OSUN STATE UNIVERSITY

INAUGURAL LECTURE

SERIES

003

Exploring the Vegetables' World: Nutraceutical and Physiological Investigations

By

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It is my pleasure to stand before this august audience today to give an account of my stewardship in the wilderness of scientific research in the field of Agronomy majoring in Plant Physiology. The research journey has been interesting taking me through the road, many times smooth, sometimes tedious, seldom tiring and once-a-while frustrating. I am euphoric because this is the first Inaugural Lecture that is coming from the Department of Agronomy, the first of its kind in the College of Agriculture and the 3rd to be organized and chaired by the pioneer Vice-Chancellor, Professor Sola Akinrinade in the history of Osun State University since it was established in September 2007. Since ours is a new University, I will like to explain the meaning of Inaugural Lecture and I take my lead from the presentation of the Imperial College, London:

"Imperial's Inaugural Lecture series provides a platform to showcase and celebrate the College's new professors. Each lecture represents a significant milestone in an academic's career, providing official recognition of their promotion to professor, bringing benefits to the lecturer, their Department and Imperial as a whole. For *new professors*, the lecture provides an opportunity to present an overview of their research career so far, update colleagues on current and future research plans, and introduce their research to wider audiences. An Inaugural Lecture, scheduled for about one hour only, represents a significant milestone in any academic's career and it marks the formal and official recognition of your promotion to Professor."

Mr Vice-Chancellor Sir, the above illustrates exactly what I will do in the process of delivering this lecture titled "**Exploring the Vegetables' World: Nutraceutical and Physiological Investigations"**. I will raise questions that informed all my scientific investigations and subsequently give answers or at best hypothesize on what I think about the questions. I will also use questions to answer questions and sometimes I will tell the audience that only God knows ! I will mention the details of how we identified each problem and what was done to subdue the problem. Finally I will make recommendations regarding what I expect from the larger community, Osun State and Nigeria as a response to the issues that I will raise.

Definitions of concepts:

The term **nutraceutical** was originally defined by Dr. Stephen L. DeFelice, founder and chairman of the Foundation of Innovation Medicine (FIM), Crawford, New Jersey. Nutraceutical, a term combining the words "nutrition" and "pharmaceutical", is a food (such as cereals, fruits, vegetables and beverages) or food product that provides health and medical benefits, including the prevention and treatment of diseases. Examples: beta-carotene, lycopene, ascorbic acid etc.

Plant physiology is the study of the mechanical, physical, and biochemical functions and processes of living plants. In plant physiology, we apply scientific methods to determine how the living plant, its organ systems, its organs, its cells and its biomolecules carry out the chemical or physical functions that operate in a cystosolic system. Plant physologists assess the functions and processes in living plants by looking at the whole plant level, cellular level and even subcellular level.

What is special about plants?

I have used my entire research life studying the physiology, nutritional profile and production of indigenous vegetables of Southwest Nigeria. My works have been on diverse species but my in-depth studies have been carried out on the nutraceutical and physiology of the Nigeria Snake Tomato (*Trichosanthes cucumerina* L) which the Yoruba call "Tomati Elejo". Perhaps to follow this lecture, I will like to first introduce the audience to the elementary world of plants:

1. Of all living organisms in this planet, the green plants are the only ones that live in two environments at the same time. A portion (root) inside the soil (dark regime) and another portion (shoot) in the open space (light regime-above ground). Plant Physiologists indeed marvel why this is so! This accounts for why higher plants are physically immobile despite being far more structurally and functionally advanced than some moving animals.

2. If not for the presence of plants on this planet, perhaps there will be no living animals here today. Not just because plants produce food for animals, but principally because the green plants absorb and filter the toxic CO_2 that comes from all sources in the processes of life. The plants utilize the CO_2 as a raw material for manufacturing carbohydrate through a process called photosynthesis. High concentration of CO_2 in the biosphere is really injurious to human survival.

3. Green plants, using the chlorophyll, harvest and utilize substantial proportion of solar radiation from the sun for the synthesis of carbohydrate also through photosynthesis. Indeed, the world would have been hotter were it not for green plant intervention. Plant Physiologists believe that green plants are created to protect man!

4. Green plants are very interesting because they possess mechanisms for upward movement/pumping of water and minerals via the root system from the soil to photosynthetic and growth sites. They also possess another mechanism for the transport of photosynthetic products (carbohydrate) from the green leaves to tissues and organs. This two-way transport system occurs only in green plants, it is not known in any other creation.

5. Plants have excellent and error-free communication network and signal recognition mechanism which are quite precise and infallible. Studies have shown that the time for the different enzymes to act in the different protoplasmic reactions, which nutrient to absorb and in what quantity, time to flower, time to shed leaves, etc are all programmed and guided by signals. The processes are carried out without any confusion in the complex cystosolic system. For a normal growing plant there is no network failure!

6. Green plants possess mechanisms to react violently to unfavourable "living" conditions that are either naturally imposed on them or those conditions that are imposed on them by man. We know that plants protest just the same way responsible people protest against irresponsible policies. Before drought or herbicide kills a plant, a lot of protest and violence must have taken place in the plant protoplasm. Death of plant indicates that the struggle for survival has been lost!!

Indigenous Vegetables of Nigeria

Mr Vice-Chancellor sir and distinguished audience, I wish to inform you that science has so far identified about 350,000 plant species comprising about 700 gymnosperms and 280,000 angiosperms. Many more plants remain to be discovered. It may interest you to know that of the 150 food-plants commonly consumed by man, 115 are indigenous African species and the world's major regions of crop diversity include Ethiopian highlands, the Sahelian transitional zone, the delta of Niger River and the humid forest zone of west and central Africa (Kiambi and Atta-krah, 2003). Endemism, which is the proportion of species not found anywhere else in the world, is high in Africa (Kiambi and Atta-krah, 2003). Endemism in Tropical Africa at the general level has been estimated to be 45% (Sayer *et al*., 1992). The Food and Agricultural Organization (FAO) of the United Nations (1998) reported that countries of West and Central Africa sub-regions have a large number of underutilized species that are important to the livelihoods of local population. On the list are 7 cereals, 8 legumes, 4 roots and tubers, 8 oil crops, 31 fruits and nuts, 17 vegetables and spices, 4 beverages, 38 medicinal plants and 44 genera of forages.

This list is not exhaustive because Adebooye *et al*. (2003) reported an expanded list of twenty-four indigenous leaf vegetables that are eaten in southwest Nigeria only. It may interest this audience to know that our study in Nigeria revealed that what is considered a weed or poisonous plant in a location is a well-cherished vegetable in another location. Several other species have been listed by Okafor (1978, 1983) in Eastern Nigeria, Abbiw (1990) in Ghana, Chweya (1997) in Kenya, , Rubaihayo (1997) in Uganda, Seck *et al*. (1997) in Senegal and Okigbo (1977) for the entire tropical Africa. The Wageningen University, Netherlands' Plant Resources of Tropical Africa (PROTA) (2004) reported an estimated 30,000 plant species for Tropical Africa and of these, only 6,376 (21%) are used by man. The PROTA called this 21% the "Basic List". The 6,376 useful indigenous African plants are made up of 1,975 medicinal plants, 820 timbers, 611 forages, 533 ornamentals, 477 fruits, 397 vegetables, 377 fibers, 240 essential oil and exudates, 220 auxiliary plants, 176 carbohydrate plants, 130 spices and condiments, 129 dyes and tannins, 104 fuel plants, 80 cereals and pulses, 54 vegetable oils and 53 stimulants. The PROTA in 2004 published the contributions of 103 authors and 46 co-authors on detailed cultivation practices for 280 African indigenous leaf vegetables. This publication included the first ever world report on the cultivation and production of "Woorowo"- *Solanecio biafrae* by this lecturer.

Indigenous leaf vegetables and fruits are an integral part of agricultural systems in Africa. Unfortunately, most African governments have not given them priority in crop development. Adebooye *et al*. (2003) reported that of all mention of the status of food in Nigeria, indigenous leaf vegetables often disappear. Most studies on leaf vegetables and fruits in research institutes and universities have focused on the routinely cultivated species. Today the importance of African indigenous leaf vegetables and fruits to human nutrition, medicine and nature has been realized. Hence the United Nations (UN) in 1986 established the Institute for Natural Resources in Africa (INRA), an arm of the United Nations University in Accra, Ghana, to build endogenous African capacity and strengthen national institutions to promote sustainable use of the continent's natural resources for development. The focus of INRA is research and training on conservation of African food plants' diversity and soil conservation. Some other African governments have shown some form of interest in indigenous plants resources conservation, but the evaluation of their genetic variability for agronomically desirable traits is still in its infancy.

In our work on status of conservation of the indigenous vegetables of Southwest Nigeria (Adebooye and Opabode, 2005), it was stated that Africa's plant diversity is being seriously eroded as a result of multiplicity of environmental, political and socioeconomic factors. As a result of the ever-increasing human population, greater competition for natural resources and some interplay of natural and human factors, Adebooye and Opabode (2005) advanced some reasons for the erosion of African indigenous plant resources. These include:

1. Erosion of culture and breakdown of traditional systems of plant resources management resulting in the loss of traditional varieties;

2. Focus on only a few crops to the extent that the industrial growth globally is dependent on continued supply of those few "elite crops" at the expense of the traditional varieties;

3. Deforestation, salinization, desert encroachment and erosion which lead to land degradation with concomitant loss of the plant genetic resources that the land supports;

4. Natural disasters, including droughts, floods, pests and diseases, which have led to widespread losses of plant diversity from both farmers' fields and natural habitats;

5. Climate change which poses a threat to diversity, as many plants are unable to cope or adapt to changing temperatures and moisture gradients coupled with salinity caused by global warming and the associated climate change;

6. Political instability, civil unrest and insurgency that have led to loss of genetic resources in fields as farmers flee from war torn areas and as *ex-situ* conservation facilities are destroyed;

7. The research mandates of most institutions focus on the routinely cultivated species at the expense of the indigenous species. This has resulted in the continued and ever-increasing relevance that the routinely cultivated species are enjoying; and

8. African governments are not making adequate investment in the area of conservation of their indigenous plants heritage.

IMPORTANCE OF INDIGENOUS LEAF VEGETABLES AND FRUITS

Indigenous leaf vegetables and fruits play a key role in income generation and subsistence. For example, Adebooye (2004) reported that "Woorowo" *Solanecio biafrae* (Olive and Heirne) C. Jeffery, an indigenous leaf vegetable in Southwest Nigeria is several times more expensive than the routinely cultivated species especially during the dry season. Experience has also shown that other indigenous leaf vegetables such as "Ugu" *Telfairia occidentalis* f. Hook, "Soko" *Celosia argentea* L., "Tete" *Amaranthus cruentus* L and "Igbagba" *Solanum macrocarpon* L. are also sold at high prices during the dry season in Southwest Nigeria. In Kenya, the report of a survey conducted by Abukutsa-Onyago (2003) showed that indigenous leaf vegetables offer a significant opportunity for the poor people in western Kenya to earn a living because indigenous leaf vegetables production can be done with little capital investment. A direct effect of this is that these vegetables provide employment opportunities for those that are outside the formal sector.

Studies on chemical composition of indigenous leaf vegetables and fruits have shown that they contain appreciable amounts of crude protein, fat and oil, energy, vitamins and minerals (Adebooye, 1996; 2001; 2002; 2004; Adebooye and Bello, 1998; Chweya, 1997; USDA, 2002; 2003 among others). They have also been known to make food more palatable and digestible.

In addition to serving as vegetables and fruits, some plants are also sources of traditional medicine in Africa. Adebooye *et al*. (2003) documented the traditional medicinal uses of twenty-four indigenous leaf vegetables in Southwest Nigeria.

Modern science has isolated many natural products with active principles of medicinal importance from many indigenous vegetables.

The indigenous vegetable species are also adapted to many tropical conditions, pests and diseases. Therefore, they can be very good sources of genes for genetic improvement of cultivated species especially in the area of pests and diseases resistance. Also, the indigenous species can be improved by introducing desirable traits from cultivated species into them.

The Nigerian Snake Tomato Research

When I joined academia at the Obafemi Awolowo University, Ile-Ife, as a Graduate Assistant, my desire was to research maize (*Zea mays* L.). I loved maize because my mentor (Late Professor Clement Oluwole Alofe) was a maize agronomist. I had mapped out my plans for maize research but one fateful day, I visited a senior colleague (Professor Amos Eniola Akingbohungbe), who after a long chat asked me briskly; "What is your research plan?" I responded with pride; "Maize agronomy!" He felt worried and I saw it immediately on his face. He said; "Your best bet is underutilized vegetables research, don't work on maize." This was the origin of my research work on the underutilized Nigerian vegetables, a group to which the Nigerian Snake Tomato belongs. Indeed, my exploit in this field of research was guided by the first tip given to me by Professor Akingbohungbe. The story will not be complete without mentioning the name of Professor Isreal Olujide Obisesan who volunteered, in 1998, to assist me by submitting my first-ever research grant application on indigenous vegetables to the University Research Council, Obafemi Awolowo University, Ile-Ife. He had to take this "risk" because I was just an Assistant Lecturer, not eligible to apply for a grant, when I developed the proposal. The application was successful and it provided my first-ever research grant to the tune of one-hundred and forty-six thousand naira (N146,000) in 1998 !

The Nigerian Snake Tomato (*Trichosanthes cucumerina* L.) is a member of the botanical family Cucurbitaceae. The family includes about 70 genera and over 700 species, which are widely distributed all over the world (Robinson and Decker-Walters, 1997). The name, "Snake Tomato" is derived from the snake-like appearance of the fruit. We know that in India, a widely cultivated species is

T. dioca L. which resembles the Nigerian *T. cucumerina*. We also know about some Trichosanthes species that are used in traditional medicine in China.

My first task was to do literature search that took me about a year seeking information on what scientists in Asia and Africa knew about the *T. cucumerina*. The responses were the same from eminent scientists contacted: "There is dearth of information in the literature on cultivation practices and physiology of *T. cucumerina*". I was worried because in the hard economic times during the military era in Nigeria, house-wives were using the fruit of *T. cucumerina* as a replacement for the vine tomato. The report of my enquiry strengthened me and decision was taken on how to proceed.

My nutraceutical and physiological research on snake tomato therefore followed this sequence:

1. Survey and collection of the landraces/morphotypes available in Southwest Nigeria. This stage included interviews that generated the first information that I had on this plant. This aspect of the work was done with the assistance of my Bachelor and Masters students through the research fund provided by the Obafemi Awolowo University, Ile-Ife.

2. Characterization of the landraces using the fruit morphology only. This aspect of the research was done with the funds provided by the United Nations University, Tokyo, Japan.

3. Detailed laboratory investigation on the food value and nutraceutical profile of the fruit to ascertain or refute the claims of the farmers regarding the nutritional potential of the fruit. The United Nations University, Japan and Council for Scientific and Industrial Research (CSIR), India funded this work.

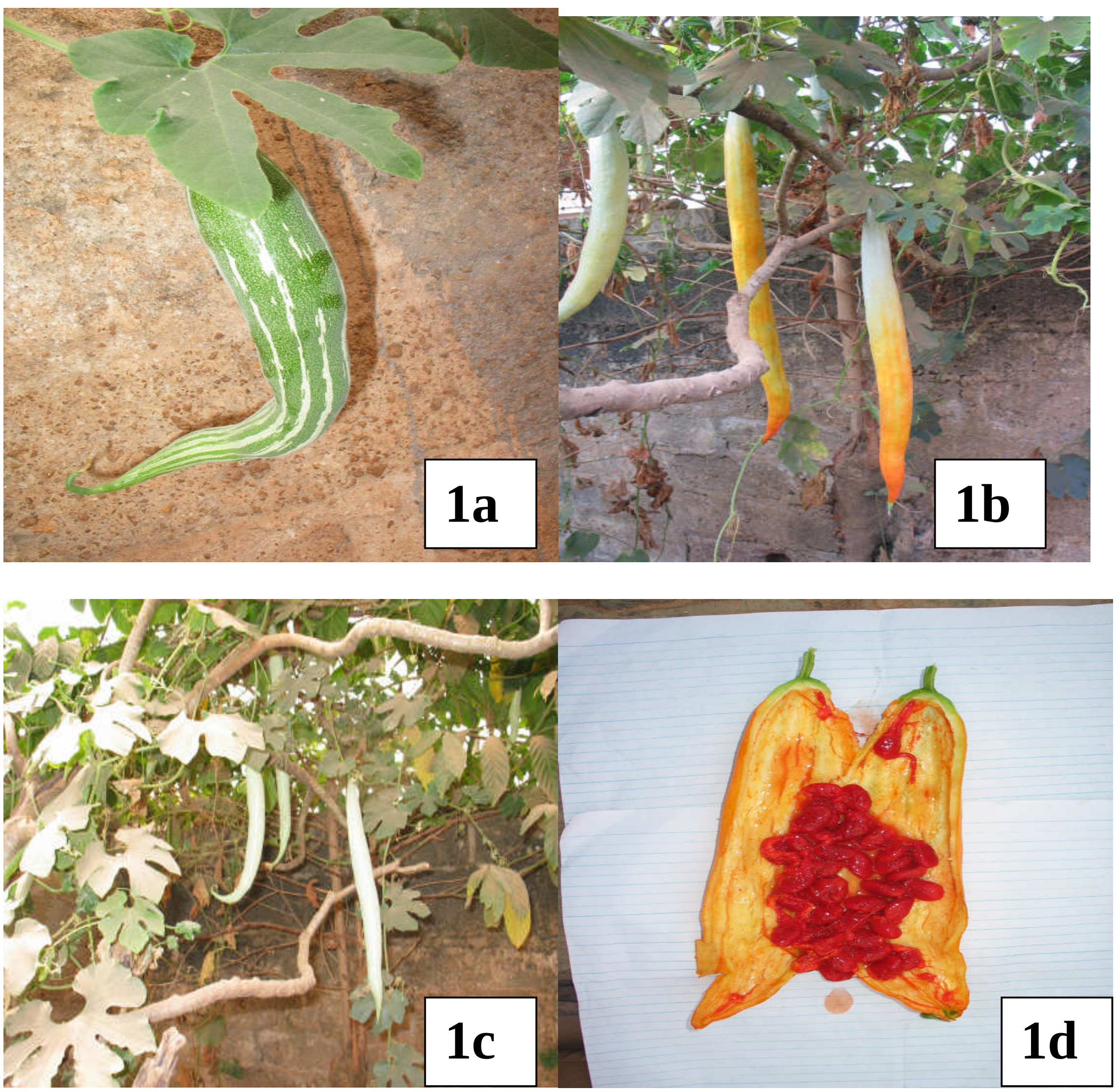
4. Field work to package agronomic practices for sustainable production of this plant. The World Academy of Sciences, Italy; Institute for Natural Resources (UNU) Accra, Ghana and Obafemi Awolowo University, Ile-Ife funded this work.

5. Advanced digitally controlled studies to elucidate the degree of "violence" that this plant can put up with when its physiology and existence are

threatened by natural or man-imposed stresses. The Alexander von Humboldt Foundation, Germany; Deutsche Forschung Gemeinschaft, Berlin; Forschungzentrum, Jülich and University of Bonn, Germany funded this work.

Morphotypes and Nutraceuticals of Snake Tomato

In Nigeria, my research work identified three landrace morphotypes of *T. cucumerina* which are distinguished on the basis of fruit colour. The three landraces were named by Adebooye *et al.* (2005) as Morphotype I (V_1), Morphotype II (V_2) and Morphotype III (V_3). V_1 has long fruit with deep green background and white stripes (Plate 1a), V_2 has short fruit with light green background and faint white stripes (Plate 1b) while V_3 has light green coloured long fruit (Plate 1c). The three landraces turn red at ripening(Plate 1d).



Adebooye *et al*. (2005) reported that *T. cucumerina* is used as a substitute to the vine tomato (*Lycopersicon esculentum* (L.) Mil) in southwest Nigeria especially by the poor people during scarcity of the vine tomato. The fruit pulp of *T. cucumerina* is sweet tasting, aromatic, deep red in colour and does not go sour as quickly as the paste of the vine tomato. These good qualities have made this plant a substitute to the vine tomato especially during the off-season when prices of vine tomato are very high, suggesting that consumption may be related to income level. The consumption was quite intense during the military regime in Nigeria when economic conditions were harsh, especially on the common citizens who could not pay for milk, egg and meat. We showed for the first time in world literature, with scientific evidence, that there is a "hidden" plant that can compete with and even replace the vine tomato in human diet. This report, published in the United States' *Journal of Vegetable of Science* was the first world report on the morphotypes, properties and use of Snake Tomato as a possible replacement for the vine tomato. Ethnobotanical information revealed that during the Nigerian Civil War (1968-1970) and just immediately after the Nigerian Civil War in 1970, fellow Nigerians in most parts of Eastern Nigeria used Snake Tomato as substitute to the vine tomato when there was no supply of vine tomato from Northern Nigeria.

Fruits and vegetables are good sources of natural antioxidants for the human diet, containing many different antioxidant components which provide protection against harmful free radicals and have been strongly associated with reduced risk of chronic diseases, such as cardiovascular disease, cancer, diabetes, Alzheimer's disease, cataracts and accelerated functional decline in addition to other health benefits (Cao *et al*., 1996; Wang *et al*., 1996; Velioglu *et al*.,1998; Cohen *et al*., 2000; Liu *et al*., 2000; Knekt *et al*., 2002; Sweeney *et al*., 2002; Amin *et al*., 2004; Sahlin *et al*., 2004). These positive effects are believed to be attributable to the antioxidants composition, particularly the carotenoids, flavonoids, lycopene, phenolics and ß-carotene (Lavelli *et al*., 2000; Amin *et al*., 2004; Zhang and Hamauzu, 2004).

We know with certainty that the vine tomato is cherished for its high anti-oxidant lycopene content which ranges from 2.6- 3.9 mg/100g FW (Sahlin *et al.,* 2004). Using advanced laboratory techniques, Adebooye (2008) reported lycopene contents of 18.0 and 16.1 mg/100g FW for snake tomato variants. This implies approximately four-times more lycopene in snake tomato fruit than the vine tomato fruit. I showed that the bulk of the carotenoids in snake tomato fruit is made up of lutein in the concentration of 15.6 and 18.4 mg/100g FW. The different values obtained for lutein, α-carotene and β- carotene in my study fall within the 0.06 to 7.4 mg/100g for α-carotene, 0 to 7.5 mg/100g for β-carotene and 0 to 17 mg/100g for lutein reported for pumpkin (Cucurbitaceae) by Murkovic *et al*. (2002). Using the ferric reducing antioxidant power (FRAP) assay, I reported a high value of harmful radical scavenging activity for the fruit of snake tomato. The high antioxidant power of snake tomato fruit pulp was suspected to be related to its high contents of lycopene, ascorbic acid, carotenoids, total flavonoids and phenolics because, earlier studies on fruits have shown that high antioxidant capacity is dependent on high content of phenolic acids, carotenoids, vitamin C and flavonoids such as anthocyanins (Halvorsen *et al*., 2002; Kähkönen *et al*. 1999; Kalt *et al*., 1999; Macheix *et al*.., 1999; Häkkinen *et al*., 1999 and Gorinstein *et al*., 2001). This work of mine was the first world report on the anti-oxidative potential of the Nigerian snake tomato.

I concluded from the results that the lycopene, phenolics, flavonoids and antioxidant power, protein, fat, ascorbic acid and amino acid composition of *T. cucumerina* fruit are high enough and compare favourably with the composition of other known important edible fruits. The high quality of its paste, its palatability and aroma are additional good qualities of *T. cucumerina*. The low and safe oxalate contents also suggested that the availability of Ca and Mg in *T. cucumerina* for man and animal use would not be threatened. The *Nigerian Tribune Newspaper* while reporting the potential of snake tomato as a cheap source of nutraceutical reported:

"Despite the good qualities of the fruit of snake tomatoes and its wide consumption by the poor rural population in Nigeria, many people are not aware of its protective potential against many chronic diseases, such as cardiovascular disease, cancer, diabetes, Alzheimer's disease and cataracts. These positive effects believed to be attributable to its antioxidants, particularly the carotenoids, flavonoids, lycopene, phenolics and ß-carotene, was substantiated by a study carried out by Dr. O. C. Adebooye, Department of Plant Science, Obafemi Awolowo University, Ile-Ife, Nigeria. The study entitled; "Phyto-Constituents and Anti-Oxidant Activity of the Pulp of Snake Tomato (Trichosanthes Cucumerina L.)" was published in the 2008 edition of the **African Journal of Traditional, Complimentary and Alternative Medicines.**" Nigerian Tribune January 8, 2009.

Adebooye *et al*. (2005) and Adebooye (2009) investigated the food value of the seed of *T. cucumerina.* We proved scientifically that the seed is a good source of nutrients containing crude protein (26.2-26.6 g/100g), fat (44.6-57.2 g/100g), phosphorus (78.0-81.5 mg/100g) and calcium (41.0-46.7 mg/100g). Fatty acid analyses of the seeds showed high composition of linoleic acid (60.1-66.3%), oleic acid (18.7-22.5%), and palmitic acid (10.1-13.6%). Other detectable fatty acids, including myristic acid, palmitoleic acid and stearic acid were present in the range of 0.1 to 2.6%. The saponification values were 195.6-206.3 mg of KOH/g of oil while the iodine values of the oils were 100.2-127.3 g of I/100 g oil and peroxide values of the oils were 2.9-3.6 meq of oxygen/kg of oil. The essential amino acids (isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine) constituted a total of 41.2 g/16 g of N while the semi-essential amino acids (arginine and histidine) constituted 21.6 g/16 g of N. In my study, it is interesting to note that linolenic acid was not detected in the seed oil of *T. cucumerina*. This is interesting because, linolenic acid, an omega-3 fatty acid has positive health effects but it easily oxidizes and is undesirable in edible oils because of the off-flavours and potentially harmful oxidation products that it forms. It is known that for oil to be good for frying, its linolenic acid level should be less than 1%. These results are significant because human population is increasing at an increasing rate and there is much pressure on food for man and feed for animal. Instead of using oil-seeds that are consumed by man e.g. soybean, groundnut, palm kernel etc to manufacture animal feed, our work suggested the use of snake tomato seed as a replacement. The high oil content could also be a valuable asset for the upcoming biofuel/biodiesel industry that is now being promoted in African, Caribbean, and Pacific Group of States (ACP) as an alternative energy source.

Physiology of Snake Tomato:

Two aspects of the physiology of snake tomato have been investigated by my team and I:

1. Field studies that evaluated the effects of season and fertilizer on the growth and performance of the snake tomato,

2. Advanced digitally-controlled growth chamber investigations on stress physiology of snake tomato, utilizing root zone temperature, ultra-violet

B radiation (UV-B), chemically-induced oxidative stress, and salinity-induced stress.

Field Studies:

Investigations on the effects of seasons on crop growth and performance are a common aspect of agronomic probe. Scientists are keen to know how yield could be affected by the time of planting. We usually want to pinpoint the exact time during the season of the year when a crop will perform best in terms of growth, yield and quality. In fact, some studies have probed the effects of daily planting on crop yield. In our investigation on the snake tomato, we went a little further than looking at fruit yield only. We were interested in how the nutraceutical components of the fruit could be improved or retained by pinpointing the most appropriate time for seeding in Southwest Nigeria. Oloyede and Adebooye (2005) showed that the early season crop (Planted in April) had significantly higher number of leaves, vine length, number of marketable fruits and fruit yield compared to the late season crop (Planted in October) while the late season crop recorded significantly higher number of aborted flowers and cull fruits. Fruit yield during the early season averaged 22.2 tons/ha while it was 13.3 tons/ha during the late season. The Morphotypes had no effect on fruit yield, number of marketable fruits, cull fruits and number of flowers aborted. The early season crop had significantly higher ascorbic acid composition (25.2 mg/100 g) than the late season crop (18.0 mg/100 g) while the late season crop had significantly higher ether extract (0.94 g/100 g), crude fiber (3.40 g/100 g) and total sugars (0.95 g/100 g) compared to the early season crop which had 0.64, 1.60 and 0.50 g/100 g, of ether extract, crude fiber and total sugars, respectively.

We safely concluded from the results of this study that early season is the best for snake tomato production because it gave significantly higher fruit yield with commensurate food value. During the early season, flower abortion and number of cull fruits were significantly reduced compared to the late season.

Investigation in southwest Nigeria by Adebooye and Oloyede (2006) on the effects of five levels of phosphorus fertilizer (0, 30, 60, 90 and 120 kg P_2O_5 /ha) using single super phosphate was published in the Elsevier journal "*Food Chemistry*" Volume 100. We showed that 90 kg P_2O_5 /ha gave statistically significant higher fruit yield (16.4 tons/ha) compared to other P levels. The fruit yield of the three Morphotypes did not differ significantly. Except for crude protein content, the 90 kg P_2O_5 /ha produced significantly higher ether extract-fat (1.22 g /100 g), crude fibre (1.93 g /100 g), moisture content (90.5 g /100 g), ash (0.90 g /100 g) and ascorbic acid (28.7 mg /100 g) than other P levels. The essential amino acids compositions were also significantly higher at 90 kg P_2O_5 compared to other lower P levels.

Stress Physiology:

On my arrival at the Institute of Crop Science, University of Bonn, Bonn, Germany where I ´was billed to utilize the German Government Humboldt Foundation Research Fellowship, I was faced with a challenge!! The challenge was that the Institute of Horticultural Science wanted to validate my published data on the food values of snake tomato fruit before I could be allowed to spend German tax-payers' money for my research on this new plant. My claims sounded impossible, especially the nutraceutical properties and the lycopene content. Good enough, I left Nigeria with some fresh but preserved fruits of *T. cucumerina*. The samples were submitted for probe!! On the third day after the submission, the Institute's Director (Prof Dr Georg Josef Noga) called a meeting where he declared the results of the probe. Mr Vice-Chancelor Sir, my data were validated as reliable, dependable and true to science!! This was a remarkable moment in my career because the German Government Humboldt Foundation wrote concerning me:

„Im Gewächshaus schlägt dem Besucher Feuchtigkeit entgegen vermischt mit einem eigentümlichen Aroma. Der intensive Duft entströmt den Blüten, Früchten und Blättern von Trichosanthes cucumerina *L., der Schlangenhaargurke. In ihrer Heimat im Südwesten Nigerias nennt man sie Schlangentomate, weil die reifen Früchte sich kräftig rot färben und ähnlich schmecken sollen wie Tomaten. Im Moment sehen die meisten Früchte eher aus wie blasse Gurken. Doch das kann auch an dem verregneten Sommer in Deutschland liegen. Denn hier, fernab der afrikanischen Sonne, wachsen rund hundert Pflanzen im Gewächshaus des Fachbereichs Gartenbauwissenschaft im Institut für Nutzpflanzenwissenschaften und Ressourcenschutz (INRES) der Universität Bonn. Hierher gebracht und aufgezogen hat sie der nigerianische Gartenbauwissenschaftler Odunayo Adebooye. Er will mehr über die bislang kaum erforschte und in seiner Heimat als eine Art Tomate für arme Leute gering geschätzte Pflanze herausfinden.“* German Humboldt Cosmos 98: 2008

English Translation:

"The humidity in the hothouse hits you in the face, mingled with a strange aroma. The intensive smell exudes from the flowers, fruit and leaves of the Trichosanthes cucumerina L., the snake gourd. Where it hails from in south western Nigeria it is also known as the snake tomato and the ripe fruit is a rich red colour and supposedly tastes like tomatoes. There are a

hundred of them growing far from the African sun in the greenhouse belonging to the Division of Horticultural Sciences at the Institute of Crop Science and Resource Conservation (INRES) at Bonn University. They were brought here and cultivated by the Nigerian horticultural scientist, Odunayo Adebooye. He wants to discover more about this little-researched plant which in his own country is dismissed as a kind of poor man's tomato. The reason for this is that Trichosanthes cucumerina is really potent. It has far more vitamin C, vitamin A, raw proteins, essential amino acids and calcium than the more popular and more widespread tomato and various other vegetables. At the same time, it is less demanding as far as soil is concerned and thus ideal for soil lacking humus such as the sort on which the farmers in south western Nigeria are forced to try and cultivate their vegetables. As a basic foodstuff and vitamin provider it could prevent malnutrition and help fight the eye diseases which are particularly prevalent amongst children in the region. And the cultivation itself would be a further source of income for farmers." German Humboldt Cosmos 98: 2008

Thereafter, I started my research on the stress physiology of my pet crop, snake tomato.

Root-Zone Temperature (RZT) Physiology:

This work was done at the University of Bonn, Bonn, Germany and Research Centre, Jülich, Germany. Two weeks before I left Nigeria, I carried out germination test of my seed and I recorded 100% emergence. Under the Southwestern Nigerian field conditions (temperature 26-36 ^{0}C, relative humidity 50-60% and rainfall 1100 mm) as monitored by meteorological station data, snake tomato seed germinates at 12 days after planting. Following the good news above from Prof Noga, I went into the greenhouse of the University of Bonn with confidence to commence my investigations. I planted my seeds. One week, two weeks, three weeks and four weeks; my seeds refused to germinate. I was worried and thrown off-balance, thinking the African way!!! I then decided to try out all sorts of seed treatments including hormonal treatment, soil sterilization and so on but all failed. After about two months of my fruitless adventure in the greenhouse, I decided to call our technicians (Mr Harry Berg and Mrs Brigitte Kitten) and asked them if they could construct a heating element that could generate steady heat in the growth medium from below. They asked me to draw my impression on a paper. I did, and three days after, they came up with an assemblage of very soft cables with adjustable temperature control, up to 50 ^{o}C (Plate 2). They made three pieces of the device for me. I installed the device and adjusted the temperature to 20, 25 and 30 ^{o}C, arranged my planting cups and planted my seeds. I used external thermometer to validate the temperature being generated by the technician-built cables. A doubting Thomas will never believe the magic that the cable assembly could do because the cable looked too ordinary.

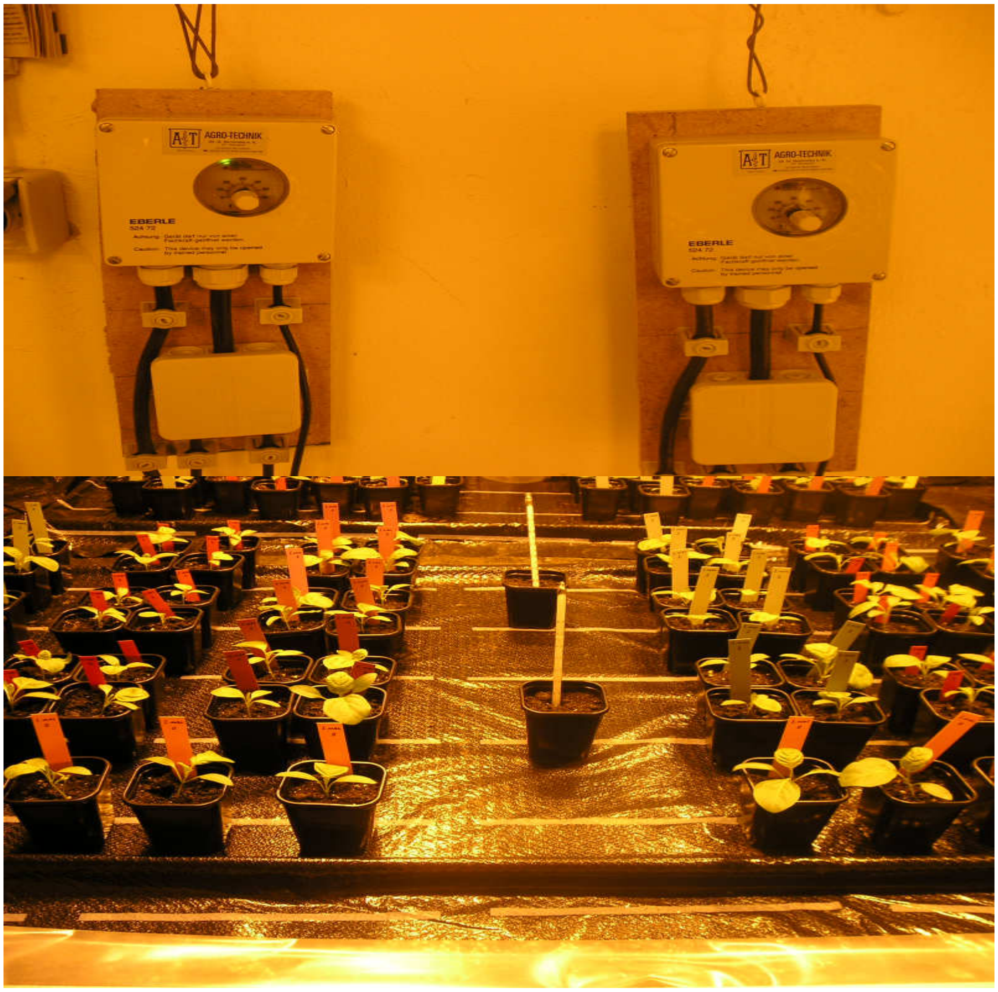


Plate 2: Heating device for Snake tomato cultivation constructed in Bonn, Germany (Adebooye, 2007)

Mr Vice-Chancellor Sir, it was perfect !! My seeds germinated. Results showed that the first emergence for seeds at RZT of 30 °C occurred at 7 days after planting (DAP) while those planted at RZT of 20 °C and 25 °C showed first emergence at 10 and 14 DAP, respectively. At RZT of 20 °C, 25 °C and 30 °C, days to 50% emergence were 18, 12 and 8 DAP while last emergence was registered at 24, 15 and 10 DAP, respectively. We succinctly concluded that for the introduction of crops from tropical to temperate climate and vice versa, air and root zone temperatures are two critical factors that must be considered and artificially regulated. Temperature is an important factor in controlling changes in development from germination and emergence through vegetative growth to floral initiation and reproductive growth. This work is unique and significant because it showed that under controlled growth chamber conditions, days to first emergence was reduced by 5 days compared to the 12 DAP recorded under tropical field conditions in Nigeria. This result could further be exploited in agronomic research for in-depth physiological manipulation in the area of yield improvement, diseases and pests control, earliness to maturity, genetic engineering and molecular biology. The work was published in the *Journal of Central European Agriculture* Volume 18. I crossed the germination and emergence hurdles successfully.

The plants started growing, luxuriant and beautiful. Flowers started blooming and I was happy. Fruits were produced massively and I was on top of the world, counting my success. The day came when we harvested the fully ripe red fruit. Unfortunately, there were no seeds inside the fruit!! I was upset and dejected and Prof Noga was not happy because this was another setback. It was a bad day in the Institute, but good enough we did not invite the media for coverage! This meant that we have not succeeded. What caused this? I needed an answer to this question.

Why didn't we have seeds? Was it a result of physiological problem? Was it a disease problem? What was the problem? Suddenly, I realized that the snake tomato is a crosser (cross pollinated) and that this is made possible by some beetles and flies in Nigeria. Unfortunately, my greenhouse in Bonn, specially constructed for my research has 100% insect control mechanism. Therefore, there was no slightest opportunity for cross pollination. This was the problem! I thereafter raised a new set of plants and upon flowering I carried out mechanical pollination using brushes and I was able to produce seeds. After this successful exploit, the German Government Humboldt Foundation wrote:

"Dabei war es anfangs nicht einfach. Mochte Bonn, anders als Adebooyes Heimatinstitut, die nötigen technischen Voraussetzungen für die Erforschung der optimalen Kultur- und Anbaubedingungen der Wunderpflanze bieten - der Schlangentomate fehlte ihr natürliches Umfeld. Die aus Nigeria mitgebrachten Samen wollten nicht keimen. Selbst im Gewächshaus war der Boden zu kalt. Also bauten die deutschen Kollegen eine spezielle Apparatur, eine Art Fußbodenheizung, die die Anzuchterde auf 25 bis 50 Grad Celsius erwärmt. Im wohlig temperierten Erdreich keimten die Pflanzen sogar schneller als daheim und wuchsen mit Hilfe künstlicher, intensiverer Lichteinstrahlung zügiger weiter. Doch das nächste Problem wartete bereits. Die in Deutschland heimischen Insekten konnten die Blüten nicht bestäuben. In

Nigeria besorgen dies bestimmte Schmetterlingsarten. Adebooye musste die Blüten mechanisch befruchten und die Pollen mit einem Pinsel übertragen, was nicht einfach war." German Humboldt Cosmos 98: 2008

English Translation:

"Yet at the beginning it wasn't so easy. Even though Bonn, by contrast with Adebooye's institute in Nigeria, had all the necessary technical prerequisites for investigating the optimum crop and growing conditions for the miracle plant, the snake tomato missed its natural habitat. The seeds brought from Nigeria just didn't want to germinate. So German colleagues built some special apparatus, a kind of under-floor heating system, to increase the temperature of the cultivation soil to 25 to 50 degrees Celsius. In the well-tempered earth the plants germinated even quicker than they do at home, and with the aid of artificial, more intensive light irradiation grew faster, too. However, the next problem was lurking just around the corner. Native German insects couldn't pollinate the flowers. In Nigeria this is the task of certain types of butterfly. Adebooye had to pollinate the flowers mechanically, transferring the pollen with a brush, which wasn't easy." German Humboldt Cosmos 98: 2008.

The day the first successful fruits were harvested was a day of great celebration with the press, the Institute's Staff and the German Humboldt Foundation in attendance. The Humboldt Foundation wrote after the great event:

„Doch noch ist es bis zum Abschied einige Zeit hin. Gemeinsam sitzen Adebooye, Noga und Christa Lankes in Nogas Büro und feiern einen ganz besonderen Augenblick: Die erste Schlangentomate aus Bonner Zucht kommt auf den Tisch. Adebooye schneidet sie mit einer Rasierklinge der Länge nach auf und serviert die tiefroten fleischigen Kerne auf dem herbeigeholten Kaffeegeschirr. Sie schmecken süßlich exotisch und erinnern an eine Kakifrucht. "Nicht schlecht. Aber der Geschmack ist sicher noch ausbaufähig", meint Noga. Ob die Schlangentomate auch etwas für den deutschen Küchentisch wäre, müssten die Konsumenten entscheiden. Nogas Institut arbeitet mit einem Partner zusammen, der sich um die Vermarktung neuer und optimierter Nutzpflanzen kümmert. Vielleicht liegt Trichosanthes cucumerina *L. also irgendwann einmal im Regal des Supermarkts um die Ecke. Möglicherweise dann an Stelle der hierzulande weit überschätzten gemeinen Strauchtomate. Odunayo Adebooye wäre sicher sehr stolz auf sein Baby."* http://www.humboldt-foundation.de/web/2425.html

English Translation:

“But there is still a while to go before he (Adebooye) has to say goodbye. Adebooye, Noga and Christa Lankes are sitting together in Noga's office celebrating a special moment. The first snake tomato grown in Bonn is about to be served. Adebooye cuts it lengthwise with a razor blade and places the deep red, fleshy kernels on the plates usually used for biscuits. They taste exotically sweet and are reminiscent of kaki fruit. "Not bad. But the flavour certainly leaves room for development," Noga comments. Whether the snake tomato ends up on kitchen tables in Germany is something consumers will have to decide. Noga's institute works together with a partner who deals with the marketing of new and improved agricultural crops. So maybe Trichosanthes cucumerina L. will be found on the shelves of the supermarket round the corner at some stage. Perhaps instead of what is vastly over-rated in this country - the common vine tomato. Odunayo Adebooye would certainly be very proud of his baby.”
www.humboldt-foundation.de/.../wt_show.text_page?

It is my joy to inform you that today the snake tomato exploitation project is in top gear in Germany. A lot of resources is being committed to it by my host University, The University of Bonn. Who knows maybe very soon the first canned paste will be exported to Nigeria!!

UVB-B stress physiology:

According to the United States Environmental Protection Agency-USEPA (1995), the ozone layer is naturally thinner in the tropics than in the mid- and high-latitudes, so there is less ozone to absorb the UV radiation as it passes through the atmosphere. Ozone depletion raises concerns since the deleterious effects of UV-B radiation have been observed in various plant species. UV-B (280–315 nm) is an obligatory component of the solar spectrum, which is efficiently absorbed by plants, and also causes direct as well as reactive-oxygen-species-mediated damage to nucleic acids, proteins, lipids and plant pigments (Bornman *et al*., 1997, Cockell and Knowland, 1999). Exposure of plants to elevated UV-B doses has been implicated in the induction of oxidative stress as a result of a process described as disturbance of the pro-oxidant-antioxidant balance in cells (Schmitz- -Eiberger and Noga, 2001). Under the assumption that solar UV-B radiation will reach peak levels on the Earth’s surface in the next few years (Kakani *et al*., 2003) and the reports of higher UV-B fluxes in the area around the equator (USEPA 1995), I designed a study to evaluate the degree of stress response and plant defence mechanisms under elevated UV-B in tropical crops using *Trichosanthes cucumerina* L -Cucurbtaceae, as a model. I therefore hypothesized that *T. cucumerina* that are apparently adapted to the current UV-B level in tropical zone will show significant stress response to further increases in UV-B doses and that varietal differences in the responses will occur. The UV-B doses were automatically simulated in the UV chamber and growth studies were carried out in digitally controlled chamber. UV-B exposure times were 0, 4 and 8 hours.

The UV-B doses induced significant stress responses as shown by the evaluation of chlorophyll fluorescence and the contents of chlorophyll *a*, chlorophyll *b,* total chlorophyll, ascorbic acid and total phenolics. Our findings are unique because we disproved the universal theory that plants respond to stress by immediately increasing their anti-oxidant profile. We showed that the first response following stress imposition is sharp decline in anti-oxidant profile followed later by steady rise. The information generated in this study is very crucial for the understanding of the physiological response of tropical plant in the event of super-optimal UV-B dose on earth due to climate change. This report was published in *Acta Botanica Croatica* Volume 67 (2007).

We demonstrated a decline in relative photochemical efficiency (F_v/F_m) due to UV-B imposition (Adebooye, Schmitz-Eiberger and Noga, 2007) at 4hrs. We reported that the decline in the F_v/F_m value as the time of exposure increased was an indication that certain damage had occurred in the photosystem II (PS II) reaction centres as a result of UV-B stress. In addition to the general damage to PS II, also D1 and D2 protein subunits of PS II reaction centres may degrade due to UV-B radiation (Melis *et al*. 1992, Friso *et al*. 1994). An enhanced UV-B radiation was shown to have negative impacts on photosynthetic activity (Zhao *et al.*, 2004). In a situation of oxidative stress imposed by UV-B radiation, Campbell (1975) reported that the chloroplast is the first organelle to show injury response, hence there is always a sharp reduction in the chlorophyll contents of leaves of UV-B treated plants. Several mechanisms have been suggested for the decline in chlorophyll contents of UV-B treated plants. Campbell (1975) suggested that chlorophyll reduction in UV-B treated plants may be related to inhibition of biosynthesis or due to degradation of chlorophylls and their precursors, while Strid *et al*. (1994) linked reduced chlorophylls to reduced synthesis resulting from reduced expression of genes encoding chlorophyll-binding proteins. In another study, Strid and Pora (1992) suggested that accumulation of chlorophyllide *a* and *b* resulted in decreased chlorophylls contents under UV-B stress. Syntheses of phenolics compounds and their derivatives are activated under UV-B exposure to serve as defence mechanism and internal screens against UV-B damage (Tevini *et al*., 1991; Day, 1993; Hoque and Remus, 1999). The crude optical properties of the phenolics with high radiation absorbance in the UV region and an excellent transmittance in the photosynthetically active region of the spectrum (Stephanou and Manetas, 1997), combined with the mainly superficial location on the cuticle (Wollenweber and Dietz, 1981), trichomes (Karabourniotis *et al*., 1992) or epidermis (Robberecht and Caldwell, 1978), make them useful in plant defence against UV radiation (Caldwell *et al*., 1983).

We reported significant increases in ascorbic acid composition following UV-B exposure. Smirnoff (1996) in his review of ascorbic acid metabolism reported that cell wall ascorbate provides a first line of defense against ozone and sulphur dioxide. Ozone fumigation has been shown to increase ascorbate and ascorbate-glutathione cycle enzyme activity (Castillo and Greppin, 1988). The biochemical functions of ascorbic acid in plants have been categorized into four: antioxidative role (harmful radical scavenger), enzyme cofactor, electron transport and oxalate/tartrate synthesis (Smirnoff, 1996). Some studies have also suggested that the protective effect of ascorbic acid in stressed plants is more related to the reduction in the level of damage caused by active-oxygen species to essential proteins and/or nucleic acids (Inzé and van Montague, 1995; Becana *et al*., 1998; Noctor and Foyer, 1998). Kerk *et al*. (2000) related mitotic quiescence in root meristems to low ascorbic acid levels. At the end of the exploit, the German Government Humboldt Foundation wrote in a report:

„Vieles, was für den Anbau und die Popularisierung der Pflanze wichtig ist, hat Adebooye in Bonn herausgefunden und mit wissenschaftlich fundierten Daten unterlegt. Er weiß, welche Mineralstoffe der optimale Boden enthalten muss, er kennt die Konzentration der verschiedenen Nährstoffe, die die Früchte ernährungsphysiologisch so attraktiv machen. Er weiß, wie viel Sonnenlicht die Pflanze für optimales Wachstum braucht und dass sie gegen Schädlinge und Pilze unempfindlich ist. Die Schlangentomate verträgt auch starke UV-Belastungen, wie Adebooye sie mit künstlicher Bestrahlung an einigen Pflanzen simuliert hat. Europäische Obst- und Gemüsearten reagieren unter solchen Bedingungen empfindlicher. Sie bekommen einen Sonnenbrand.“

http://www.humboldt-foundation.de/web/2425.html

English Translation:

"In Bonn, Adebooye has discovered a lot of things which are important for cultivating and popularising the plant and has supported them with scientifically-sound data. He knows which minerals the ideal soil has to contain; he knows the concentration of the various nutrients which make the fruit so attractive from a nutritional physiological point of view. He knows how much sunlight the plant needs for optimum growth and that it is not susceptible to pests and fungi. Adebooye demonstrated that the snake tomato can also withstand strong UV exposure as shown by a simulation with artificial irradiation on some of the plants. European fruit and vegetable varieties react much more sensitively under the same conditions. They get sunburnt." http://www.humboldt-foundation.de/web/2429.html

Double-edge stress on snake tomato:

Adverse stress effects, at the whole plant level, which include reduction in growth, decrease in photosynthetic activity (often associated with alterations in C and N metabolism), decline in yield or possibly plant death, were reported by Foyer *et al*. (1994) and Berova *et al*. (2004). At the molecular level, exposure of plants to stress factors has been shown to result in higher production of harmful free radicals, such as single oxygen, hydroxy-radicals, hydrogen peroxide and other peroxyradicals (Hausladen and Alscher, 1994). In response to the deleterious effects of stress, plants are known to increase their contents of radical scavenging substrates and gene products in order to combat the harmful effects of the free radicals (Smirnoff, 1993; Okpodu *et al*., 1996).

In some circumstances, plants are faced with two or more limitations, which often impose stress on the growth, biochemistry and productivity. Against this background, I woke up one day and designed a study to investigate how two stress-inducing factors [root zone temperature (RZT) and paraquat (toxic chemical) would interact to induce anti-oxidative defence mechanism in snake tomato. Paraquat ($C_{12}H_{14}N_2Cl_2$), a bipyridylum herbicide is typically used to induce oxidative stress in plants (Schmitz-Eiberger and Noga, 2001). Therefore, paraquat was used in our study as a chemical to induce a definite dose of stress in the snake tomato tissue. Paraquat is known to initiate electron deterioration in photosystem II (PS II). It acts in the chloroplast, in the presence of light through the generation of superoxide in a chain reaction, producing ROS (reactive oxygen species) (Dodge, 1994). Root zone temperature has been shown to play an important role in germination, emergence and total growth of snake tomato

(Adebooye *et al*., 2007). Low temperature stress has been shown to induce considerable changes in biochemistry and physiology of plants. The main known effects are reduction of chlorophyll levels, blocking of photosynthetic electron transport, reduction of photosynthetic enzyme activity and stomatal conductance, and general inhibition of the light and dark reactions of photosynthesis (Berry and Björkman, 1980; Huner *et al*., 1989; Katterman 1990; Berova *et al*., 2004). Therefore, we conducted a study to gain insight into the oxidative response, photosynthetic activity and defence mechanism of *T. cucumerina* to a two-way stress: stress-inducing chemical (paraquat) and RZT.

To achieve this objective, snake tomato was grown with roots at 25 and 30 ^oC root zone temperature and maintained at 20 ± 1 ^oC air temperature in a digitally controlled growth chamber. Plants at each RZT were subjected to paraquat treatment (+P) and without paraquat treatment (-P). Paraquat (0.2 mmol/L) was applied as aerial spray. Results showed that the individual main effects of RZT and paraquat treatments significantly affected the chlorophyll fluorescence and gas exchange parameters, while the interaction of both treatments had no significant effect. Results showed that the total phenolics and ascorbic acid contents of snake tomato at 30 ^oC were significantly higher than at 25 ^oC. The *T. cucumerina* plants in +P treatment recorded significantly lower relative photochemical efficiency (F_v/F_m), net photosynthesis (A), transpiration rate (E), intercellular CO_2 concentration (Ci) and stomatal conductance (g1) compared to untreated plants. Also, plants raised at 30 ^oC recorded significantly higher Fv/Fm, A, E, C_i and g_1 compared to plants raised at 25 ^oC. Plants that were sampled at 48 h after paraquat treatment recorded a higher degree of oxidative damage compared to those sampled at 24 h after treatment. We showed that the degree of damage suffered by *T. cucumerina*, when treated with paraquat either at 25 or 30 ^oC RZT was similar at 48 h after treatment. We published this work in *Acta Physiologiae Plantarum* volume 30.

At the end of my research on snake tomato physiology in Bonn, Prof Georg Noga claimed:

"Oft höre ich, dass Wissenschaftler aus Entwicklungsländern nur hierher kommen, um bei uns etwas zu lernen. Die klassische Entwicklungshilfeeinbahnstraße sozusagen. Doch bei diesem Projekt findet es statt, das viel beschworene Geben und Nehmen. Die Zusammenarbeit führt zu einem Wissensgewinn auch auf unserer Seite!" http://www.humboldt-foundation.de/web/2425.html

English Translation:

"I often hear people saying that scientists from developing countries only come here to learn something from us - classic one-way street development, so to speak. But in this project, the give and take that people are always talking about really is taking place. Cooperation is increasing knowledge on our side, too," http://www.humboldt-foundation.de/web/2429.html

The Federal Republic of Germany's Chancellor, Angela Merkel also reacted to my works through the Federal Minister for Development, Mrs Heidemarie Wieczorek-Zeul, who reacted as cited below in the popular German Newspaper, ***General Anzeiger*** of 5th May, 2008:

„Adebooyes Forschungsaufenthalt im vergangenen Jahr in Bonn hat dazu beigetragen, die Kenntnislücken zu schließen. Von dem Forschungsaufenthalt profitieren auch die Bonner Gastgeber. Denn die Schlangentomate verträgt erstaunlich gut hohe UV-Belastungen, bei denen europäische Pflanzen längst mit einem Sonnenbrand reagieren. Ihre Erforschung könnte helfen, neue, sonnenbrandunempfindlichere Nutzpflanzen zu züchten und damit heimische Pflanzen gegen die Folgen des Klimawandels resistenter zu machen. So wird wissenschaftliche Entwicklung zur Zweibahnstraße", schrieb Entwicklungsministerin Heidemarie Wieczorek-Zeul jetzt in einem Beitrag zum zehnjährigen Bestehen des Stipendien-Programms, das im April mit einem internationalen Forschertreffen in Bonn gefeiert wurde." ***General Anzeiger*** *of 5th May, 2008*

English Translation:

"Adebooye research stay in University of Bonn has helped to bridge the gaps in knowledge. From the research stay will also benefit the Bonn host. The snake tomato tolerates surprisingly high UV-B radiation exposure, to which European plants would react with sunburn injury. The research could provide useful information that could help to mitigate the adverse effects of climate change. This scientific development is the two-way street," said Development Minister Mrs Heidemarie Wieczorek-Zeul when marking the tenth anniversary of the scholarship program, which was celebrated in April with an international research meeting in Bonn." ***General Anzeiger*** 5th May, 2008

The Humboldt Foundation recalled me to Bonn, Germany in April 2009 for a three-month research stay to further advance on the physiology of snake tomato. It was a time to investigate the inhibitory effects of root zone temperature on photosynthesis, mineral partition and chlorophyll fluorescence of snake tomato.

Prof Noga also added another task of investigating the salinity effect on oxidative stress, EDX minerals and trichomes of snake tomato.

Advanced Physiological Study on Snake Tomato:

Adebooye *et al.* (2008) had earlier demonstrated that at 30 °C RZT significantly higher number of tendrils, number of leaves, fresh leaf weight, stem length, fresh stem weight, root length, root weight and root volume were recorded followed by 25 °C RZT and least at 20 °C . We also showed that sub-optimal RZT (20 °C) produced adverse effects on both emergence and growth of snake tomato.

In our quest to dig deeper into the physiology of the Nigerian snake tomato, we hypothesized that sub-optimal root zone temperature (RZT) will cause a reduction in the bioactive components contents, adversely affect PS II and hinder uptake/partitioning of mineral elements in the Morphotype III or V_3 of the snake tomato. Three RZT (20, 25 and 30 °C) were evaluated in a digitally controlled growth chamber. Results showed that for all the mineral nutrients analysed (Ca, Mg, P, K, Fe and Mn) in Figs 1-6, the amounts absorbed by the plant increased as RZT increased with each nutrient displaying different characteristics with respect to the quantity partitioned into root, stem and leaf at the different RZT. At sub-optimal RZT (20 °C), significantly higher amounts of Ca and K were found in the root whereas at normal RZT (25 and 30 °C) higher amounts of Ca were recorded in the stem and about 50% of the amounts in the stem were found in the leaves. For all the RZT, the amounts of Mg in the leaves were significantly higher than in the root and stem while the amounts in the stems were also significantly higher than the amounts in the roots. At normal RZT (25 and 30 °C) almost equal amounts of P were present in the root, stem and leaf. The amounts of phenolics, ascorbic acid, chlorophyll "*a*", "*b*" and total chlorophyll increase as the RZT increases.

Photosystem analyses showed that at 30 °C, the F_v/F_m (relative photochemical efficiency) was 0.76 while at 20 and 25 °C, the values were 0.35 and 0.60, respectively. The F_v/F_m value (0.35) obtained at 20 °C confirmed the adverse effects of sub-optimal RZT on the photosystem II (PS II). Photosynthetic measurements showed that as the RZT increased, so also the *A* (net photosynthetic efficiency), *E* (transpiration rate), C_i (intercellular carbon-dioxide concentration) and g_1 (stomata conductance) increased. We postulated that the higher *E* and g_1 at high RZT have a great physiological implication on plant performance because transpiration cooling would be improved, especially during the summer but the lost water must be complemented by adequate irrigation. The totality of the results confirmed our hypothesis that sub-optimal root zone temperature (RZT) will cause a reduction in the bioactive components contents, adversely affect PS II and hinder uptake/partitioning of mineral elements in *T. cucumerina.* This work was published in *Acta Physiologiae Plantarum* volume 32.

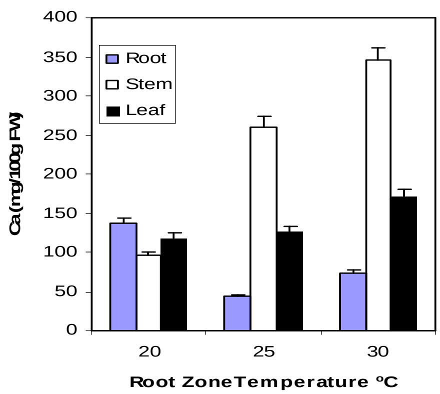


Fig 1: Calcium concentration in the root, stem and leaf as affected by root zone temperature.

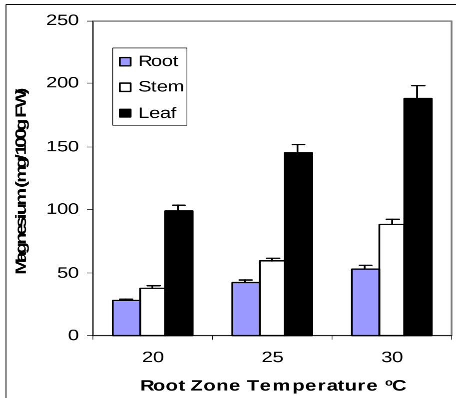


Fig 2: Magnesium concentration in the root, stem and leaf as affected by root zone temperature

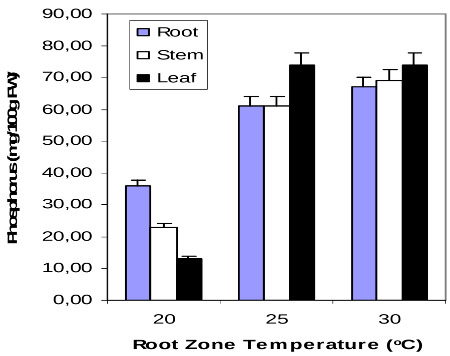


Fig 3: Phosphorus concentration in the root,stem and leaf as affected by root zone temperature

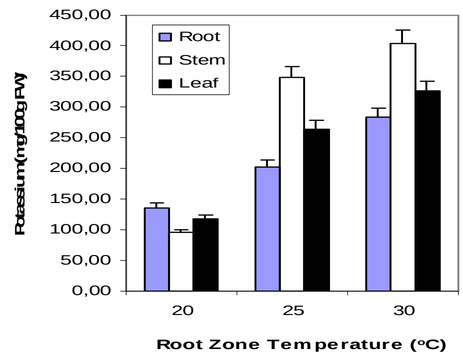


Fig 4: Potassium concentration in the root, stem and leaf as affected by root zone temperature

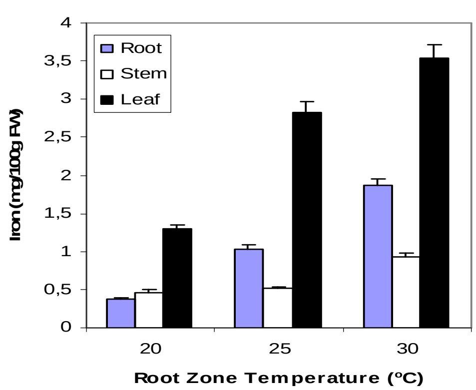


Fig 5: Iron concentration in the root, stem and leaf as affected by root zone temperature

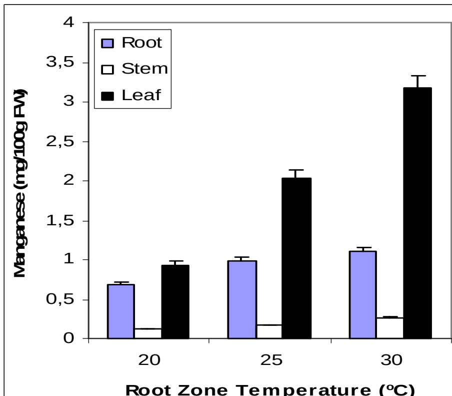


Fig 6: Manganese concentration in the root, stem and leaf as affected by root zone temperature

Further advancement was made with respect to how snake tomato will behave at the cellular level with respect to trichomes and stomata densities and their micro-morphology if salt stress was introduced. Two morphotypes (Variant I and Variant II) of *T. cucumerina* and four levels of salinity 0, 60, 120 and 180 mM NaCl were used. This study identified for the first time in the world two discernible types of trichomes in *T. cucumerina* namely "Conical shaped" trichome and "Globular-headed" trichome that are segmented into three or more distinct sections (Plates 3 A, B, C, D). Results showed that there were significantly more stomata on the abaxial than the adaxial surface irrespective of the morphotype and salinity treatment. Under the control treatment (no salinity), the Variant II had significantly higher stomata on the abaxial side than Variant A-Green, while for adaxial side, the reverse is the case. Results also showed that the conical and globular-headed trichomes densities decrease as leaf age increases. The leaf petioles of the two variants are dominated by globular-headed trichomes.

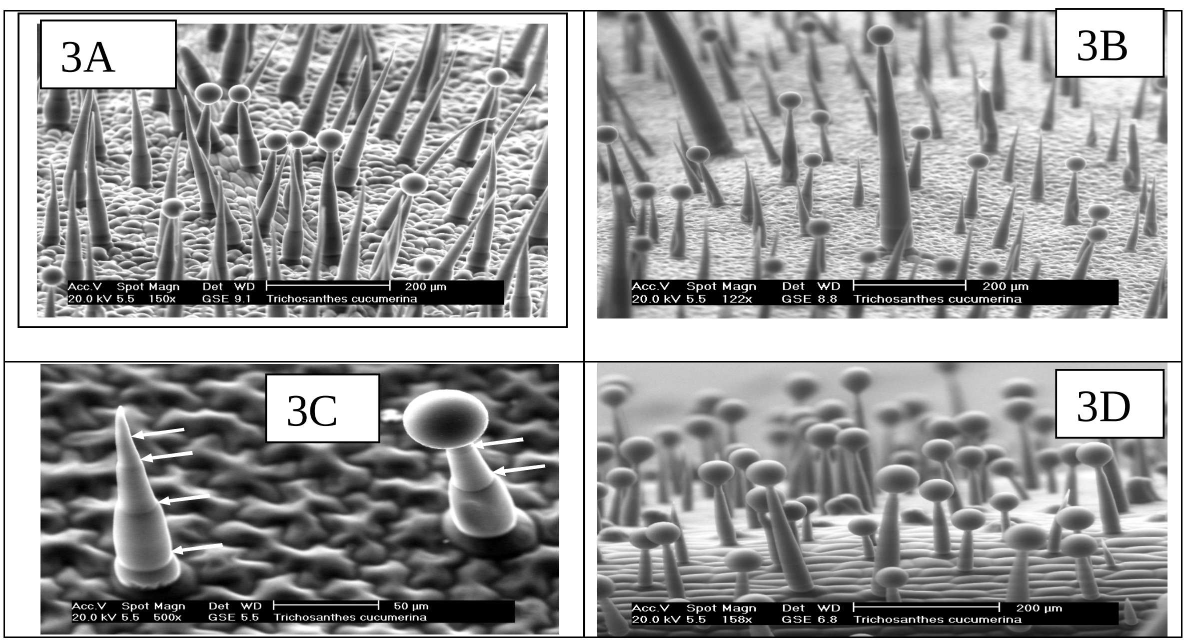


Plate 3 A, B, C, D: Conical shaped" trichome and "Globular-headed" trichom

Other significant research:

Mr Vice-Chancellor, distinguished audience, all I know is not only snake tomato. In the research wilderness, I have collaborated with engineers, food chemists, botanists and mathematicians. I have published significant research findings on several indigenous vegetables, cowpea seeds, fruit trees, legumes and cucurbits physiology but time will not allow me to give the details of my findings. In the area of application of mathematical sciences to agronomy, together with my colleagues (Dr Suraju Ajadi and Dr Abraham Fagbohun of OAU, Ile-Ife) the accuracy of the formula for estimating plant population in a four dimensional experimental plot was investigated. The study showed that plant population estimation based on the existing formula was not accurate:

$$Pp = \frac{10{,}000(m^2) \text{ x no of seeds per stand x no of ha}}{\text{Product of spacing } (m^2)}$$

We (Adebooye, Ajadi and Fagbohun, 2006) then derived a new mathematical formula that can estimate correctly the plant population in four dimensional regular fields of sole crop. We also developed the optimization principle for non-regular field. Our work concluded as follows:

"Therefore, for any given four dimensional regular field of length (L) and breadth (B), given a spacing of ($l \times b$), number of seed per stand (N), plant population can be accurately estimated by this equation:

$$Pp = \frac{(B + b)\,(L + l\,)}{lb} \times N$$

For non-regular field we proposed plant population formula whose sides can be represented as a function of a variable. Where dL′, dB′ are the elemental length and breadth of farm field respectively, while dl′, db′ are the length and breadth of spacing respectively, then the above equation becomes:"

$$Pp\,(l, b) = \frac{\int_o^L \int_o^B dB'dL' + \int_o^B \int_o^l d'l'\,dB' + \int_o^L \int_o^b db'dL' + \int_o^l \int_o^b db'\,dl'}{\int_o^l \int_o^b db'dl} \times N$$

This unique work was published in the *Journal of Agronomy*.

Other Studies:

As a United Nations scientist at the United Nations University(UNU), CFTRI, India, we (Adebooye, Singh and Vijayalakshmi, 2008) demonstrated that chlorophyll '*a*' and '*b*' occur in ratio 3:1 in the *Amaranthus cruentus* and *Solanum nigrum*. We also showed that irrespective of the pre-treatment imposed this chlorophyll ratio remained unchanged suggesting that they are tied together in each of these vegetables. Our study showed that there was no peroxidase activity in *A. cruentus*, irrespective of the pre-treatment imposed, while *S. nigrum* showed high peroxidase activity. We also showed that there was a significantly higher content of antioxidant carotenoids in *A. cruentus* when compared with *S. nigrum*, while the antioxidant total phenolics, total flavonoids and total tannins contents were higher in *S. nigrum* when compared with *A. cruentus*, irrespective of the pre-treatment method used. This work was published in the Springer's *International Journal of Food Science and Technology* Volume 43

Also at UNU, India we (Adebooye and Singh, 2008) studied the physiology of cowpea starch and reported its physico-chemical properties. We modified the starch isolation procedure, eliminated the protein matrix and obtained 100% pure cowpea starch (Plate 4). This new method developed by us is now being used in world class laboratories to eliminate protein matrix from plant products. We compared the industrial properties of cowpea starch with the other known popular starch sources. We finally suggested, based on the findings, the possible industrial applications of cowpea starch. This work was published in the Elsevier's *Journal of Innovative Food Science and Emerging Technologies*.

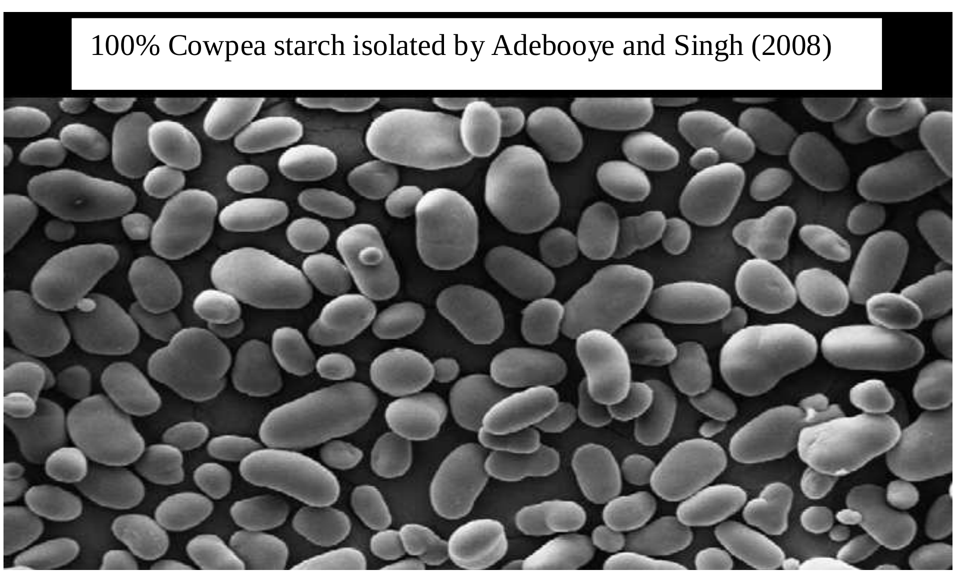


Plate 4: Cowpea Starch (Adebooye and Singh, 2008)

Conclusion:

Mr Vice-Chancellor sir, distinguished and accomplished scholars here present, we have come thus far on indigenous vegetables and snake tomato research and I am bold to say that in the dreadful wilderness of academic pursuit, I am standing up today to say "hitherto the Lord has helped me". I will continue to advance knowledge in the plant physiology speciality and build human capacity to replace myself after my retirement. I also intend to dig deeper into communication network within the plant system using the laser imaging technology with a view to explaining the signals and instructions that are given by leaf to stem, root to leaf, leaf to root, stem to root, fruit to leaf, leaf to seed and so on. I am also planning to further investigate the processes of detoxification of harmful radicals that are generated in the different segments of plant life processes in reaction to stress.

Mr Vice-Chancellor sir, with all humility, you will pardon me for this next attempt to state some of my services and other achievements. In addition to serving as external examiner to University of Fort Hare, South Africa where I have examined three PhD theses, I have also served as permanent reviewer for highly reputable journals published by Elsevier, Springer, Taylor and Francis, Wiley, Blackwell, Acta series, Chinese journals, Japanese journals etc. I have edited three books that were published by the Cuvillier Publishers, Germany. I have served project assessor for the Danish Agency of International Development (DANIDA), Denmark. In the last 15 years, I have won up to 12 competitive research grants from international organizations and while at the Obafemi Awolowo University, Ile-Ife, I successfully secured full funding from the German Humboldt Foundation for organizing two international Humboldt Conferences (2008 and 2009) that attracted scientists from about 13 countries, including European countries. I have attended international conferences in about 20 countries across the continents of this world. I am also listed as a member of the Global Facilitation Unit of experts on under-utilized plants by the Bio-versity International, Rome. Professionally, I am a member of the International Society of Horticultural Science (ISHS) Belgium, Japanese Society of Horticultural Science (JSHS), German Society for Horticultural Science (DGG), Horticultural Society of Nigeria(HORTSON); Fellow, College of Research Associates, UNU/INRA, Ghana; Fellow, Central Food Technological Research Institute, India;

Association of Food Scientists(ASFST), India and Fellow, United Nations University, Tokyo.

In the year 2000, I was awarded the best presentation award at the Underutilized Plants Workshop which held in Karachi, Pakistan. Again, in June 2006, I was also awarded the best presentation award at the Indigenous plant symposium which held at UNU/CFTRI, India. At home, I was hired by the Osun State Government in 2003 to serve on the team that formulated the Agricultural Development Policy that the State is implementing today. At the Obafemi Awolowo University from where I transferred to UniOsun, I successfully served in Senate, Congregation and Appointment and Promotions Committee (A&PC). At UniOsun, I am currently the Head of Agronomy Department and the Editor-In-Chief, UniOsun Journal of Sciences that has just taken off.

Mr Vice-Chancellor sir, with all human humility, I am happy to inform this audience that on Monday June 8, 2009 at about 4.00pm, far away in Berlin, Germany I was decorated by the Government of the Federal Republic of Germany as the German Humboldt Scientist Alumni Award winner. The award was based on my innovative networking initiative and overall contribution to scientific research. The ceremony was attended by over 1000 eminent world scientists, including Nobel Laureates and Presidents of German Universities. The award ceremony was unique because it was the first-ever to be granted and I happened to be the first Nigerian to win this highly prestigious award.

Mr Vice-Chancellor sir, with all humility, I am happy to inform this audience that upon my assumption of duty at UniOsun, I have been able to work with my colleagues in an atmosphere of mutual respect and tranquillity. In addition to the huge investment of UniOsun in promoting digital science laboratory, I in 2010, obtained a grant of N8.0million naira from the Bundesministerium für Bildung und Forschung, Germany through the Humboldt Foundation to buy additional state-of-the-art laboratory equipment for our plant physiology laboratory. Today, at the click of a computer button, in a few minutes, we can carry out analyses of plants at cellular level at UniOsun, Ejigbo Campus. We can digitally quantify a lot of parameters without destroying your living plant sample!!! We have removed the stress of holding burettes and pipettes from our scientific research life !! I have also secured funding from the Canadian Government's International

Development and Research Center (IDRC) which will provide additional N17 million state-of-the-art digital laboratory equipment for Ejigbo Campus. Mr Vice-Chancellor sir, we are moving forward gradually and gradually, and catapulting UniOsun to global scientific recognition. This is one of the reasons that I admonish the Government of Osun State not to allow political motives and personal objectives to destroy this noble and futuristically rewarding UniOsun project. I am having the feeling that at the rate we are going, this citadel of learning may be able to produce a Nobel Laureate in the next 20-25 years if we allow it to flourish. I agree perfectly that there are vital issues to resolve, but we can do all these at the table while sharing coffee !!

Mr Vice-Chancellor sir, distinguished and accomplished scholars here present, I again with all human humility inform you that myself and Dr Durodoluwa Oyedele of Obafemi Awolowo University, Ile-Ife in collaboration with our colleagues from the Cape Breton University, Canada and the University of Manitoba, Canada developed a proposal on sustainable use of indigenous vegetables for food security for the Canadian Government's IDRC. It is my joy to inform you that in January 2011, the Canadian Government graciously provided $3.0 million for the implementation of the project. It is a UNIOSUN-OAU/CBU-UofM collaborative project in which I am the Principal Investigator from UniOsun and Dr Oyedele is the Principal Investigator from the Obafemi Awolowo University, Ile-Ife. The Vice-Chancellor, Professor Sola Akinrinade has just appended his signature and put UniOsun's seal on the grant agreement. On this project, 10 researchers from UniOsun will travel to the University of Manitoba and Cape Breton University, Canada for 1 month training each. We are also securing additional digital equipment through this grant support from the IDRC. Our University will provide leadership in field work, data analyses and interpretation, report writing, publication preparation and general coordination of the research project.

Recommendation:

There are several vegetables which are eaten by only the poor rural dwellers which I often refer to as "food of our fathers" because most urban elites do not know them and possibly have never seen them before. As demonstrated for snake tomato, there may be some of them that could be better sources of nutrients for our health. Some of them could also be sources of bioactive compounds that can solve most of our modern health challenges. This therefore calls for a re-orientation of the research mandate in our Universities and Research Institutes. In fact, in response to this challenge the International Centre for Under-Utilized Crops (ICUC) has been established with headquarters in Sri Lanka.

As a response in Nigeria, at the National level, I propose the establishment of a National Under-utilized Plants Research Institute (NUPRI) by the Federal Government of Nigeria. I also propose that this new Institute should have its headquarters in Osun State because; out of about 30 national research institutes in Nigeria, none has its headquarters in Osun State. Osun State has reliable natural water resource which could be used for the sustaining the field gene-banks during the dry season. Branches of this proposed Institute are expected to be sited the East, South and Northern Nigeria. The various departments in the NUPRI will include: Agronomy Section, Food Science section, Plant Health Section, Genetic Resources and Breeding Section, Extension Section, Analytical Laboratory Section and Central Administration and Finance Section. This proposed Institute will focus on those indigenous under-utilized species on which no organized research had been conducted with the following mandates:

1. Collect the indigenous fruits, vegetables, spices and legumes of Nigeria and conserve them in seed banks and field gene banks. This way, the "food of our fathers" can be conserved for generations yet unborn.
2. Conduct research into sustainable production practices for the high premium indigenous species including seed production and plant health.
3. Engage in breeding and improvement of the indigenous fruits, vegetables, spices and legumes.
4. Provide information on food value of the different species as a guide for farmers and consumers.
5. Conduct research on utilization and value-addition for the fruits, vegetables, spices and legumes.
6. Disseminate information and train farmers on all aspects of under-utilized plants production and utilization.

Mr. Vice-Chancellor sir, distinguished scholars, ladies and gentlemen, thank you for your patience and attention.

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