (EZINWA OF ETCHELAND) by Ndem Etche Progressive Association (NEPA) 2006.

- Award of Honor (Mother of the Year) by National Association of Plant Science and Biotechnology Students, 2005
- Award of Excellence by National Association of Plant Science and Biotechnology Students, 2007
- Excellent Service Award by Institute of Petroleum Studies (IPS), University of Port Harcourt, 2013
- Recognition Award by Faculty of Agriculture, Uniport, 2014.

Faith and Family Life

Prof. Love is a devoted Christian. She is the Patroness of Student Christian Movement (SCM) and Anglican Youth Fellowship of St. James Church, Ndashi-Etche. She has supported other christian fellowships like the Scripture Union Campus Fellowship (SUCF) and Joint Christian Campus Fellowship (JCCF). She is a Life Member, Full Gospel Business Men's Fellowship International. She has also served in various capacities in Our Saviour's Chapel (OSC), University of Port Harcourt. These include Chapel Caretaker Committee, Constitution Drafting Committee (1994), Welfare Committee; Chairman, Mothering Sunday Planning Committee and Chairman, Harvest Planning Committee (2015 and 2016); Member, Our Saviour's Chapel Board of Trustees.

The awards she has received from Christian ministries include the following:

- Distinguished Achiever Award by Divine Media International, in recognition of her contributions towards the development of Campus Christian Ministry (2000).
- Ambassador of the Kingdom honorary Award by SCM, Nigeria, 2006
- Ambassador of Goodwill for Israel, 2006

- Merit Award (Ezi Ada) by the women of St. James (Ang.) Church Ndashi, 2009
- Award of Excellence by Ndashi Parish Anglican Youth, 2010

She is married and has three children (all graduates) and four grandchildren.

Vice-Chancellor Sir, distinguished Ladies and Gentlemen, please join me to welcome the 144th Inaugural Lecturer, an Astute Academic and Administrator, a former Associate Dean, Faculty of Science and Dean, Faculty of Agriculture, the Ezinwa of Etcheland, a Professor of Plant Physiology and Ecology, Professor Love Akaja **Akonye**.

Thank you.

Prof. Ebi R. Amakoromo
Orator