FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

PECKING INTO THE WORLD OF SECONDARY METABOLITES IN PLANTS: A TOOL FOR BUILDING A HEALTHY AND WEALTHY NATION

By

PROFESSOR ABDULLAHI MANN
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Professor of Chemistry

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COURTESIES

In the Name of ALLAH, the most Beneficent, the most Merciful.

The Vice-Chancellor, Deputy Vice-Chancellor (Academic), Deputy Vice-Chancellor (Administration), Registrar and other Principal Officers of the University, Dean, School of Postgraduate School, Dean of Physical Sciences, other Deans present, members of Senate, my distinguished colleagues, our unique students, distinguished audience, ladies and gentlemen.

1.0 INTRODUCTION

I give thanks to *Allah Subhanahu wata'allah*, the Maker of all things including plants, for allowing me to see this day. May He continue to guide us to the straight path not the path of those who have gone astray. Ameenu. It is with joy, honour, privilege and deepest sense of humility and a challenge for a Professor to be accorded the opportunity to stand before you to face "this public hearing conducted on a Professor" otherwise called Inaugural Lecture.

I very much welcome you to this Inaugural Lecture titled **"Pecking into the World of Secondary Metabolites in Plants: A Tool for Building a Healthy and Wealthy Nation"**. It is with the deepest sense of humility that I stand before you to deliver the 4th

Inaugural Lecture of this University from the Department of Chemistry. It is, however, a greater challenge and problem for a Professor of Chemistry to address this heterogeneous audience without luring them to sleep with much of chemical structures. I will therefore try as much as possible to make this presentation less structurally cumbersome, while at the same time urging you to appreciate the message these structures convey. The purpose of this Lecture is to showcase a little, from my humble contribution to the body of knowledge in Chemistry, as an Organic/Natural Products Chemist, which earned me a chair of chemistry in this great University. I hope by the end of this Lecture, I would have been able to convey a message that Natural Products Chemistry is a lot simpler to understand and will enable us to grasp the happenings in our daily lives. Specifically, this Inaugural Lecture will address the studies of secondary metabolites from medicinal plants as the merger of science with the culture which is an important way of developing the natural resources of a nation that harbour the rich biodiversity for the benefits of the wealth creation.

1.1 Conceptual Clarification

As just indicated, one concept need to be clarified before we proceed with the lecture is Pecking; which in this context:– When a bird strikes or bites something with its beak.

By natures' design, anything valuable or precious such as gold, petroleum and secondary metabolites are hidden; and man has to make concerted efforts to harness them for betterment of humanity. In this context, secondary metabolites are hidden treasure and searching for them has a similitude to a woodpecker striking hard to reach out to a hidden honey in a wooden or rocky cave through a tiny hole. It will take several days or even months for this to be done, but with requisite skills, determination, patience, endurance, perseverance and hard work; the fate can

be achieved with a resounding and rewarding success that is usually celebrated as shown below by these birds (**Plate Ia**).

Plate I: (a) Woodpecker Working Hard with Skills, Patience and Perseverance ending with Celebration of Great Treat of Getting to the Honey (b) Christopher Columbus (1451 -1506) with his members of expedition

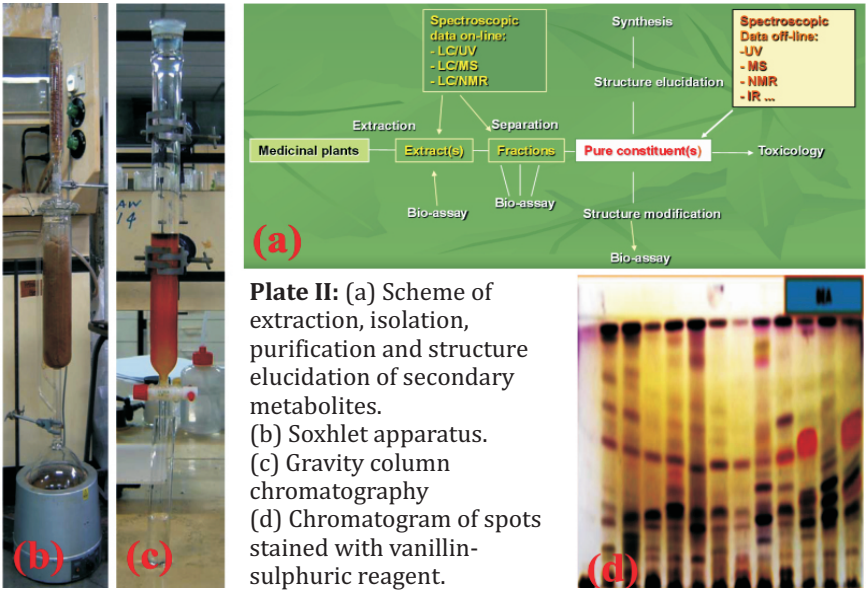


Plate II: (a) Scheme of extraction, isolation, purification and structure elucidation of secondary metabolites.
(b) Soxhlet apparatus.
(c) Gravity column chromatography
(d) Chromatogram of spots stained with vanillin-sulphuric reagent.

In this context, plants use the cells to harvest energy from sunlight through photosynthesis to produce energy-rich molecules, glucose which eventually get converted to secondary

metabolites. These molecules are transported and securely stored in cell vacuoles at the remotest parts of the plants for the purposes of growth and defense. The medicinal property of plants are determined by these different classes of secondary metabolites namely: alkaloids, flavonoids, steroids, tannins, saponins, etc which always occur as complex mixtures in the plant matrix cells. From experience, the process of the removal of these secondary metabolites from plant cells for human therapeutic usage is a long, time-consuming, labour, cost-intensive, and tedious task. Therefore, scientific expertise and dexterity of Natural Products Chemist in designing the isolation and purification techniques to safely bringing out these fragile chemical substances with their origin structures intact are required, so that pharmacophores responsible for the medicinal properties are not lost in the process of removal. This Inaugural Lecture is an attempt to explain how Natural Products Chemistry try to remove secondary metabolites from the complex mixtures stored in plant cells and at the same time to elucidate molecular structures of these highly valuable pharmacologically active molecules for the benefit of humanity in building healthy and wealthy Nation. In doing this, just like the woodpecker; the Natural Product Organic Chemists have to possess characteristics of being hard working, self-determined, endurance, patience, persevere and above all must have requisite skills in order to be successful and if possible celebrate the fate of accomplishing getting a drug from secondary metabolites for the common good of mankind.

1.2 In My Humble Beginning

My dream as a young boy who lived in a Nupeland village, Emitete, 13 km along Bida-Doko road was to be a successful Agriculturist, full of zeal to harness the potentials of the agrarian society we lived in. As a young person then, I was very inquisitive and adventurous, which even now I can still remember vividly with nostagia that herbs as such: *Lemu-bakagi* (*Citrus limon*), *Yesabakagi* (*Nelsonia canescens*); *Kpace* (*Terminalia avecennioides*), *Eyekosudangi* (*Abrus precatorius*) and *Kukunci* (*Combretum glutinosum*) that were fetched from our backyard vegetations by our mothers for baby care (were usually boiled for

drinking and bathing for their medicinal values). At the same time, plants obtained from the village environs and used for snacks making include: *Rumiania* (Sword lily, corm of *Gladiolus daleni*) for *fura* and *Dara* (Tamarind tree, the fruits of *Tamarindus indica*) for kunu-dara or kunu-tsamiyan. Similarly, some ingredients for daily soups also gotten from the same immediate vicinity are: *Luwogi* (spring onions, *Allium fistulosum*); *Nungbere* (calyx of *Annona senegalensis*); *Kula susu* (seeds of *Parkia biglobossa*); *Emagi* (calyx from *Hibiscus surattensis*); *Kuka* (leaves of Baoba tree, *Adansonia digitata*/*Ceiba pentandra*) etc. were cooked and sumptuously consumed regularly by all and sundry. In those days our fathers, also used to collect plant materials from our environs for enhancing livestock production and preservation of farm products – *Tanmotswangi-eba* (whole plants of *Hyptis suaveolens*), *Nimu* (seed and leaf extracts of *Azadirachta indica*), *Tanmotswangi – wawagi* (aerial parts of *Ocimum gratissimum*) were also commonly used for preservation purposes.

This background was fresh in my mind, when I started the study of Chemistry that led to my graduation with BSc (Hons) in Chemistry as a General Chemist in 1987 from Bayero University, Kano. The knowledge of basic chemistry stimulated and strengthened my inquisitiveness the more as I was fascinated by the way chemical substances interacted with each other in living organisms (in both plants and animals) and with their environment. At that stage of my life, the urge of wanting to contribute to the development of our local herbal resources that are abundant in our homestead spurred my interest and later at graduate levels, the enthusiasm to modernized herbal medicine to complement orthodox medicines was born.

On the completion of a Master Degree in Organic Chemistry from Bayero University Kano; I was endowed with the wisdom to investigate the secondary metabolites in the indigenous plants used in Northern Nigeria by farmers as medicines and as grain protectants under the guidance of Prof. M. O. Fatope. I went

further to acquire a PhD in Organic Chemistry from Ahmadu Bello University, Zaria under the supervision of Prof. J. O. Amupitan. In the course of these travails, I was privileged to accumulate more knowledge in Organic/Natural Products at the Department of Chemistry, College of Science, Sultan Qaboos University, Oman where I did bench work under the tutelage of Prof. M. O. Fatope. All these exposures sharpened me to understand the workings of secondary metabolites treasured in Nigerian plants. With all the trainings mentioned above, *Allah Subhanahu wata'allah* has endowed me with the powers to provide explanations and proffer solutions to happenings in our health and agronomic practices. I chose to do research in the area of secondary metabolites especially those that possess potential therapeutic activities.

2.0 CHEMISTRY AS A VITAL TOOL OF EXPLORING PLANTS

2.1 What is Chemistry?

Chemistry is the science of matter which deals with the structures, compositions, properties and interaction of substances under different conditions. Chemistry strives to provide reasonable explanations for various phenomena in the human environment. Therefore, chemistry remains central in economic development globally as it plays major roles in food security (production of pesticides, storage, fertilizer, animal feed, etc); development of renewable energy, pollution prevention and environmental protection and disease control among many more activities of man.

The curiosity of man led to the exploration of his environment, particularly the plants. Therefore, to properly explore the environment; man needs to ask several questions of why, what and how? For instance, one need to understand why an autumn leaf turns red, or why a butterfly hovers around flowers, why and how certain insects avoid their predators or why grasses do not grow on anthills or termite hills. All these phenomena require first, a basic understanding of Chemistry. This is why with the input of the chemists, the scourge of scurvy disease that ravaged the members of Christopher Columbus voyage (**Plate Ib**) was

treated with fruits. The phenomenon was scientifically explainable based on the Vitamin C present in the fruits. Thereafter, vitamin C (ascorbic acid) was mass produced to drastically reduced the scurvy disease. Therefore, the plant even after man's initial knowledge of its herbal efficacy certainly require the inputs or contributions of the chemist to identify its active constituents. We strongly believe that it is right to try to understand the world of chemistry surrounding us as much as we can and to use that understanding beneficially. This is what I want to share with you.

2.2 What is Organic/Natural Products Chemistry?

Organic Chemistry is the study of chemistry that involves the preparation and reactions of carbon-containing compounds with different functional groups (pharmacophores) and correlating their behaviour with their structures that make up all living organisms. While Natural Products Chemistry is the branch of chemistry that deals with the isolation, identification and characterisation (structure elucidation) of chemical substances produced by living organisms in nature that has distinctive pharmacological effects. The need to understand natural products and also to produce them on the bench is the meeting point of an Organic Chemist and a Natural Products Chemist. Generally, Natural Products Chemistry through systematic investigation using chemical principles has helped to develop drugs for chemotherapy in modern medicine and agrochemicals for agronomic practices. Natural Products Chemists usually work with herbs, bark, leaves, shoots and different parts and sizes of plants as used in herbal medicine. Natural Products Chemists should not be confused with herbalists (*babalawo* or *boka* or *boci*) because they do their own work with a procedure different from the herbalists. A Natural Products Chemist extracts leaves, roots, stems or flowers of a plant like other herbalists do, but they will not extract ten different plants together like they (herbalists) do. A Natural Products Chemist will try to identify the active ingredients in the plant by knowing the compounds present in the extracts, isolate and know their structures. However, herbalists play an important role in supplying ethnomedical

information to Natural Products Chemists to work with and most research arises largely because plants form the foundation of traditional pharmacopeias. The study of natural products is multidisciplinary (**Figure 1**).

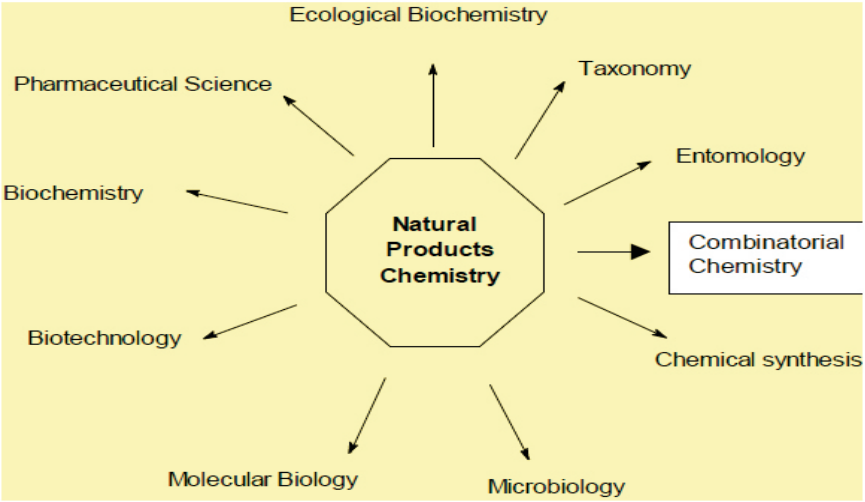


Figure 1: Research areas in Natural Products Chemistry intersect with many fields
Source: *Macahig & Dayrit (2012-2013)*

In this Lecture, I hope to show you the linking of our culture in ethnomedicinal plants with the science in the medical uses of secondary metabolites derived from these plants and the fact that Allah has granted the needs of every community in plants for Natural Products Organic Chemist to explore and exploit for the benefit of immediate community and nations at large.

3.0 BIOSYNTHESIS OF SECONDARY METABOLITES DERIVED FROM PLANTS

3.1. Primary and Secondary Metabolites

Plants are capable of synthesizing a plethora of metabolites that is why they are described as inventive chemists since they have an almost limitless ability to synthesize metabolites through photosynthesis

using simple starting materials: water, carbon dioxide, nitrogen, phosphorus and their salts, essential minerals (sodium, calcium, potassium, magnesium, iron and selenium) as shown in **Figure 2**. Plant cells produce two types of metabolites: Primary and Secondary metabolites. Primary metabolites are essential metabolites (sugars, fats, proteins, nutrients and minerals) found in all plants and they are responsibilities by participating in the growth and reproduction (Pagare *et al*., 2015). Secondary metabolites are organic molecules such as alkaloids, terpenes, sterols, flavonoids and tannins that are produced by living organisms (Ramawat *et al*., 2009). Distribution of secondary metabolites in plants is much more species-dependent. Plants act as chemical industries and as such they act uniquely as food factory, perfume and cosmetic factory, vegetable oil factory, insecticide factory, textile fiber factory, drug factory, etc. Since the existence of human civilization, a considerable number of the secondary metabolites produced by plants are utilized as nourishment, pharmaceutical and beautifying agents due to their medical, colours, aromas, flavours, dietary properties (Mohiuddin, 2019).

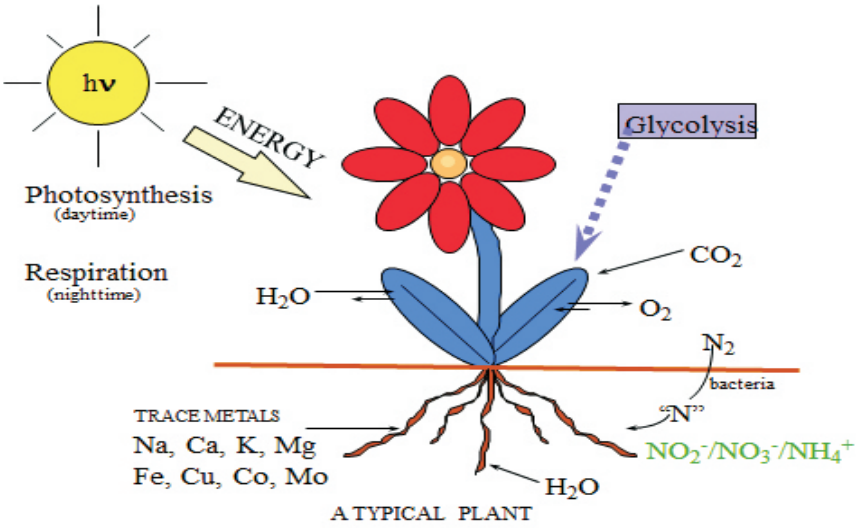


Figure 2: Basic Features of a Typical Plant Interaction with the Environment
Source: Taiz & Zeiger, 2010

3.2 Secondary Metabolites as Agents of Chemical Communication in Plant Defences

Secondary metabolites play ecological roles in nature; thereby deter would-be pests, predators or pathogens. Nearly all ecosystems contain a wide variety of bacteria, viruses, fungi, nematodes, mites, insects, mammals and other herbivorous animals that communicate with each other by using signalling compounds (secondary metabolites) as demonstrated in **Figure 3**. Evolution gave different organism different "Chemical Tools" to communicate with individuals of the same species or to defend themselves against predators. Plants have evolved both physical and chemical defense measures to protect itself against predators. Secondary metabolites are produced as toxicants for providing defense against the attacking organisms. Therefore, plant organs possess secondary metabolites that permit plant communication with its environment. For instance, colouring chemical substances embedded in flowers enable plants communicate with pollinators or protect the plants from feeding on them by animals or infections by producing specific phytoalexins after fungi infections that inhibit the spreading of the fungi mycelia within the plant. These secondary metabolites have important ecological functions of providing protection against attack by herbivores and microbes, as well as, serving as attractants for pollinators and seed-dispersing agents. They may also contribute to competition and invasiveness by suppressing the growth of neighbouring plant species (a phenomenon known as allelopathy). Therefore, plants produce high diversity of chemical defense compounds called allelochemicals that selectively eliminate the plant competitors (Morrissey, 2009). Pheromones are chemical products used between individuals of the same species in order to induce a specific behaviour (chemical communication). Allomones are chemical products released by an organism which has a negative effect on another organism (chemical defence) (Taiz & Zeiger, 2010). Insects are

usually small in a crowded world and they find others of their own species and the opposite sex by smell. It may surprise you to note that nature is wonderfully and buoyantly expressed in chemical world of secondary metabolites that insects communicate through chemical tools called pheromones; which are volatile natural compounds produced by most insects to find its mates that smells a potential mate in incredibly weak concentrations with exact precision. Several small animals have evolved toxic compounds that make the prey poisonous (ants, spiders, frogs, toads, lizards, snakes and fishes) to be consumed by the predator. On the basis that they emitted droplets of chemicals such as alkaloids that exhibit toxicity, deterrence, repellence or inhibition. Therefore, researchers can utilise these toxic compounds for the betterment of humanity.

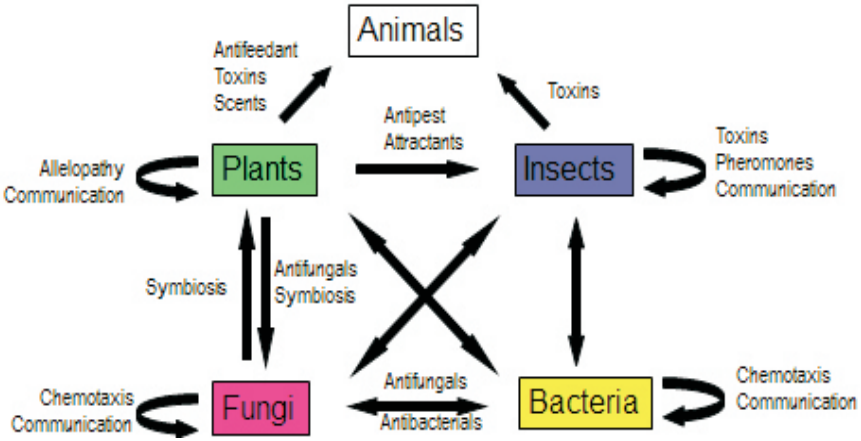


Figure 3: Secondary Metabolites as Agents of Chemical Communication and Defense
Source: *Macahig & Dayrit (2012-2013)*

3.3 Medicinal Plant Research and Drug Development from Plant Secondary Metabolites

Currently, these stored secondary metabolites in plants are the basis of bioactive principles of many herbal medicines and

orthodox drugs for the majority of the world's population. Extraction, isolation, purification and structure elucidation of secondary metabolites from complex plant extract mixtures are the major bottlenecks in Natural Products Chemistry research. In order to achieve complete resolution of the mixtures, natural products chemist applies different separation and identification techniques to the extracts and fractions including using chromatographic methods to isolate the active principles. Modern structural elucidation (i.e. characterization) is done by spectroscopic methods to obtain complete structural elucidation of bioactive principles as shown in **Figure 4** (Mann *et al*., 2012).

4.0 DRUGS DEVELOPED FROM SECONDARY METABOLITES

Mr. Vice-Chancellor sir, ladies and gentlemen, I will now discuss some of these numerous natural products-derived drugs developed by pecking into secondary metabolites in order to highlight how they have aided changes in the global health-care delivery and pharmaceutical enterprises.

4.1 Antimalarial Compounds

Malaria is caused by parasite of *Plasmodium falciparum*, which is one of the leading parasitic infectious diseases in many tropical regions including Nigeria. Natural products have made an important impact in the area of antimalarial drugs.

During the 17th century, the Jesuits brought the bark of the quina (*Cinchona officinalis*) tree **Plate III(a)**, from South America to Europe, where the plant concoction was developed by the Inca people for the treatment of malaria. Some scientists isolated quinine [**1**] and quinidine from the bark of quina (*Cinchona officinalis*) tree as the active compounds against malaria. Due to the development of resistance by the dangerous *P. falciparum* to antimalarial drugs; sesquiterpene, artemisinin [**2**], a reactive

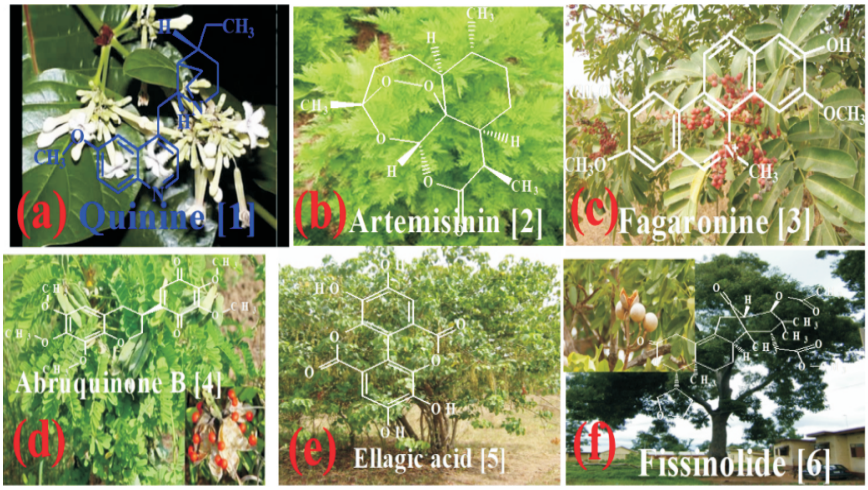


Plate III: (a) *Cinchona officinalis* with flowers **(b)** *Artemisia annua* **(c)** African satinwood (*Fagara zanthoxyloides*) [*Hausa = H: Fasakuwari, Igbo = I: Ogiri, Nupe = N: Kosonkori, Youruba = Y: Ata*] with red fruits **(d)** Cat's eye rosary pea (*Abrus precatorius*) [*H: Idon zakara, I: Otoberebere, N: Eyekosun dangi, Y: Oju - ologbo*] with red seeds as inset **(e)** Christmas bush (*Alchornea cordifolia*) [*H: Bambami, I: Ubobo, N: Dzudzanci, Y: Ipa, Esinyin*] with the fruits and flowers **(f)** Mahogany (*Khaya senegalensis*) tree [*H: Madaci, I: Ono, N: Wuchi, Y: Oganwo]* with the stem and fruits.

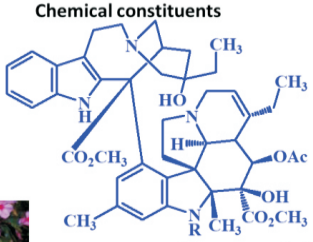
Traditional use: Treatment of malaria, pain, diabetes, hypertension, rheumatism and cancer.
Parts used: stem, barks, leaves.

Pharmacology: Antimalarial

Rose flower
Catharanthus roseus Linn

Traditional use: Treatment of Menstrual pain, insect bites, diabetes, hypertension, asthma, inflamation, rheumatism, neurological disorder and cancer.
Parts used: stem, leaves, and roots.

Chemical constituents



R = CH_3 vinblastine [7]
R = CHO vincristine [8]

Pharmacology:
Anti-cancer
Anti-diabetic
Anti-tumor

Plate IV: Catharanthus roseus (Rose) with white, red and pinkish flowers having structures of some isolated Anticancer (Antitumor) Compounds

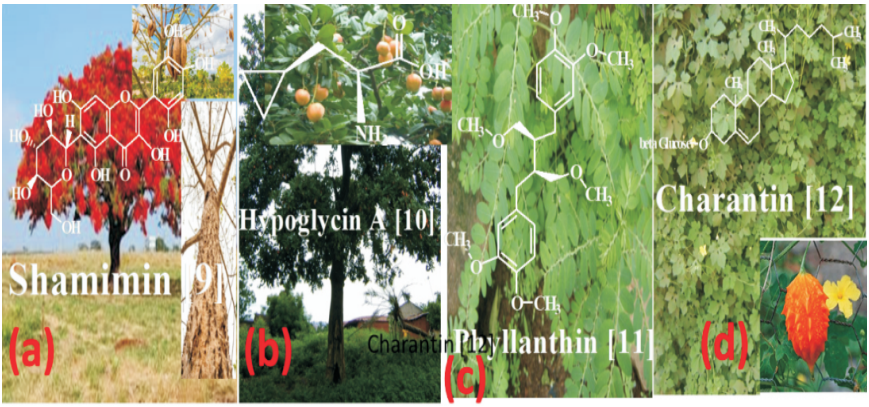


Plate V: (a) Red silk - Cotton tree (*Bombax ceiba*) [*I: Akpu, Akpe; N: Kutukpachi, Y: Ogbolo, Toroto*] with thorny trunk and fruits as insets **(b)** Akee apple (*Blighia sapida*) [*H: Gwanja kusa, I: Okpu, N: Yilanchi, Y: Ishin*] with fruits as inset **(c)** Egg noma (*Phyllanthus amarus*) [*H: Majiryan-kurmi, Bakin alambu, N: Sunyegboro-sunzumma, Y: Iyin-olobe, debi-sowo*] **(d)** African cucumber (*Momordica charantia*) [*H: Daddagu, Garaafinii, I: Akban ndene, Kakayi, N: Garafini, Y: Ejinrin were, Igbole-aja*] with flowers and fruits as insets

Traditional use: Treatment of breast cancer, stroke, fever, gonorrhea and diabetes separately used.

Parts used: seeds, leaves, stem bark, roots and ripe fruits.

Pharmacology: Anti-diabetic

peroxide bridge, compound was isolated in 1972 by Chinese chemists from the medicinal plant, *Artemisia annua* **Plate III(b)** for malaria therapy (Ramawat, 2009).

In Nigeria, it is common to have mixture of pawpaw (*Carica papaya*) leaves, lemon grass (*Cymbopogon citratus*) leaves, Cashew (*Anacardium occidentale*) leaves and neem (*Azadirachta indica*) leaves used in 'steam therapy', in which the malaria patients are covered with a thick blanket and made to inhale the vapour from the cooking pot (Mann *et al*., 2003). Several antimalarial compounds have been purified and isolated from rich flora of Nigerian biodiversity as thus: fagaronine [**3**] from *Zanthoxylum zanthoxyloides* **Plate III(c)**; abruquinone B [**4**] from

Abrus precatorius **Plate 4 III(d)** and ellagic acid [**5**] from *Alchornea cordifolia* **Plate III(e)**; fissinolide [**6**] from *Khaya senegalensis* **Plate III(f)** (Adebayo and Krettli, 2011).

4.2 Anticancer (Antitumor) Compounds

Cancer is a human tragedy that is growing swiftly worldwide with high morbidity and mortality and poses both economic and psychological challenges in developed and developing countries. It caused about 13% of all human deaths in 2007 (7.6 million) (Das *et al*., 2012). Vinblastine [**7**, Velban®] and vincristine **8**, [Oncovin®] were isolated from the flowers of a prominent ornamental plant, *Catharanthus roseus*, also known as *Vinca rosea* (Rose flower) **Plate IV** mostly found in Nigerian primary schools in 1970s as one of the most effective cancer treatments to date (Ramawat, 2009).

4.3 Antidiabetic Compounds

Diabetes is dreadful disease found in all parts of the world and is becoming a serious threat to mankind health (Grover *et al*., 2002). Nigeria is among the top 5 countries that have the highest number of people affected by type 2-diabetes in sub-Saharan Africa. Nigeria has about 1.2 million people that are affected (Udenta *et al*., 2014).

Several of antidiabetic compounds have been obtained from plants. The search for antidiabetic principles from medicinal plants revealed that in Nigeria, good number of traditional antidiabetic plants have been evaluated for antidiabetic activity with significant amount of secondary metabolites having therapeutical potentials: shamimin [**9**] isolated from *Bombax ceiba* **Plate Va)**; hypoglycin A [**10**] from *Blighia sapida* **Plate V(b)** fruit; phyllanthin [**11**] from *Phyllanthus amarus* **Plate V(c)**; charantin [**12**] from *Momordica charantia* **Plate V(d)** (Ezuruike and Prieto, 2014).

4.4. Plant Vitamins and Phenolic Compounds as Antioxidants

Toxic Reactive Oxygen Species (ROS) are produced because oxygen is easily activated by Ultra Violet (UV) radiation and heat from the sunlight to form free radicals ($O2^{-}$), singlet oxygen ($^{1}O2$), hydrogen peroxides (H2O2) and reactive nitrogen species such as nitric oxide as generated in animals and humans during metabolic reactions (Halliwell & Gutteridge, 2007). Excessive amounts of ROS may be harmful because they can react with important macromolecules of cells, such as proteins, lipids and nucleic acids leading to cell injury and death, and create oxidative stress causing numerous chronic disorders. There has been a growing considerable interest to identify new sources of safe and inexpensive antioxidant potential of natural origin.

Natural and synthetic antioxidants are widely used in modern medicine (Altemimi *et al*., 2017). Fruits and vegetables like cucumber, tomato, cabbage, pumpkin and carrots are common sources of safe and easily accessible natural antioxidants. They have been linked to reducing the risk of major chronic diseases like inflammation, cardiovascular disease, cancer and aging related disorders. This is because secondary metabolites such as carotenoids (lycopene, carotene, lutein, zeaxanthin, retinoic acid); vitamins (vitamin A, vitamin C (ascorbic acid), E, K, thiamine (B_1) and riboflavin (B_2), pyridoxine (B_6); minerals (potassium, phosphorus, magnesium, iron, and selenium) and phenolic compounds (flavonoids, phenolic acids) are responisible the nutritional and medicinal values. Many of chemical substances play antioxidant roles in delaying aging, reducing inflammation, and preventing certain cancers (Altemimi *et al*., 2017; Haslam, 1996) as depicted in **Figure 4**. Increasing the consumption of fruits and vegetables has been recommended by many agencies and health care systems throughout the world.

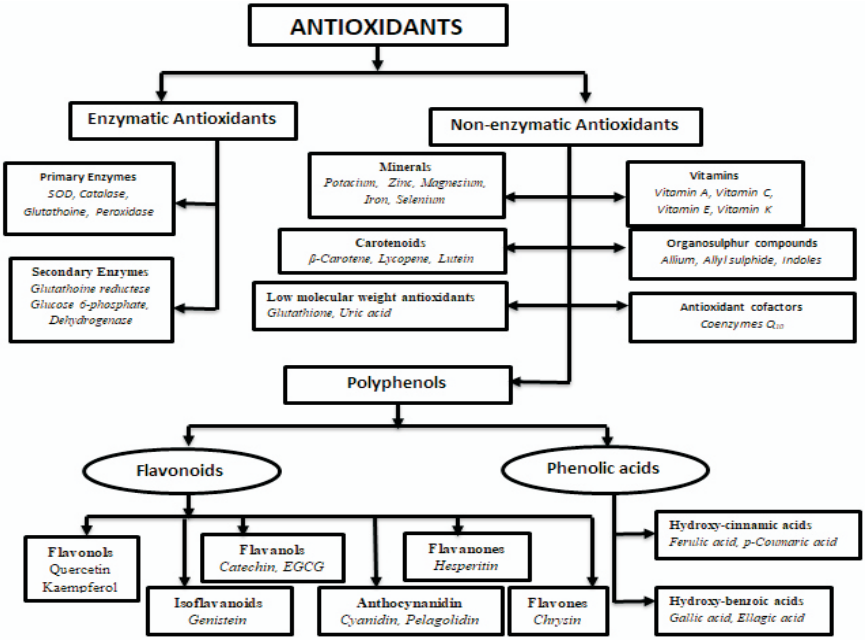


Figure 4: Classification of antioxidants

Source: Shalaby & Shanab, 2013

5.0 SECONDARY METABOLITES AS SOURCES OF NATION'S WEALTH

5.1 Merging science with culture option

One of the important ways for salvaging the economic down-turn in developing nations is by pecking into secondary metabolites of indigenoeus plants that merges science with culture. This is based on the fact that only 15% of plant species have been systematically investigated for the presence of secondary metabolites, moreover, the potentials of the marine environment as a source of novel drugs remains virtually unexplored (Cragg & Newman, 2013).

Africa is the world's second largest continent after Asia, both in terms of area and population and 10% of its unique flora

diversity has potential for commercial exploitation and half of them are underutilized. Despite vast natural resources, most African countries, Nigeria inclusive are still struggling to provide basic amenities for their people. Many of these biological resources are used for obtaining pharmaceuticals that have a high national and international economic value. The increased awareness of medicinal plant potential has led to a rising demand for plant medicines in the USA, Europe and Japan (Vasisht and Kumar, 2004); to the extent that the demand is exceeding supply. The global market of herbal drugs is estimated to be about US$ 60 bn per year, growing at a rate of 7% (Vasisht and Kumar, 2004). The health budget for Africa is largely spent on conventional medicine and is not sufficient to meet requirements. Public expenditure on health is about 2% of gross domestic product (GDP). Medicinal plant resources in Africa are also the major source of income (Vasisht and Kumar, 2004). It is argued that the reason why African countries including Nigeria have low expectancy rates is partly because they are not exploring their natural resources to their fullest potential.

There is an assertion that any nation that focuses only on non-renewable resources (petroleum) is not a wealthy nation. While, a nation that harnesses her renewable resources (plants, animals, water, soil, wind and air) is considered to a wealthy nation. In Nigeria, there are several untapped natural resources that could be explored and exploited for health and economic gains most especially for her health sector where she still depend on importation of foreign drugs. Totipotency empowers plant cells and organs to deliver valuable secondary metabolites *in vitro* which will improve profitability and quality. This is a favourable condition for entrepreneurs in the business of drugs derived from plant secondary metabolites. If produced, many of these secondary metabolites will be used as drugs, agrochemicals, dyes, flavours, pesticides, fragrances thus increasing the economic value of the associated industries

(Vasisht and Kumar, 2004). Overall international trade in medicinal plants and their products was US$ 60 billion in 2010 and is expected to reach US$ 5 trillion by 2050 (Nirmal *et al.*, 2013).

5.2 The Success Story of Cannabis for Medical Purposes - Lesotho Experience

Globally, medical cannabis (marijuana) is currently a big business. The market for medical cannabis is currently estimated to worth $150bn (£121bn) a year and could reach $272bn in 2028. In 2017, Lesotho as a nation got hold of this business opportunity and decided to tap into the booming medical cannabis industry as her "green gold" for global health delivery and economic gains (Bloomer, 2019). The scientific community of Lesotho found a particular species of cannabis plant from their country that produces non-psychoactive substance in high-quality, cannabidiol (CBD) oil - which is the compound used in medicines to treat a variety of conditions. They also found that 2,000kg of biomass can produce more than 1,000 litres of cannabis oil at a cost between $6,000 and $21,000 per litre. In order to meet legal standards, the chemist designed a method to remove the traces of tetrahydrocannabinol (THC, about 0.03%) - the main psychoactive constituent responsible for marijuana's intoxicating effects and used for recreational purposes, from the seeds (Bloomer, 2019).

The Government of Lesotho then granted a number of international companies licences to grow, distribute and to export cannabis-based products. The country has managed to attract Canadian investors, who invested $19.3m into cannabis-growing facilities in Lesotho economy. This project boost the GDP and gave hope to the hopeless by providing the impoverished local communities of Lesotho with job opportunities (Bloomer, 2019).

Numerous Nigerian plants with this type of medical potentials are abundantly available, so pecking into secondary metabolites from Nigerian rainforests that harbours these plants presents huge economic opportunity for this nation to attract investors for associated businesses (farming, pharmaceutical enterprises, marketing, machineries, haulage, transportation, etc.) as a "green gold" for Nigerian economic diversification that can salvage the present situation of petroleum dependent economy as preached by the present Federal Government of Nigeria. Therefore, onus lies with Nigerian chemists to exploit this situation by pecking for new and novel secondary metabolites and the biotechnologists through plant cell biotechnology to carry out metabolic design for the generation of secondary metabolites (metabolomics) to produce these compounds in sufficient quality and quantity for the purpose of drug development and economic gains for Nigeria and other nations of the world.

6.0 MY MODEST CONTRIBUTIONS TO KNOWLEDGE

Mr. Vice-Chancellor sir, distinguished ladies and gentlemen, having provided detailed background information on the subject area of Natural Products Chemistry with emphasis on **SECONDARY METABOLITES**, let me highlight some of my major contributions in line with the traditions of Inaugural Lectures in order to appreciate that nature still holds many secrets which we can learn from.

Nigerian biodiversity still have many plant species containing novel secondary metabolites of agronomic and medicinal values, which are yet to be discovered. My efforts at carrying out phytochemical studies and pharmacological evaluation of the extracts, semi-purified fractions and purified compounds as basic requirements before therapeutic utilization forms the

major areas of my research focus which was divided into two components thus:

- **Natural Products Chemistry** – Extraction, purification, isolation and characterization of triterpenoids and their pharmacological activities of antimicrobial, trypanocidal, antimalarial, insecticidal, antioxidant and antidiabetic activities; and agronomic properties.

- **Environmental Chemistry** – Investigation of environmental contaminations of organic substances such as pesticide and polycyclic hydrocarbon residues; development of corrosion inhibitors using Natural Products as well as their application as novel biosorbents in the removal or purification of heavy metal contaminants from the environment.

6.1.0 NATURAL PRODUCTS CHEMISTRY

6.1.1 Natural Products with Pesticidal Properties

My first contribution to knowledge and a major foundation in my Natural Products studies started in 1994, through the research works in the field of pesticidal properties of indigenous plants with grain protectant effects (Mann *et al*., 2003). These works were based on my childhood background of peasant farm setting in northern Nigeria that uses various indigenous plants to protect cereals and legumes against pest damage during storage.

In the course of this research, we developed and employed a simple bioassay technique to assess plants for their ability to protect cowpea from damage by weevil during storage. Of the 10 plants screened *Hyptis suaveolens* **Plate VIa** showed the best protectant effects after 4 months (Fatope *et al*., 1995). Chemical analysis of the essential oils from leaves of *H. suaveolens* revealed the main constituents as 1, 8-cineole [**13**], β-caryophyllene [**14**] and eugenol [**15**] as the bioactive secondary metabolites responsible for protectant effects (Fatope *et al*., 1995).

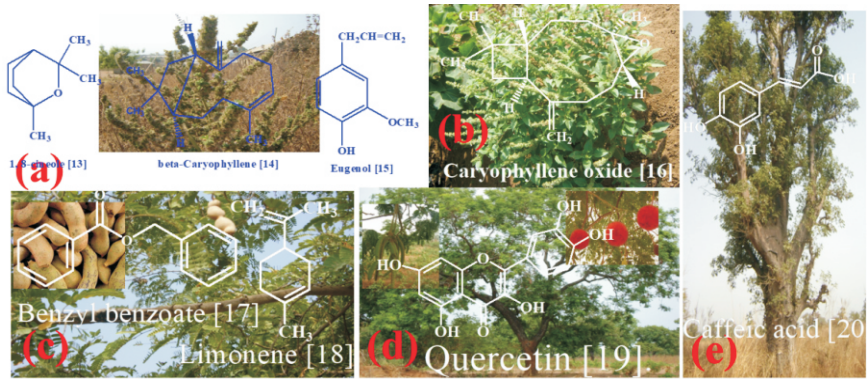


Plate VI: (a) *Hyptis suaveolens* [*H: Daidoya ta daji, I: Nchanwu, N: Tanmotswangi-eba, Y: Efirin*] **(b)** Tea bush or Wild basil (*Ocimum gratissimum*) [*H: Daidoya ta gida, I: Ahuji, N: Tanmotswangi-wawagi, Y: Effinrin-nla, efirin-gidi*] **(c)** Tamarind (*Tamarindus indica*) [*H: Tsamiya, I: Icheku-oyibo, N: Darachi, Y: Ajagbon*] with fruits **(d)** African Locust Bean Tree (**Parkia biglobosa**) [*H: Dorowa, I: Ogirili, N: Lonchi, Y: Iru, Igba*] with flowers and fruits **(e)** Baobab Tree (*Adansonia digitata*) [*H: Kuka, I: Akpu, N: Muchi, Y: Oshe*] with the structures of the Chemical Constituents.

Traditional use: Treatment of asthma, wounds, fever, toothache, body pain, diarrhoea and as eye lotion.

Parts used: Whole plant, leaves and fruits.

Pharmacology:
Pesticidal
Nnutritional

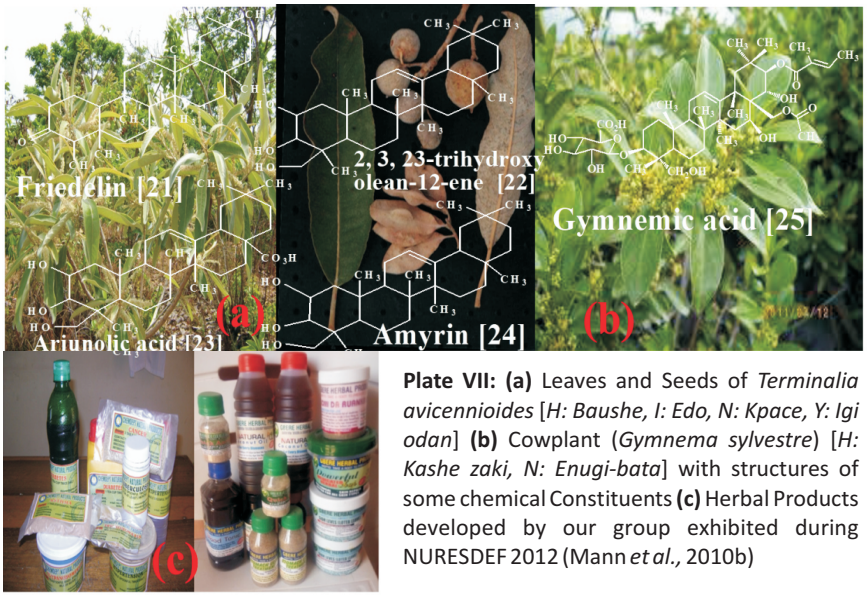


Plate VII: (a) Leaves and Seeds of *Terminalia avicennioides* [*H: Baushe, I: Edo, N: Kpace, Y: Igi odan*] **(b)** Cowplant (*Gymnema sylvestre*) [*H: Kashe zaki, N: Enugi-bata*] with structures of some chemical Constituents **(c)** Herbal Products developed by our group exhibited during NURESDEF 2012 (Mann *et al.*, 2010b)

Furthermore, *Ocimum gratissimum* **Plate VIb** which is an herbaceous plant reputed for many agronomic practices amongst Nigerian peasant farmers known to serves as an insect repellant was investigated for grain protectant activity against *C. maculatus*. Our preliminary investigation into chemical analysis of the essential oils from *O. gratissimum* aerial parts revealed the main constituents to be eugenol, 1, 8-cineole, β-caryophylene, caryophyllene oxide [**16**] and thymol; hence responsible for the deterrence property (Mann, 2012).

The undergraduate and graduate projects which I supervised over the years have contributed immensely to the antioxidant, antimicrobial and antidiabetic activity of the plant extracts. We believe the information will assist in addressing the issue of drug development from local sources as a solution to health problem in Nigeria.

6.1.2. Natural Products Containing Nutritional Properties

After our work on the pesticidal effects of indigenous plants that gave good results supporting the traditional agronomic practices. There was growing interest in the ethnodietetics backed up with my childhood observations that some Northern Nigerian dishes (soups) and snacks use indigenous plants and their nutritional properties needed to be assessed to provide information on the functional ingredients required for the proper human growth and development. These constituents have their individual health-promoting qualities that compel people to combine the different food sources to achieve healthy eating and maintain good health. Vegetables are succulent herbaceous plants that are harvested and eaten whole or in part, raw or cooked as part of a main dish or salad. Some of these fruits and vegetables are valued for their bulking effect/thickening power and others may be used as garnishes or spices. However, in Nigeria consumption of fruits and vegetables is generally low. The above reasons form

the basis for our interest to investigate both the wild and domesticated fruits and vegetables known to be good sources of nutrients commonly consumed in Nigeria diets to enable healthy living and wealth creation. Therefore, we embark on:

(i) Evaluation of the physico-chemical compositions and nutritional properties of wild Nigerian vegetables, seeds and fruits commonly consumed in Niger State, Nigeria were assessed for their nutritional potentials and were found to be rich sources of essential minerals such as Ca, K, Mg, Mn, Na and P that are essential for human growth and development as well as vitamins (A, B_2, B_6 and C); and thus could alleviate the symptoms associated with deficiency of these vitamins. These substances may be responsible for the health related properties of these plants, some of which are basis for their anti-infective activities (Mohammed *et al*., 2013; Otori & Mann, 2014; Jacob *et al*., 2016).

(ii) Chemical investigation of selected fruit extracts of *Parkia biglobosa*, *Tamarindus indica* and *Adansonia digitata* **Plate VI(a-c)** gave their vitamin C contents of 26.78, 31.68 and 37.96 mg ascorbic acid/100ml sample respectively. Phytochemical investigation of the parts of *T. indica* **Plate Via** showed the presence of benzyl benzoate [**17**], limonene [**18**], caffeic acid [**19**], xyloglucan and quercetin [**20**]. They are well known for their anti-inflammatory and antioxidant activities. Recently, there is increase medical interest in the use of purified xyloglucan from tamarind in eye surgery for conjunctival cell adhesion and corneal wound healing (Mann, 2011).

6.1.3 Natural Products Containing Antimicrobial Properties

Microbial infections (bacteria, fungi, viruses) have posed great challenge to human health concern and it is even exacerbated by the growing resistance to most conventional drugs in Nigeria. As

such this forms another area of my research which resort to searching for remedies from plants for life-threatening and common ailments to combat these resistant pathogens. Northern Nigeria's flora is rich in its ethnomedical heritage including treatments for infectious diseases (bacterial, fungal and viral infections) and uses several medicinal plants in different preparations.

My publications on Nigerian ethnomedicinal plants (Mann, 1998; Mann *et al*., 2003)were very informative and fascinated my interest in phytochemical and antimicrobial investigations on collaborative basis to screen the numerous medicinal plants used in ethnomedicine as thus: antimicrobial investigation of the extracts of Nigerian medicinal plants found in Niger State, Nigeria exhibited significant antimicrobial activity against human pathogens (Abalaka *et al*., 2011; Mann *et al*., 2008a; 2009a).

6.1.4 Natural Products Containing Antitubercular Properties

In our search for antimycobacterial drugs, we collaborated with researchers from National Institute for Pharmaceutical Research Development (NIPRD, Garki-Abuja) and conducted ethnobotanical survey of medicinal plants used locally for treating tuberculosis and other respiratory diseases in Niger State, Nigeria with the aim of identifying plants used in traditional medicine for treating TB and other pulmonary ailments (Mann *et al*., 2007). Investigation of the crude methanolic extract of the *T. avicennioides* root bark against *M. tuberculosis* and BCG gave significant inhibitory activity at 78 and 200 µg/ml respectively (Mann *et al*., 2008; 2009).

Chemical investigations of *Terminalia avicennioides* **Plate VIIa** gave friedelin [**21**], arjunolic acid [**22**], α-amyrin [**23**] and 2, 3,

23-hydroxylolean-12-ene [**24**] (Mann *et al*., 2011; 2012). The isolated compound, friedelin demonstrated significant antimycobacterial activity against BCG at 4.9 μg/mL (Mann *et al*., 2011; 2012).

In continuation of my interest in Natural Products Chemistry, we are engaged in collaboration with colleagues in the area of natural products with antitrypanosomal, antidiabetic, antioxidant and antimalarial properties.

6.1.5 Natural Products Containing Antioxidant Properties

In furtherance to our interest in the ethnodietetics of selected Northern Nigerian dishes (soups) and snacks due to the richness of these traditional dishes, we identify culinary herbs and spices in which secondary metabolites (phytochemicals) such as polyphenols, phenolic compounds, flavonoids and terpenoids are the source of their medicinal properties. Epidemiological studies have consistently shown that regular consumption of fruits and vegetables are strongly associated with reduction of risk of developing chronic diseases like cancer, high blood pressure and diabetes.

Our main focus was to identify natural antioxidant potentials in the traditional culinary herbs or spices which can quench the effect of ROS and free radicals that cause oxidative damage to biomolecules such as lipids, proteins and DNA in humans. Therefore, we tried to identified the local culinary herbs or spices content in the traditional dishes such as *Miyan-kuka, Miyan-kubewa, Kunun-zaki, Kunun-tsamiya, Kunun-gyada, Fura, Gboruagi, Nakiya, Dakuwa, Kulikuli* and *Kudo* (Alabi, 2007).

My research on these culinary herbs or spices revealed that their medicinal, seasonings, flavouring and fragrance values are due to complex mixtures of numerous secondary metabolites in these plant parts are chemotypes like eugenol, thymol, citral, ethyl

cinnamate, geraniol and linalool which have been identified to be important medically and economically (Mann, 2011).

6.1.6 Natural Products Containing Antitrypanosomal Properties

Nupeland is located on the coastal basins of Rivers Niger and Kaduna in North Central Nigeria with savannah-forest vegetational biodiversity rich in medicinal plants. This type of vegetation also harbours tsetsefly which are the vector of trypanosomes, thus making the area highly endemic to sleeping sickness. Nupeland inhabited predominantly by Nupe tribe are traditionally noted for generations of using medicinal plants in curing human trypanosomal infections; many of which have not been scientifically proved. In our effort to identify secondary metabolites with antitrypanosomal activity, we have worked on several plants which are implicated in Nupe ethnomedicine for management of trypanosomiasis.

In this regard, we were prompted to conduct screening of plants for biological activities on *in vivo* and *in vitro* tests which was supported with OPCW Research Grant L/CA/ICB/153507/09: Chemotherapy of Malaria and African Trypanosomiasis: Exploring the Therapeutic Potentials of Nigerian Medicinal Plants". Phytochemical analysis and *in vitro* antitrypanosomal activity of selected medicinal plants in Niger State, Nigeria revealed significant *in vitro* antitrypanosomal activity and these plants may be potential source for the *in vivo* treatment of trypanosomiasis. Evaluation of the antitrypanasomal activity of Nupeland medicinal plants indicated remarkable antitrypanosomal activity (Haruna *et al*., 2017; Madaki *et al*., 2016; Mann *et al*., 2009b; Mann & Ogbadoyi, 2012).

6.1.7 Natural Products Containing Antidiabetic Properties

Nupe tribe is traditionally noted for centuries of using medicinal

plants in curing human diseases including diabetes (Mann *et al*., 2003).

In this connection, our research team carried out many phytochemical and antidiabetic evaluation of selected medicinal plants in Niger State, Nigeria and the studies of hypoglycemic effect indicated decrease in the blood glucose levels of rats in most cases as *Anacardium occidentale* leaves (Saidu *et al*., 2012); *Globimetula braunii* is a parasitic plant (mistletoe) used to treat diabetes and hypertension by Nupe speaking people of Niger State, Nigeria (Muhammad *et al*., 2014a).

A woody climber plant, *Gymnema sylvestre* **Plate VIIb** also known with these common names: Cowplant and Miracle Plant is found in tropical forests of India and Africa and used in diabetes management. In Nigerian traditional medicine, *G. sylvestre* is popularly known as sugar destroyer (*Kashe zaki* in Hausa; *Enugi-bata* in Nupe), this is due to its ability to suppress sweetness of sugar. Several scientific research evidences suggest that *G. sylvestre* is efficacious for the management of serum glucose levels in type 1 and type 2 diabetes. Gymnemic acids are thought to be responsible for its antidiabetic activity and it is the major component of an extract shown to stimulate insulin release from the pancreas. Our research objective is to identify the bioactive gymnemic acid [**25**] as one of the drug constituents or biomarkers responsible for the control and management of diabetes (antidiabetic activity) in the locally grown *G. sylvestre* for local and international utilisation as part of our contribution to knowledge (Ila, 2017; Andrew, 2019) in drug discovery for the control and management of diabetes.

6.1.8 Natural Products Containing Antimalarial Properties

After many years of struggle with malaria, the disease is still an important health concern. Currently, it is very endemic in

tropical and sub-tropical countries of the world, such as Nigeria:

(i) In pursuance of our search for antimalarial drugs of plant origin, we worked on "Bioactivity-driven Chemical Investigation for the Novel Cytotoxic and Antimalarial Compounds from the Lesser-known plants used by Kambari tribe in North Central Nigeria" which was a Research Grant given to our team from the University Board of Research (UBR) that enabled us to embark on the antiplasmodial activity screening of Nigerian medicinal plants. *Hyptis pectinata* and *Solanum incanum* leaves contain important phytochemicals responsible for their antiplasmodial activity and these results have supported the traditional usage of these plants for treatment of malaria (Ado, 2017).

(ii) Furthermore, ETF Research Grant ETF/DESS/RP.AIP/B1/BIDA/VOL.1/2011: "Ethnobotanical Survey and Antimalarial Studies of Plants Used for Treatment of Malaria in Nupeland of Central Nigeria", we evaluated the antimalarial activity, phytochemical constituents and the acute toxicity of the methanolic extracts of Monkey's faru (*Lannea barteri*), Camel's foot tree or Monkey's bread (*Piliostigma thoningii*), Haggar bush or Garden quinine (*Clerodendrum aculeatum* and Three leaved-caper (*Crateva adansonii*) commonly used in the treatment of malaria. The presence of some of the phytochemicals in the plants' extracts could explain the reasons for their use in the traditionally treatment of malaria (Nda-Umar *et al*., 2017).

(iii) Another Research Grant TETFUND/FUTMINNA/2014/24: "Exploring the Therapeutic Potentials of Nigerian Medicinal Plants for the Chemotherapy of Cancer, African Trypanosomiasis and Malaria" with me as a co-researcher assisted the purification and structural identification of the

mosquito larvicidal compounds present in *Ocimum gratissimum* leaf extracts against *Culex quinquefasciatus* mosquito larvae that gave caryophyllene oxide [**16**] at 2.21ppm after 24 h with percentage mortality of 100% (Adefolalu *et al*., 2015). A related research on evaluation of the antimalarial activity of the crude extract and fractions of *Phyllanthus amarus* in *Plasmodium berghei*-infected mice and showed significant antiplasmodial activity crude extract and aqueous fraction at 76.74 and 56.40 % inhibition of parasite growth (Alozieuwa *et al*., 2018). Furthermore, the antimalarial potency of three plants (*Nauclea latifolia, Terminalia glaucescens* and *Agauria salicifolia*) traditionally acclaimed in Nso ethnic tribe in Cameroon to treat malaria were evaluated. The purification and structural identification of the pentacyclic triterpenoids: lupeol, β-sitosterol, stigmasterol and β-amyrin were found in *T. glaucescens* extract that exhibited potent antimalarial activity and can be exploited for antimalarial drug development (Eustace, 2019).

6.1.9 Natural Products Containing Other Pharmacological Properties

We also worked on the area of reproductive health on collaborative basis with colleagues on natural products with contraceptive and aphrodisiac properties.

(i) *Eriosema psoraleoides* is an ethnomedical plant used among the Nupes for fertility control. The crude seed extract of *E. psoraleoides* exhibited common biochemical changes associated with the synthesis of steroidal compounds involved in the inhibition process of ovulation. It further suggests that the crude extract mediates its effect via the mixed functional oxidase pathway rather than the conjugate glucuronide pathway (Mann *et al.,* 2007b).

(ii) Aphrodisiac activity of *Byrsocarpus coccineus* (short pod) root extract was evaluated. Aphrodisiac activity of both the crude extract and the ethyl acetate fraction were found significant on wistar albino rats, which is an indication that the ethyl acetate fraction contains more of the phytoconstituents responsible for sexual drive. Therefore, *B. coccineus* root extract could be recommended for the treatment of low libido and sexual dysfunction in human beings as claimed by the traditional healers (Muhammad *et al*., 2018).

Therefore, pecking into the world of secondary metabolites in plants: A tool for building a healthy and wealthy nation is my modest contribution of scientific investigations of indigenous plants from Nigerian biodiversity which is necessary before therapeutic utilization. However, most of the investigations were stalled at the active extracts, fractions and purified fractions due to the unavailability of state-of-art equipments required for purification and structural characterization. Due to these problems, we adopt the new paradigm shift to sustainable drugs and global health care delivery services of using phytomedicines supported by evidence-based approach of pharmacological, chemical and clinical studies which gave assurance of safety, quality and efficacy of medicinal plants and herbal products involved (UNU-IAS, 2015). There are enormous researches of herbal products for the remedy of ailments e.g. several antidiabetic products such as Diabecon®, Glyoherb, Diabeta Plus, had been developed and are available in the global market for management of diabetes. Our Natural Products Research Group adopted this new approach because of its potentials to back role creating solutions to global health concern.

6.1.10 Herbal Product Development

In furtherance of the above and based on the philosophy of this great University of Technology to proffer solutions to local and

global problems, the main purpose of our Natural Products Chemistry Research is to peck into our local medicinal plants in order to translate our cultures associated with these medicinal plants into the development of viable alternative medicines based on the bioactive components and safety. Since herbal product development is central to value addition of turning medicinal plants into drugs which will bring about easy accessibility and affordability of chemotherapy to the wider society.

Our Natural Products Research Group has been involved in the medicinal plant research over the years with the focus of moving the research from academia into the market place. Most herbal remedies in Nigeria came from traditional medicine. Evidently, these standardized herbal products as shown in **Plate VIIc** were found adequate in macronutrient, micronutrient and phytochemical profiles that can retard and prevent the proclaimed diseases. Therefore, similar to the phytomedicines from India and China as well as those formulations from local plant extracts namely: NIPRISAN, a preparation for the Management of Sickle Cell disease and CONAVIL of HIV/AIDS developed by NIPRD. Our research findings led to the formulation of eight phytomedicines for the management of diabetes, ulcer, hypertension, asthma, tuberculosis, cancer, African trypanosomiasis and venereal diseases **(Plate VIIc)** as exhibited during 5th Nigerian Universities and Research Development Fair (NURESDEF) (Mann *et al*., 2012b) and in other similar fairs. Arrangements are ongoing to patent these phytotherapeutic agents.

6.2.0 ENVIRONMENTAL CHEMISTRY

Mr. Vice-Chancellor sir, distinguished ladies and gentlemen, my interest in this area of study was informed by the large body of agricultural and industrial wastes especially of organic compounds such as pesticide residues and polycyclic

hydrocarbon without due consideration for the hazardous nature of such wastes. As Organic/Natural Products Chemists, we are interested in the levels of these organic contaminants. We started research in this area in the Department of Chemistry in 2011, in which I have supervised 1 MTech and 1 PhD students in pesticide residues area and 1 PhD in biodiesel production to mitigate the effects of global warming due to fossil fuel consumption. We have recently graduated a PhD student in polycyclic hydrocarbon in this area of research. In addition, we have also supervised two PhD graduates in the area of development and application of biosorbent employed in the purification of heavy metal contaminants as well as many MTech graduates in corrosion inhibition using Natural Products as corrosion inhibitors and we have made very useful contributions to this discipline which are available for industrial applications.

6.2.1 Assessment of Pesticide Residues in the Environment

Agricultural practices often include the use of pesticides to enhance crop yields. However, constant use of pesticides often caused pollution of soils and water worldwide. This was the work of my first PhD student, Dr. I. C. Ogbonnaya who assessed and detected organocholorine and organophosphate residues in the soils and water from Fadama farming communities in Minna and Bida, North Central Nigeria (Ogbonnaya *et al*., 2018).

6.2.2 Assessment of Polycyclic hydrocarbon Residues in the Roasted Foods

Food that is not stored or preserved can be attacked by spoilage agents such as microorganisms which release spoilage enzymes to the food, insects and animals. The attack by spoilage agents may lead to the breakdown of the food components particularly the nutrients to yield amongst others undesirable biomolecules. To combat this problem, various methods of preservation/storage have been evolved such as smoking which

is an age-long practice. However, the outer layers become coated with deposits of tars, phenols and aldehydes which have powerful bacterial action and this is why the process has a preservative effect. Indeed, guaiacol (2-methyoxyphenol) present in fairly large concentrations in smoke has been associated with the bactericidal effect. Toxic hydrocarbons are dangerous constituents of natural smokes. The most dangerous known component is the polycyclic hydrocarbon, 3, 4–benzopyrene which is a carcinogen. Moreover, the washing of smoke-dried fish and meat before being cooked and consumed, reduces or totally eliminates the carcinogenic substance in view of its high solubility in water. We investigated the polycyclic aromatic hydrocarbons (PAHs) and heavy metal contents of barbecue fish, beef and chicken obtained from Minna, Niger State, Nigeria using standard procedures. The study revealed concentrations of the metals in chicken and beef samples were in the general order: Fe>Pb>Cu>Mn. The study also advised the need to continually check the contents of PAHs and heavy metals in barbecue food since they have bio-accumulative tendencies which is deleterious to health (Inobeme *et al*., 2018).

6.2.3 Natural Products Containing Biosorbent and Corrosion Inhibitor Properties

Environmental contaminations are caused by anthropogenic activities include: application of fertilizers, traffic and heavy metals has been a worldwide concern to both the governmental and regulatory bodies that are anxious to prevent further environmental deterioration due to toxicity to plants/crops, animals and humans. Several reports indicated that metals can bioaccumulate in plants and eventually find their way to animals and humans eating them. Numerous studies on the agricultural by-products as source of activated carbon indicated high adsorption ability (biosorbent) for heavy metal removal (Jibrin *et al*., 2015; Musah *et al*., 2016).

6.2.4 Natural Products from Wild Plant Seeds for Biodiesel Production

Biodiesel has gained support and recognition as a fuel to replace fossil fuel which has cause a lot of damage to the environment. The world has been confronted with an energy crisis due to depletion of resources and increased environmental problems, therefore exploitation of bioenergy and phytoremediation has attracted much scientific and commercial attention. Nigeria is well known for many under-utilized wild seed husks and vegetable oils (both edible and non-edible) from the fruit wastes which constitute environmental nuisance. Production and characterization of the biofuel derived from wild Nigerian grown plant seeds to mitigate the global warming effects has been our focus (Otori *et al*., 2018).

CONCLUDING REMARKS

Mr. Vice-Chancellor sir, Principal Officers, distinguished guests, ladies and gentlemen, we are created by Almighty Allah and He has made adequate provision for our existence including the type of plants needed by each community and Nation. Thus, He provides us secondary metabolites and endowed us with the appropriate knowledge of chemical techniques of isolation and structural elucidation so that we will be able to live a healthy and wealthy life free of diseases and other environmental hazards.

- Although a lot of research to discover new, effective and cheap drugs is in progress in the disease endemic developing countries, it is not yet possible to fully develop leads and drug candidates from natural products, hence, people in these countries continue to rely on traditional medicines. Poor economies and technological capabilities, lack of human resources (experts), and good management and possibly government non-chalant attitude or policy in these countries are the major constraints to progress in research and development work for new drugs and agrochemicals.

- During the course of my search of Nigerian plants for secondary metabolites to date, I have worked on several plants from which I have isolated, characterized and identified 6 compounds (triterpenoids and carboxylic acids). This has provided the scientific template for the exploitation of some medicinal plants for future development as antiinfective, antimalarial, antidiabetic and insecticidal agents. Development of drug requires the wide involvement of all relevant stakeholders (industry, academia, drug regulatory agencies, and international policy-making agencies) who must collaborate effectively to deliver optimal future therapies for diseases.

- This has been made possible by scholarships and research grants received, which include the ETF, TETFund, and UBR of Federal University of Technology, Minna. In the course of my career, I have produced two PhDs (Drs. Ogbonnaya, I. C. and Otori, A. A.) and co-supervised four other PhDs with twenty one MTech graduates in Chemistry in different positions in academia, while currently training three PhD and one MTech students. In addition, I have co-supervisd many PhD and MTech graduates from Departments of Biochemistry, Microbiology and Physics (development of solar cells in battery).

- Mr. Vice-Chancellor sir, I hope I have shown in this lecture that chemistry plays a critical role in broadening the knowledge base by providing a ''platform'' for understanding and investigating the fundamental properties of atoms and molecules. Plants take their energy from the sun to produce what we use as foods, medicines and other secondary metabolites needed for the survival of humanity. Diverse secondary metabolites will continue to be biosynthesized as long as plants exist in nature. Our natural environment is full

of untapped novel secondary metabolites for exploration and exploitation by man for a healthier and wealthier living through the application of techniques in natural products chemistry. The lecture also show the various biologically active extracts, fractions and compounds extracted from plants found in our environment. Nigeria is home to thousands of indigenous and naturalized plants; many of which have been used for centuries as medicinal plants. Many of these plants have diversity of secondary metabolites with pharmacophores (biological activities) for applications to solve human problems. Many of these plants serve a dual function both as a food and medicine. Common ailments traditionally treated with plants include: malaria fever, cancer, diabetes and tuberculosis. Each has been treated efficaciously with some herbs from plants indigenous in Nigeria. For us to make significant impact in national and global science and economy, we have to utilised our natural resources by involving ''Cutting-Edge Chemistry'' research and training agenda that must be innovative in its methodologies and relevant. Improved quality, increased attention to the scientific study of these plants, and more favourable public policies are needed to strengthen this sector and provide economic opportunities to all those involved as well and provide more affordable medicines and agrochemicals. Nigeria does not currently have the capacity to develop modern/orthodox drugs. Nigeria should add value to traditional medicine and scientists should collaborate and formulate herbal medicines from research data: reduce drug importation costs, improve drug availability.

- My current research endeavour involves marine organisms, since Niger State is full of many rivers and water bodies, we have started investigating her biodiversity niches that harbours many venomous marine organisms, specifically the

freshwater venomous fishes: stingrays (*Potamotrygon garouensis*; Nupe: Efafinin) and puffer fish (*Tetraadon fahaka strigosus*; Nupe: Finyan) from Rivers Niger and Kaduna, Nigeria. This is with the aim of isolating the untapped biologically active compounds that could be useful sources of pharmacological leads for the development of human and animal chemotherapy.

RECOMMENDATIONS

Based on my experiences as an Organic/Natural Products Chemistry researcher, I have reviewed the past, the current trend and insight into the future of natural products chemistry, my humble contribution to this field of scientific innovation, medical and economic impact of this unique science known as natural products chemistry. It is therefore my hope that the stakeholders will begin to appreciate the pains, frustrations and sacrifices of pecking into world of Natural Products research. I wish to make the following recommendations:

- From the natural products chemistry point of view, we strongly advise the consumption of our traditional culinary herbs or spices such as vegetables, legumes and fruits which are rich in vitamins, minerals, dietary fibres and disease-fighting secondary metabolites to minimize or prevent the incidence of diseases like coronary heart diseases, diabetes and certain categories of cancer. E.g. baobab tree leaf (*Kuka*), ginger rhizome (*Chitta*), locust beans seed condiment (*Dadawa*), clove buds (*Kanufari*), garlic bulb (*Tafarnuwa*) and tamarind fruits (*Tsamiya*) are important constituents of ethnodietetics (traditional dishes) which are highly potential functional foods. Vegetables that possess colours (purple, red, green and orange) such as apple, carrots and oranges are known to contain carotenoids and anthocyanins which are disease-fighting secondary metabolites.

- ❖ It is a known fact that drug discovery pipeline in modern drug discovery is tedious and getting dry and modern world is looking towards the herbal world with great expectations. So sustainable utilization of scientifically approved semi-purified fractions of indigenous medicinal plants as herbal medicine will contribute greatly towards the socio-economic upliftment of Nigeria by making manufacturing of herbal medicine a viable venture and simultaneously providing good quality life for all.

- ❖ It is expected that the activities of the scientific community and entrepreneurs will strengthen the medicinal plant sector in Nigeria, by making comprehensive policies, formulating projects to supplement the R&D activities and creating an environment abling for the growth of plant-based medicine industry that will bring economic benefit to the nation through the rising in global demand for medicinal plants. It will also help Nigeria to improve the health of their people by using their own resources and a system of medicine which is less expensive than modern medicine.

- ❖ There is the need for the Natural Products Chemist to continue to be interested in the chemical structures and bioactivity of the secondary metabolites from the indigenous plant sources around us. All we need is the provision of necessary facilities, since the most 'equipped' laboratories in Nigeria barely host enough instrumentation to enable the performance of adequate extractions, purifications, isolations and characterizations. For Chemists to be able to put themselves forward as Natural Products Organic Chemists they need extensive training up to the PhD and postdoctoral levels. They should have state-of-the-art analytical spectrometers and facilities for the proper identification of the compounds that are isolated from

natural sources or synthesized products. The Spectrometers required are Nuclear Magnetic Resonance (NMR), Fourier Transform Infra-Red (FT-IR) spectrometers, Recordable Double Beam Ultra-Violent spectrometer, Gas Chromatography/Mass Spectrometers (GCMS). Lack of these vital instruments seriously hamper quality work to be done in Nigeria, as such all our bright promising young academics are going abroad to develop at our expense. If these pieces of equipment are acquired for our laboratories, it will enable quality work to be carried out that would assist generation of quality published works before they get bogged down with teaching and administration.

- Ample laboratory space is of paramount importance for research to grow in the sciences. The ideal situation is for a **Professor of Chemistry** to have a laboratory where he carries out his research with his students. A situation where a professor in science does not have a laboratory dedicated to him is abnormal. I hope adequate provisions in the design and construction of the School of Physical Sciences is made in Gidan Kwano in order to provide more laboratories for research work and conduct of experiments. By so doing we will have more research output that will elevate FUT to higher ranking institution in research.

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PROFILE OF THE INAUGURAL LECTURER

Born 58 years ago to the family of Mallam Abubakar Gbafi of Emimallam Habibu, Bangbara, Bida by the late Alhaji Hussaini Ndamasin Umaru-Mann and Hajiya Hauwa-Kulu Hussaini, Prof. Abdullahi Mann had his primary education at Kuchi Primary School from 1968 to 1973. From there, he proceeded to the Government Secondary School, Rijau, Niger State and Zungeru College Arts and Science (ZUCAS), for his Secondary Education. Thereafter, he proceeded to the Bayero University, Kano for his tertiary education where he obtained B.Sc. in Chemistry and M.Sc. Organic Chemistry. He attended the prestigious Ahmadu Bello University, Zaria where he got doctoral degree in Organic Chemistry in 2010.

During this period, he received several awards, scholarships and fellowships including:

- Niger State Government Scholarship – 1982–1987.
- Federal Government of Nigeria Scholarship – 1991.
- Fellow, Chemical Society of Nigeria – 2010.
- Fellow, Institute of Chartered Chemists of Nigeria (FICCON) – 2012.

Prof. Mann, after his National Youth Service, began a teaching career as an Assistant Lecturer in 1988 at the Federal Polytechnic, Bida and rose to the rank of Chief Lecturer in July, 2003. In September, 2011, Professor Mann transferred his services to the Federal University of Technology, Minna as a Senior Lecturer and with self-determination, hard work, dedication and personal sacrifice he was elevated to the rank of Professor in 2016.

His well-deserved elevation to this rank is the manifestation of an outstanding scholarly career in the University system. His research achievements include co-authoring of a book that had contributed immensely to the study of natural products chemistry in Nigeria: Mann, A., Gbate, M. and Nda-Umar, A. (2003). Medicinal and Economic Plants of Nupeland. Jube-Evans Books and Publications, ISBN 978-33921-9-0, Bida, Niger State, Nigeria, 276. He had been a member of two collaborative research projects, namely: Chemotherapy of Malaria and African Trypanosomiasis: Exploring Therapeutics and Potentials of Nigerian Medicinal Plants financed by the Organisation for the Prohibition of Chemical Weapons (OPCW) and Conservation of Medicinal & Economic Plants of Nupeland (especially the endangered species) financed by the Global Environment Facility/Small Grants Programme ("GEF/SGP"). His other scholarly works include: over sixty published works in reputable Journals and Conference Proceedings at International meetings in South Africa, India, Dubai and Pakistan.

Prof. Mann also successfully combined his research activities with a productive teaching/students supervision programme in the University. In the course of his career, he has produced 2 PhD holders as major supervisor and 8 PhD holders as co-supervisor. He has also supervised 21 MTech students and over 35 BSc holders. Many of his former students currently hold high positions of authority in Government and in the organized private sector.

Prof. Mann has held several administrative positions in the Polytechnic and University systems over the years.

(i) Member, Governing Council**,** The Federal Polytechnic, Bida (2007 – 2008).

(ii) At various periods he served as HOD, SLT., Dean, School of Applied Arts and Sciences and Director, Academic Planning Unit at Federal Polytechnic, Bida (199 – 2011).

(iii) Head, Department of Chemistry, Federal University of Technology, Minna (2017 – date).

(iv) Member of Several University-wide Ad-hoc Committees at FUT, Minna.

His contributions to national development are equally very impressive. He has served as a member (Resource Person) of National Board for Technical Education in Accreditation Visitation Team to several Nigerian Polytechnics.

Some of his other state and national assignments include:

- Chairman, Technical Working Group (TWG) on Traditional Medicine Practice in Niger State, Niger State, Ministry of Health & Health Services (2015 to date).
- Participated and presented a position paper on: Chemical substances released into the environment to the Brain Storming Workshop on Review of the Niger State Waste Management Framework, 2016 sponsored by United Nations Development Programme (UNDP) in collaboration with Niger State Government in 2017.

Prof. Mann has contributed to the development of other polytechnics and universities through his participation as External Examiner to:

i. The Federal Polytechnic, Idah, Kogi State (2005 – 2008)
ii. Kaduna Polytechnic, Kaduna, Kaduna State (2005 – date)
iii. Nigerian Turkish Nile University, Abuja – 2014
iv. Ahmadu Bello University, Zaria – 2014 – date)
v. University of Abuja – 2018
vi. Federal University, Lafia – 2018
vii. Federal University, Dutsin-Ma – 2019
viii. Nigerian Defence Academy, Kaduna – 2019.

Apart from the professional achievements, Prof Mann devoted considerable effort to community service as he served as:

i. **Chairman**, Kuchi Development Association (KUDA), Lavun Local Government, Niger State 2001 to 2003.
ii. **Chairman**, Ndayisa Multipurpose Cooperative Society Ltd, Lavun Local Gov't Area, Niger State 1987 to 2003.
iii. **Chairman**,Education Programme of Bida Youth Association (BIYA) 2000 to 2005.
iv. **Chairman**, Shura Committee, Muslim Ummah, The Federal Polytechnic Bida, Niger State 2004 to 2011.
v. **Magajin Garin Kuchi**, Kuchi Gbako, Bida Emirate Council 2006 – date.
vi. **Member**,Regional Centre of Expertise (RCE, Minna)which is a non-governmental organisation (NGO) founded in 2011 under UNU-IAS authority.

His activities and contributions in these positions have touched the lives of several people, who in turn, have influenced the attitudes of others.

Prof. Mann is happily married to Halima Mann and Asmau Mann who have created a harmonious environment for a stable family and pursuit of academia. They are blessed with children.