NRCRI AT 100

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FOREWORD

As the National Root Crops Research Institute (NRCRI), Umudike celebrates 100 years of existence, I am pleased to write the foreword to this book highlighting the accomplishments of the Institute. The growth and development of the root and tuber crops (RTCs) sector, which make up the majority of Nigeria's food production and are crucial to our survival and subsistence (being food security and resilient crops), is a key strategic objective of NRCRI.

The Institute's publication of this Centenary book “NRCRI at 100” which chronicles her achievements over the decades is a welcome development considering the food security agenda of the present administration in Nigeria. RTCs are key to achieving Nigeria’s self-sufficiency in food production and perhaps poverty alleviation. The book serves to showcase the remarkable strides made by the Institute in the research of RTCs, which are integral to both food security and socio-economic progress over the past century. These achievements are the result of the tireless efforts of dedicated scientists and their collaborators, both within and outside Nigeria, who have worked diligently with the Institute's mandate crops, such as Cassava, Yam, Cocoyam, Sweet potato, Potato, Ginger, Turmeric, Livingstone potato, and Amora, among others.

Within the book, readers will discover a variety of strategic Research Programmes that complement the development of these crops, including Biotechnology, Seed Technology, Product Development, Yam, Cocoyam, Potato, Sweetpotato, Ginger, Minor Root Crops, and Farming Systems and Extension. Additionally, the Institute's outstations located in Kuru (Plateau State), Otobi (Benue State), Nyanya/Karu (FCT/Nassarawa State), Maro/Kajuru (Kaduna State), Igbariam (Anambra State), and Iresi (Osun State) are led by the committed, visionary, and dynamic Executive Director, Professor Chiedozie Egesi, also contributes significantly to the development of RTCs.

The book delves into a broad spectrum of scientific advancements in agriculture, encompassing agronomic practices, genetic enhancement, biotechnology, production techniques, seed systems, processing, storage, marketing, farming systems, and extension services. These ground-breaking innovations have been effectively disseminated to farmers through various methods. In the last ten years, the Institute has partnered with IITA, Ibadan and CIP to introduce over 60, 20, 3, and 3 improved, high-yielding, pest and disease-resistant varieties of cassava, yam, sweet potato, and potato, respectively. A significant milestone has been achieved with the official registration of two ginger landraces by NRCRI after thorough characterization. Since Nigerian ginger is highly sought-after internationally, it is essential to have an official trade name. The Institute is also making notable strides in the cultivation of Cocoyam, ginger, turmeric, living stone potato, amora, and other crops.

I applaud the Executive Director, Management, Scientists and all Staff for their good work. They have in no small measure achieved the national mandate of NRCRI, Umudike. It is my honour to recommend this well-illustrated and designed centenary book of achievements to the public and private sectors to exploit the state-of-the-art technologies showcased for the creation of agro-allied enterprises. The information contained in this book can trigger value chain investment in small, medium and large enterprises. The academic community including academics, researchers, agricultural consultants, students of tertiary institutions and the reading public will find the book a veritable asset.

Professor Garba Hamidu Sharubutu (*mni*, *FASN*)
Executive Secretary, ARCN

PREFACE

The National Root Crops Research Institute (NRCRI), Umudike, has achieved a remarkable milestone with the timely and appropriate publication of the book "NRCRI at 100". This book showcases the Institute's remarkable achievements, and it is imperative to recognize and underscore the significance of the various outstanding research contributions made by Research Scientists at NRCRI.

NRCRI has made immense contributions towards enhancing livelihoods, especially smallholder farmers who have been instrumental in sustaining food production in Nigeria and lifting people out of poverty. The Institute's research efforts have far-reaching implications for the growth and development of agriculture in Nigeria and beyond. The publication of "NRCRI at 100" is a significant milestone that highlights the importance of research and innovation in agriculture. The book is a testament to the dedication and hard work of the researchers at NRCRI, who are committed to finding sustainable solutions to the challenges facing the agriculture sector in Nigeria.

The publication of this Book is indeed a timely intervention, as it presents a comprehensive overview of the collations and contributions made by NRCRI as a Research Centre and Institute over the decades. The author has succeeded in emphasizing the significance of repositioning and refocusing NRCRI towards fulfilling the mandate of the present administration on Food Security. This is a crucial step towards achieving self-sustaining growth in all the sub-sectors of agriculture and the necessary structural transformation for the overall socio-economic development of the country. Furthermore, this publication highlights how the improvement of the quality of life of Nigerians is intricately linked to the success of these efforts.

NRCRI has been at the forefront of research aimed at enhancing the value chain of root and tuber crops in Nigeria for decades. To achieve this goal, the institute has effectively mobilized both internal and external resources. Through research and development, the institute has improved crop quality, developed new varieties, and increased productivity. It has also worked with stakeholders to improve the value chain efficiency, contributing to increased income for smallholder farmers, improved food security, and sustainable development.

The Book has been meticulously collated with the history of NRCRI in Nigeria and highlights its significant achievements from various Programmes, including Cassava, Biotechnology, Yam, Sweetpotato, Potato, Farming Systems, Extension Services, Cocoyam, Ginger, Minor Root crops, Product development, and Seed Technology. These programmes showcase NRCRI's research accomplishments and its partnerships in the development and testing of varieties with desirable attributes that meet the needs of different end-users and the agronomic packages that contribute significantly to the agricultural and food economy of the nation.

Over the decades, NRCRI has played a pivotal role in the rapid popularization and spread of its Research and Development activities through training along the value chain for root and tuber crops, using the rural empowerment concept. This approach has been instrumental in empowering farmers, enhancing their livelihoods, and contributing to the socio-economic development of rural communities. The Book serves as a valuable resource for researchers, policymakers, agribusiness entrepreneurs, farmers and other stakeholders interested in advancing the agricultural sector in Nigeria and beyond.

Prof. Chiedozie Egesi (*FBSN*)
Executive Director/CEO, NRCRI

ACKNOWLEDGEMENTS

In March 2023, Professor Chiedozie Egesi, the Executive Director of the National Root Crops Research Institute (NRCRI) in Umudike, highlighted the importance of documenting the Institution's significant accomplishments in a publication to commemorate its centennial existence as a research Centre and Institute. The proposed book, entitled "NRCRI at 100," is expected to offer a critical analysis of the institute's decades-long successful research endeavours and ground-breaking achievements. This presents a unique opportunity to celebrate the institution's legacy while contributing to the advancement of root and tuber crop research.

We would like to take this opportunity to express our sincere gratitude to the Executive Director for exhibiting exceptional purpose-driven leadership and providing immense inspiration in accepting to undertake this project and steering the process to its successful completion. Additionally, we would like to extend our heartfelt appreciation to the Internal Management Committee and the Centennial Celebration Planning Committee for their unwavering cooperation, support and guidance throughout the entire process. Without their dedication and hard work, this project would not have been possible.

The completion of this book is the result of the hard work and dedication of our esteemed Programme Coordinators and Scientists from various Programmes. Their relentless efforts in collating and documenting decades of remarkable achievements from their respective fields and programmes have made this work possible. Without their valuable input and expertise, this book would not have come to fruition. Their tireless efforts have contributed immensely to the academic community, and we are grateful for their contributions.

The Institute has made significant strides in collating and documenting its achievements spanning a century, with particular emphasis on its mandate crops, mission, and vision. The primary objective was to ensure that the information was presented with the utmost accuracy and brevity. Nevertheless, it is worth noting that the documentation of these accomplishments is not all-encompassing and exhaustive by design, and there could be other noteworthy achievements that were not incorporated in this compilation.

We are extremely grateful to God for enabling us to plan and execute the contributions of "NRCRI at 100". Our deep and sincere appreciation goes to God for giving us the strength, wisdom, and resources to successfully carry out various activities and contributions to achieve this significant milestone.

NRCRI @ 100
Publication Committee

NOTES ON CONTRIBUTORS

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Amanze, Ngozi J, *HND (Agriculture), PGD (Agricultural Extension), M.Sc. & PhD (Plant Breeding and Genetics), (ABSU),* is a Chief Research Officer. A Research Team Member of local and international projects. Her research interests include the development of new varieties of root and tuber crops. She has several articles published in local and international scientific journals, proceedings and conferences.

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Dr. Samuel Onwuka is a Principal Research Scientist with the Seed Technology Program of NRCRI, Umudike. He is a Development Expert with a background in Agricultural Economics. His research interests include root and tuber crops research for the enhancement of livelihoods and ensuring food security for rural communities, agribusiness management and gender equity. He is skilled at using data-driven insights to create sustainable farming methods and opportunities among vulnerable groups in the rural communities of Nigeria.

Udemezue Joseph Chidozie, *B.Agric, M.Sc. in Agricultural Extension, University of Nigeria, Nsukka and Ph.D. in Agricultural Extension (Communication), Chukwuemeka Odumegu Ojukwu University (COOU) Anambra State Nigeria.* He is a Principal Research Officer (PRO) with research interest in agriculture-related information, climate change, farm broadcasting, public relations/advertisements on firms that deal with agricultural clients and editing of agricultural papers. He has published over 100 research works to his credit.

Dr Solomon Olufemi Afuape *(B. Agric., FUNAAB; M.Sc. (Plant Breeding and Genetics), MOUAU; PhD, (Plant Breeding), WACCI, University of Ghana, Legon)*, is an Assistant Director and Coordinator, Sweetpotato Programme. He is a plant breeder Head of, the Sweetpotato Breeding Program, and a Member, of the CIP-Sub-Sahara Africa Community of Breeders with over 20 years of experience in sweetpotato breeding/research. His breeding research activities focus on developing climate-smart, nutrient-fortified sweetpotato varieties that combine product-profiled productivity and food quality traits for varied end-users using genomic tools and speed breeding techniques. As a Seed System Specialist, his works involve enhancing the sweetpotato seed value chain which ensures the delivery of high-quality planting materials of improved sweetpotato varieties to farmers for increased productivity. He is an expert in the training of farmers on sweetpotato best agronomic practices in root and vine production. As a team player, Dr. Afuape works with many national and international research partners in many collaborative projects within and outside Nigeria.

Okoye, Amala Christiana, *B. Agric-Agricultural Extension (Nig.), MSc and PhD-Agribusiness and Entrepreneurship Management (MOUAU),* is a Principal Research Officer with the National Root Crops Research Institute, Umudike, Nigeria. Research program for the past 12 years spans issues on Agricultural Extension, Agribusiness, Entrepreneurship Development and Management, Food Security, Production Economics, Farm Management, Agricultural Marketing, Gender Studies, Rural Development, Adoption Studies, Productivity and Efficiency, Climate Studies, Seed System, Sustainability Plan and Business Models. She has been part of international and trans-disciplinary research and Training programmes funded by JUMPSTARTING, BNFB, SAHSA, TAAT, WINNN, etc. In collaboration with the aforementioned projects, she has to her credit developed four (4) business sustainability plans and models for sweetpotato seed business in Nigeria which can be adapted for other root and tuber crops. Dr. Mrs. Okoye has over 70 publications in various media including national and international Journals and Conference proceedings.

Engr. Dr Stephna Tolubanwo E. is a graduate of Engineering with a Bachelor of Engineering in Agricultural & Bioresource Engineering with an option in Soil & Water Engineering. She is an expert in irrigation procedure and management and dredging of the institute's dam. She has both Master's & Doctorate degrees in the same field and became an authority in her chosen field. She has applied this knowledge in the planting and multiplication of sweet potato and other root crops as part of the mandate of the Institute. She has written some publications and continues research in this regard that will assist farmers in sustainable food production. She won the institute's staff award for Excellency for Invention in 2005. She is happily married with Children.

Anyaegbunam Helen Nkoli (Ph.D.) is an Assistant Director and Coordinator of the Extension Services Programme. She holds a Doctorate in Agricultural Economics with specialization in Agricultural Marketing, from Michael Okpara University of Agriculture Umudike. Areas of research interest include Agricultural Marketing, Dissemination and adoption, Value chain systems, Farm management, Resource Economics and Food Security. She is a specialist in training and has been involved extensively in training farmers to improve their livelihoods. She has served as a Monitoring and Evaluation Officer and field coordinator in both National and International projects such as IFAD, GCP, WAAPP, ATA and BASICS. Member of SLIDEN AFRICA, APA and ASN. She was the past Assistant Treasurer and current Business Manager of the Agricultural Society of Nigeria. She has over 100 papers in peer-reviewed national and international reputable journals; and conference proceedings. She is a team player.

Ali Saleh, PhD: *A Microbiologist (Environmental Microbiology) with NCE in Biology/Chemistry (JSCOE, Gumel), BSc. Microbiology (BUK, Kano), MSc. Microbiology (ABU, Zaria) and PhD. Microbiology (BUK, Kano).* A Senior Research Officer (SRO) and current HOS-Maro with both local and international publications in Journals and Book chapters. Also attended National and International Conferences, Seminars and Workshops. The research areas focus on Microbiological Analysis of Food, Bioremediation of the Polluted Environment with Agrochemical or industrial effluent (Soil and Water) and also focuses on how the use of agrochemical (Herbicides, Pesticides etc.) affect the life of microorganisms present in the soil, water and the residues of such chemicals in the agricultural produce.

Nwokocha, Ivy Nwamaka (Ph.D) is a Senior Research Officer. She holds a Doctorate in Agricultural Extension with an area specialization in (Rural Sociology and Development) at Michael Okpara University of Agriculture, Umudike. Areas of research interest include Dissemination and adoption, Value chain systems, Farm management, Technology utilization, and Gender. She is presently the supervisor in charge of the demonstration farm of the Extension Services Programme. She has been involved in training farmers and students on excursions to improve their knowledge and skills in root and crop production. She has served in both National and International projects such as ABCPRP, FADAMA III, and WAAPP, and still serving as a Desk officer in Monitoring and Evaluation of BASICS II component 3 in NRCRI, and SEEDEQUAL. Member of ASN, Organic Agriculture Association of Nigeria, Nigerian Forum for Agricultural Advisory Services (NIFAAS), The International Association of Research Scholars and Fellows, Licensed Seed Inspectors LSI (Third-party certification of NASC/BASIC II). She has several scientific publications in peer-reviewed national and international reputable journals; books of readings and conference proceedings.

Janet Ogbeyalu Nwaekpe, *B. Agric. (Agricultural Extension and Rural Sociology), MSc. and PhD (Rural Sociology and Development) (UMUDIKE),* is a Principal Research Officer/Acting Head of Adopted Villages and Outreach Schools unit. Her work spans various aspects of root and tuber crops research, including socioeconomic analysis, value chain analysis, gender, technology dissemination, and community outreach. She has several articles published in local and international scientific journals, proceedings and conferences. She is a member of various professional associations, including the Agricultural Society of Nigeria (ASN), the Rural Sociological Association of Nigeria (RUSAN), Organization for Women in Science for the Developing World (OWSD) to mention but a few.

Ano, Queen U., *BSc (Microbiology), MSc & Ph.D. (Post-harvest Physiology and Management of Crops).* She is a senior research scientist at National Root Crops Research Scientist (NRCRI). My experience includes yam quality, pest and disease management of crops and gene editing. She is currently in charge of editing annual reports in the Yam programme NRCRI and is also a member of the Accelerated Breeding Initiative (ABI Team). She has articles in learned journals. Mrs. Ano is an active member of the Agricultural Society of Nigeria and also belongs to several research networks within and outside Nigeria.

Njoku, Regina Nwanyieze, *HND (Soil Fertility and Plant Nutrition), PGD, M.Sc., PhD (Soil Fertility and Plant Nutrition) Abia State University Uturu.* A certified Soil Scientist is an Assistant Director/Coordinator of the Minor Root Crops Research program at NRCRI Umudike. She has been the head of some units in the Institute. Chairman and member of several NRCRI-constituted committees. She has many publications in reputable local and international scientific journals including proceedings. A member of of Agric. Science Society of Nigeria (ASN), Soil Science Society of Nigeria (SSN), International Soil Science Society (ISSS), Crop Science Society of Nigeria (CSSN) and Organization of Women in Science for the Development World (OWSD). Her research interest includes Soil management to improve agricultural sustainability.

Kolawole Oyekunbi Foluke is a Senior Research Scientist with a Minor Root Crop Research Program at the National Root Crop Research Institute, with a BSc in Botany (OSU), MSc in Plant Taxonomy and Biosystematics (MOUAU). A Taxonomist with an interest in characterizing newly developed root and tuber crops, she has several scientific publications in local, national and international journals

Chioma Harbor, *B.Sc Biochemistry (ABSU), MSC and PhD Biochemistry (Umudike)*. She has devoted nearly a decade to groundbreaking research on root crop production and utilisation. Her research focuses on evaluating the health benefits and nutritional content of root crops, improving yield, disease resistance, and post-harvest preservation. She has a keen interest in addressing the agricultural challenges of the local communities across Nigeria, making recommendations to improve their livelihoods. Harbor has several of her publications in international reputable journals and supports the Organisation for Women in Science for the Developing World (OWSD).

Nwokocha, Christopher Chukwuma (RSS*), B. Agric (Pedology), M.Sc (Soil and Water Conservation), PhD (Soil Physics/Conservation) (Nig),* is an Assistant Director (Research)/Coordinator Research Support Services, a Registered Soil Scientist and a Soil and Water Conservation Specialist. His research focuses have been on the use of mulch, and organic and inorganic amendments to improve the fertility of degraded *Ultisols* of southeastern Nigeria. He led a team of scientists that established the NPK fertilizer requirements of turmeric, Livingstone potato, Hausa potato, and Polynesian arrowroot. He successfully linked soil health indices to their roles in cocoyam root rot disease suppression/promotion. A member Nigerian Institute of Soil Science (NISS), Soil Science Society of Nigeria (SSSN), Agricultural Society of Nigeria (ASN), West African College of Soil Physicists, International Union of Soil Science (IUSS), and NRCRI Editorial Board. He has authored/co-authored many peer-reviewed articles in reputable Journals of Soil/Agriculture/Environmental Sciences. He holds the Certificates of Excellence in Reviewing of the International Journal of Environment and Climate Change (IJECC); Current Journal of Applied Science and Technology (CJAST) etc.

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Ezebuiro, Nathaniel Chika (PhD) is a Director and Coordinator of the Farming Systems Research Programme. Before now, he was the Coordinator of the Extension Services Programme. He holds an Ordinary/Higher Diploma in General Agriculture from the Federal School of Agriculture, Umudike. Post-graduate diploma in Agricultural Economics and Extension (Nsukka), M.Sc. in Agricultural Extension and Rural Sociology (Uturu) and Ph.D. in Rural Sociology and Extension (Umudike). He was a Senior Lecturer at AE-FUNAI in the Faculty/Department of Agriculture while on Sabbatical. He was the Manager, of NRCRI Farms Limited, Head of, the Genetic Resources Unit of the Institute. His Community-based activities have no equal; Team Leader, Abia State Village Seed Entrepreneur (VSE) Downstream Sector, Team Leader for the execution of the Adopted Village Project of ARCN/NRCRI, Umudike, Team Leader, responsible for Research-Extension-Farmer-Input/Marketing Linkage System (REFILS) in South East, Nigeria and responsible for On-Farm Research (OFR) and other Extension activities in Eket Zone of Akwa Ibom State. He was equally responsible for the establishment of Germplasm species in the Institute, characterising, evaluating and documenting root and tuber crops across Nigeria. A member of some professional bodies like ASN, and NRSA. He has several publications in reputable scientific journals, proceedings and conferences at International and national levels.

Okereke, Charles Ogbonnaya, *B. Sc (Animal Science, (ABUS), M.Sc & PhD (Animal Nutrition and Biochemistry (UMUDIKE),* an Assistant Director of Research/ Head of sub-station Otobi. The former Coordinator of the Minor Root Crop Research Programme, also the head of the institute poultry and feed mill, furthermore, started the institute Grasscutter unit. A Team member of several Institute's constituted committees. A member of Nigeria Institute of Animal Science (NIAS), Animal Science Association of Nigeria (ASAN), Nigeria Society of Animal Production (NSAP) and Agricultural Society of Nigeria (ASN). His research interest is in the area of the use of alternative feed ingredients and best practices in the use of roots and tuber crops in poultry and livestock feed. He is a reviewer of some local and international journals, proceedings and conference papers. He has several articles published in reputable scientific journals, proceedings and conferences.

Ikoro, Anyim Ikoro, *B.Agric. Crop Production (MOUAU), MSc. Agronomy (MOUAU), Ph.D., Agronomy (MOUAU)*. Currently, the Head of Station, NRCRI, Igbariam Sub-Station.

Jude Obidiegwu has served as lead personnel of the Yam programme in the last 5 years. He has a background in Plant Breeding and Genetics. He is passionate about developing yam varieties that increase yam productivity whilst reducing production costs and environmental impact by developing and deploying end-user-preferred varieties with a higher yield, greater resistance to pests and diseases and improved quality. His integrated breeding approach encompasses precision phenotyping, socio-dynamic surveys and market intelligence. He is an active member of the yam breeding community. He compliments his breeding efforts with seed system development, participatory research for development, and research coordination. He works with a multidisciplinary team with practical field experience. Under his lead role, NRCRI has released 9 yam varieties in partnership with collaborators. Jude has significant experience in international and national agricultural research and development systems.

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Mbanaso Maryrose Ogeri (Mrs.) *B. Ed. Administration/Political Science, Nnamdi Azikiwe University (1995); MBA (Human Resources Management), Michael Okpara University of Agriculture, Umudike*. Mrs Mbanaso is the Director of Administration/Administrative Secretary of the Institute. She is a member of the Institute of Professional Managers and Administrators of Nigeria and a Fellow of the Institute of Corporate Administrators of Nigeria. She has attended both Local and International training in Human Resources Management. She is a seasoned Administrator.

Njoku, Damian Ndubuisi, *B.Agric. Crop Science (UNN), M.Sc in Agronomy (MOUAU) and Ph.D. in Planting Breeding & Genetics (Univ. of Ghana, Legon)*. He was the Head of the Plant Genetic Resources Unit (PGRU), Coordinator Sweetpotato and Cocoyam programmes, and currently, Coordinator of the Cassava Programme. He is also an Assistant Director at NRCRI Umudike. He has authored some books and over 60 published research articles. He has trained over 100 interns and students and co-supervised many postgraduate students at M.Sc & PhD degrees. Dr. Damian has attracted some projects to NRCRI and is also supporting the breeding team on some cassava projects in the Institute. He has actively participated in developing and releasing some cassava varieties in Nigeria. A member of ASN, BSN, GSN, NPBA and APBA. His research studies have been on the genetic improvement of cassava for nutrition (pro-vitamin A, iron & zinc, starch content, dry matter content), delayed post-harvest deterioration, drought tolerance and increase in cassava yield in Nigeria.

Dr. (Mrs) Ugo Chijioke is a Chief Research Officer with NRCRI Umudike. She holds a Bachelor of Science degree in Food Science and Technology from the Federal University of Agriculture Markudi, a Master of Science in Food Processing and Preservation from Michael Okpara University of Agriculture Umudike and a PhD in Food Science and Technology from the University of Nigeria Nsukka. Dr Chijioke is currently attached to the Cassava Programme of NRCRI, where she is saddled with the responsibility of profiling the food quality attributes of cassava at different stages of breeding. She also collaborates with many International Research Institutes in projects targeted at enhancing food security in Nigeria. She is currently the Focal Point, Root Tuber and Banana Breeding Quality, for NRCRI, a project sponsored and funded by the Bills and Melinda Gates Foundation, and has several publications in many reputable International and Local Journals. She has spearheaded protocols that can assist breeders in mainstreaming food quality attributes into the breeding pipeline to ensure the needs and preferences of end-users of our staple crops are met. As a Food Scientist, She is very passionate about empowering and improving the livelihood of rural women and has served as an advocate to create awareness on the importance of consumption of Vitamin A biofortified staple crops such as cassava, sweetpotato and Maize by pregnant, lactating mothers and growing children. She is also involved in training on value addition of Root and tuber crops in different states of Nigeria.

Joseph Okpani Mbe is a research scientist in the Cassava Programme of NRCRI Umudike. He holds a B.Sc., M.Sc. and Ph.D. in Soil Science/Pedology from the Federal University of Technology (FUTO), Owerri, Nigeria. He also has an M.Sc. in Plant Breeding and Genetics from Tamil Nadu Agricultural University (TNAU) Coimbatore, India and currently pursuing a second Ph.D. (Pant Breeding) at the West Africa Centre for Crop Improvement (WACCI), University of Ghana, Legon. Dr. Mbe's research interest includes using modern and innovative tools for genetic improvement and the development of resilient varieties of staple crops, particularly root and tuber commodity crops, for food and nutrition security in Africa.

Mazza, Mary-Ann, *HND in Agric. Extension & Farm Management (FCA Ishiagu), MSc & PhD in Agricultural Extension (MOUA Umudike),* is a Chief Research Officer with the Seed Technology Research Programme and also with the Planning, Monitoring & Evaluation Department of NRCRI Umudike. Chief Liaison Officer NRCRI Farms LTD. Former Head of the Human Capacity Development Division and Current Head of NYSC/Internship Unit of NRCRI, Secretary of NRCRI Editorial Board. She is experienced in Seed production of Root and Tuber Crops and the extension of technologies to rural farmers. Proficiency in documentation of Research Reports.

Dr Kanu Ann Nkeiruka, *BSc Food Science and Technology (ESUT), MSc Food Microbiology and Biotechnology (Umudike). PhD Food Processing Technology (World Bank Scholarship, BSU).* A Research Scientist with the Product Development Programme of NRCRI, a reviewer with Tylor and Francis, and published in both local and International journals. Her extensive research portfolio encompasses a wide range of studies, primarily focused on the transformation of root and tuber crops into diverse food products. These research endeavors have been conducted with a meticulous approach, involving the assessment of multiple critical parameters. Her commitment to thorough research and exploration of diverse food products underscore her dedication to contributing valuable insight to the scientific community. Skilled in the use of data, software, and GraphPad.

Nwankwo, Innocent Ifeanyi Maxwell *HND General Agriculture (Umudike), PGD Agriculture (ABSU), MSc Agricultural Economics(ABSU), MSc Plant Breeding and Genetics (MOUA-Umudike), PhD Plant Breeding and Genetics (MOUA-Umudike),* Assistant Director Research, Former Head, Plant Breeding laboratory and Ex-Coordinator Sweetpotato Research Programme. He was the first to KICK START the official release of Orange fleshed Sweetpotato varieties in Nigeria and the official Registration of Yam landraces as VARIETY in the history of Yam releases in Nigeria in addition to the release of hybrid Yam genotypes. He supervised International student PhD work under the GENE Project on the Drought Tolerant Sweetpotato Breeding Project in West Africa. He was a Co-PI on the SweetGAINS Project on the Sweetpotato Breeding Project in Nigeria by CIP. He is a member of Professional bodies such as the Agricultural Society of Nigeria, the Crop Science Society of Nigeria, the Genetic Society of Nigeria and an Associate member of Nigeria Breeders. He has contributed to knowledge by writing several articles published in reputable Technical papers, National and International Journals, Conference Papers and Proceedings. Currently, he is the Assistant Director for Breeding and Coordinator of Research activities in the Cocoyam Research Programme of NRCRI Umudike, Nigeria.

Nwadili, Christain O. is a Plant Pathologist with specialization in Mycology and based at the Potato Programme, Kuru station (Plateau state) of the National Root Crops Research Institute, Umudike. He is the Coordinator of the Potato Programme and currently the Head of Station, Potato Programme in Plateaus State. He is passionate about using pathology methods to solve plant disease problems particularly diseases of yam, cassava, potato, sweetpotato, ginger, cocoyam and other root and tuber crops. He obtained his PhD from Michael Okpara University of Agriculture while he was a Research fellow at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. His dissertation focused on the characterization of *Colletotrichum gloeosporioides* (Penz) populations responsible for yam anthracnose and the evaluation of the f_1 mapping population for water yam (*Dioscorea alata*) disease resistance in Nigeria. He has also published many research papers in top academic journals and he is a reviewer of many journals. Christian Nwadili is a highly accomplished and promising researcher in the field of Plant Pathology. His work has the potential to make a significant impact on the way plant diseases are managed.

Ihuoma Chizaram Okwuonu, *B.sc (combined Microbiology/Chemistry); M.Sc (Applied microbiology); PhD (Plant Biotechnology),* is an Assistant Director/ Coordinator of Biotechnology Research programme. Currently, she leads multiple externally-funded research projects such as the Virca-Plus project, and the Cassava Source-Sink research among others and she is also an awardee of notable grants such as the BAYER grant for Gene Editing. She is passionate about her research on exploring the potentials of genetic engineering, genome editing and genomics in developing root and tuber crops with improved nutritional content and resistance to biotic and abiotic factors. She has several publications in reputable journals, proceedings, and book chapters and has made meaningful contributions to multiple seminars/training workshops. Additionally, her high premium on capacity-building is evidenced in her mentorship approach/hands-on laboratory training for younger scientists. She is a member of several professional associations which include the Biotechnology Society of Nigeria (BSN), Agricultural Society of Nigeria, OWSD, etc.

Nnadozie, Longinus Dexter is a Chief Extension Officer (Agribusiness) at the Michael Okpara University of Agriculture, Umudike. With a background in Agricultural Economics, Agribusiness and Cooperatives, he oversaw monitoring and evaluation of outreach programmes at the MOUAU Extension Centre. He is currently in charge of the Agribusiness Research and Business Development Studio of his institution. With core competence in digital publishing and e-learning platforms, he has contributed to many academic publications. He is an editorial assistant on the Board of the ASN, and member of Nigerian Forum for Agricultural Advisory Services (NIFAAS).

Okoye, Benjamin Chukwuemeka *[B. Agric, Agricultural Economics (Nig.), MSc and PhD (Farm Management and Production Economics, and Agricultural Marketing respectively (Umudike)]* is an Asst. Dir. with the Cassava Research Programme. His research programme spans issues around food security, production economics, farm management, agricultural marketing, efficiency, transaction costs, gender, resource economics, adoption and applied microeconomics and econometrics. Quantitative and qualitative approaches for sustainable management of resources, and critical assessment of the distinction between “quantitative” and “qualitative” research with particular attention to the question of measurement. Assessment of various techniques of data collection and “fact-finding” instruments such as; interviews, observation and archival studies to locate their potentiality for construction of successful research projects. A team player, experienced in developing and managing collaborative projects and research networks for effective technology/knowledge sharing amongst relevant institutions and networks.

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CHAPTER 01

INTRODUCTION

1.0 Introduction

The National Root Crops Research Institute, Umudike started as a Provincial Experimental Farm on 1st Jauary 1923 to a complex regional Agricultural Research and Training Station in the early 60s, and was upgraded to a commodity Institute in 1975 and renamed the National Root Crops Research Institute in 1976, and is currently under the supervision of the Agricultural Research Council of Nigeria (ARCN). Located 8 kilometres South East of Umuahia¬Ibeku, and situated on la6tude 51 $^{1}/_{2}$°N and on longitude 7$^{1}/_{2}$ ^{O}E and 122m. The Institute is divided into two by a trunk B road which runs from Umuahia-Ibeku Township to Ikot-Ekpene, and joins a trunk *A* road from Aba to Oron on the Calabar route.

1.1 Mandate of the Institute

The Institute has the following mandates:

The National Mandate of NRCRI Is to research into genetic improvement, production, processing, storage and socio-economics of root and tuber crops of economic importance (Yam, Cassava, Potato, Sweetpotato, Cocoyam, Ginger, Hausa Potato (*Solenostemon Rotindifolinus)*, Sugerbeet, Radish, Rizga, and Amora (Arrow Root).

NRCRI also has the Zonal Mandate of reaching into the entire farming system of the South-East Agro-Ecological Zone. The zone covers Abia, Anambra, Ebonyi, Enugu and Imo State of Nigeria.

NRCRI additionally execute agricultural extension services in liaison with relevant federal and state agencies such as National Agricultural Extension Research and Liaisons Services (NAERLS) and the state's agricultural development projects (ADPS) on its mandate crop within the mandate zone.

Technologies to maximize the potential of root and tuber crops have been developed by the Institute in partnership with national and international organizations and have significantly continued to contribute to the nation's food security and sufficiency through research and extension activities on root and tuber crops. With an average yearly production of 63.03mt (cassava), 50.37mt (yam) and 3.22mt (cocoyam) (FAOSTAT, 2021), Nigeria has continued to be ranked first in the world production of cassava, yam and cocoyam.

The National Root Crops Research Institute at Umudike has produced considerable gains in root and tuber crop production, farm size, productivity, processing, and consumption in Nigeria. The Institute has also facilitated the rapid popularization and spread of its Research/Developmental activities by training along the value chain for root and tuber crops using the rural empowerment concept.

The research activities of the institute are organized into programmes which include Cassava, Yam, Potato, Sweetpotato, Ginger, Cocoyam, Minor Root Crops, Farming System, Extension and Post-Harvest Development headed by Coordinators. There are five Research Divisions: - Root Crops Research, Tuber Crops Research, Farming System and Extension Research, Planning, Monitoring and Evaluation and Biotechnology.

1.2 Mission Statement & Vision

To provide necessary improved technologies that would enhance total value chain development of root and tuber crops towards national food security, income generation, gainful employment and industrial development.

To be recognized internationally as a centre of excellence in root and tuber crops research in Nigeria.

CHAPTER 02

HISTORY OF NRCRI

2.1 History of NRCRI Establishment

The station first started as a Provincial Experimental Farm on the 1st of January, 1923. Then the farm activities were controlled by the Nigerian Department of Agriculture with headquarters at Moor Plantation, Ibadan. During the first year, only 20 hectares (50 acres) of land were cleared and stumped. By the end of 1937, the total area developed had reached 123 hectares (304 acres) of which 41.3 hectares (102¬acres) were devoted to experiments on annual crops, while 24.3 hectares (60 acres) were under permanent crops mainly oil palms. In 1960/61, an additional 165 hectares (407 acres) on the Eastern side, now referred to as Eastern Farm was acquired. In 1965 a further 122 hectares (300 acres) to be known as Western Farm or Olokoro Extension was also acquired bringing the total acreage of the station to 409 hectares (1007 acres). The acquisition of swamp land on either side of Umudike stream, an area of about 7.5 hectares (18 acres) was also developed in 1973. In the early period, numerous small plot experiments directed from Moor Plantation were carried out, either to confirm results of similar trials in progress at Moor Plantation or to solve problems of maintenance of soil fertility in a region where the soil is notably sandy and generally deficient in mineral nutrients.

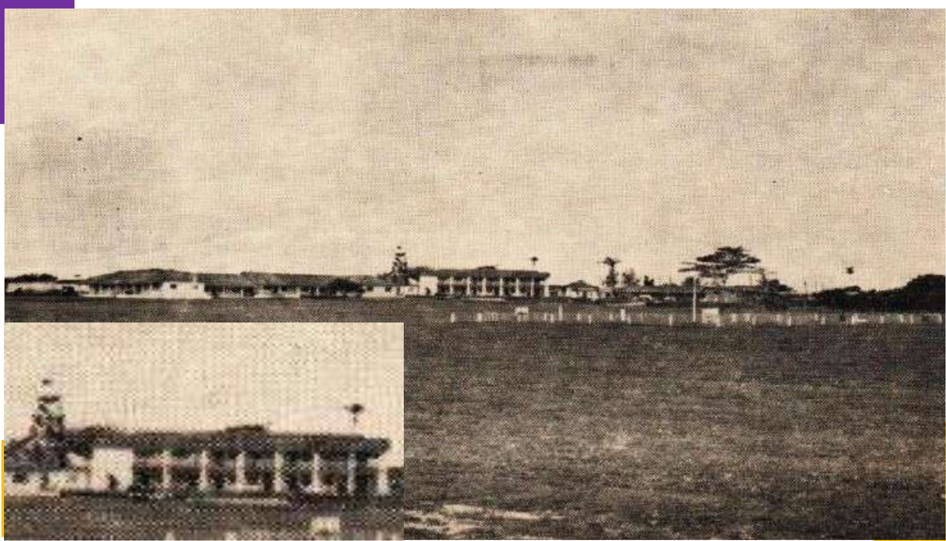


Fig. 1: Front view of the Federal Agricultural Research and Training Station, Umudike: 1973

As a result of political changes that took place in the early '50s' most Government Departments including Agriculture were regionalised in 1954 and, from then onwards, the activities of the station as well as those of other agricultural stations in Eastern Nigeria were controlled by a Director of Agriculture whose headquarter was based at Enugu. Following the regionalisation, the need to establish an agricultural research station similar to that at Moor Plantation in Ibadan and at Samaru in Zaria was felt. Two years later, in 1956, the Eastern Nigeria Agricultural. Research Station was established at Umudike and it took over the site of the Provincial Farm. By this time a School of Agriculture, similar to that at Moor Plantation in Ibadan and that at Samaru in Zaria, was also established at Umudike. The School and the Research Station remained separate entities until 1965 when both were amalgamated under the name Agricultural Research and Training Station (A.R.T.S.).

In the 1962/68 Development Plan in which agricultural development generally was given due prominence, the station was to be considerably developed through a loan agreement between the United States Agency for International Development (USAID) and the Eastern Nigeria Government. In this agreement, the USAID was to provide funds for capital development, while the Government took care of recurrent costs. By 1966/67, large quantities of commodities (stores, vehicles; equipment etc.) had arrived from USA. Unfortunately, this plan of development was not implemented before the outbreak of the civil war. At the end of the civil war, it was discovered that in spite of the greatest care, most of the stock of stores, hostels, classrooms and scientific equipment built up at the station over the years had been lost or badly damaged. Several buildings especially residential quarters and laboratories were stripped of fixtures and fittings and the major portions of the pre-fabricated buildings were dismantled and carried away. Furthermore, as a result of the 12 State structure, the station was inherited by the East-Central State Government which had so much reconstruction work on hand that there were hardly sufficient funds to reactivate the station to its pre-war level.

However, on the 26th of January 1971, the station was fortunate to be honoured by a visit of the Head of State, His Excellency, General Yakubu Gowon who was accompanied by the Administrator of the East Central State, Mr. Ukpabi Asika (Fig. 2). They were shown round the station and at the end, the Head of State commented: *I wish you all the very best of luck. I am sure that you will soon find your feet and be of great service to our farmers and economy*. This visit was later followed up on the 13th of March, 1972, by a visit of the Federal Commissioner for Agriculture and Natural Resources, Dr. J.O.J. Okezie, accompanied by his East Central State counterpart, Mr. Z.O. Dibiaezue, and the Permanent Secretary, Federal Ministry of Agriculture and Natural Resources, Dr. B. Shaib. On the 1st of April 1972, the Federal Government took over the station and it became known as the Federal Agricultural Research and Training Station. This history would not have been complete without the mention of this State visit which paved the way for the Federal Government take-over and financing of the station. Administratively, the Federal Agricultural Research and Training Station operated under the Federal Ministry of Agriculture and Natural Resources, Lagos, is headed by a Chief Research Officer and comprises two main Sections: the Research Division and the Training Division (the School of Agriculture).

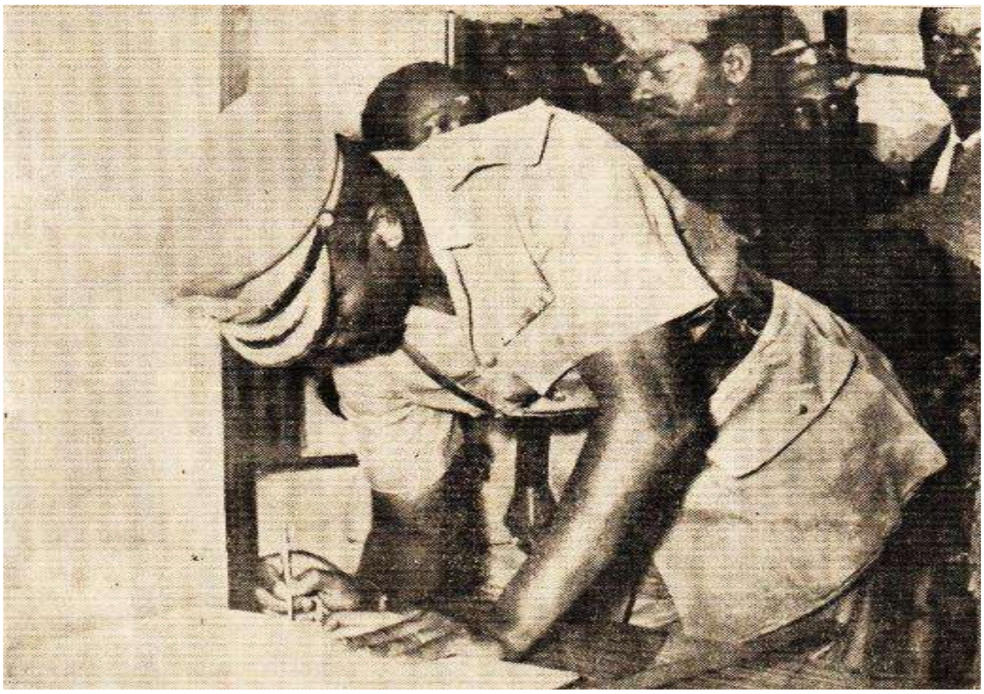


Fig. 2: The Head of State, General Yakubu Gowon signs the visitor's book on the occasion of his visit to the Federal Agricultural Research and Training Station Umudike, on January 26, 1971

Fig. 3: March 13 1972 the Federal Commissioner for Agriculture and Natural Resources Dr. I.O.J. Okezie (3rd from left) accompanied by his State counterpart Mr. Z.O. Dibiaezue (2nd from left) and his Permanent Secretary Dr. Bukar Shaib. (4th from /left) inspected Umudike Station, a visit which paved the way for the final takeover of Umudike by the Federal Government. In the picture, Dr. L. S.O. Ene (extreme left) explains a research project to the Honourable Commissioner and his entourage

2.2 Research Administration: NRCRI

The Institute is administratively supervised by the Agricultural Research Council of Nigeria (ARCN) which is accountable to the Honorable Minister of Agriculture and Rural Development. Executive Director as the Chief Executive is responsible for the running of the institute. Presently the Executive Director is assisted by seven (7) Technical Directors who in addition with the Director, Finance and Accounts, Head of Administration department and Head of Internal Audit Unit constitute the Institute Internal Management Committee (IMC). The institute is structured into departments for efficient and effective management. These include Crop Research Operations Department (CROD), Research Outreach Department (ROD), Planning Monitoring and Evaluation (PME), Research Support Services (RSS), Biotechnology and Product Development, Agricultural Engineering & Mechanization Department, Information and Documentation (I&E), Administration and Finance and Accounts. These departments are further subdivided into Divisions, Programmes, Sections and units as follows:

1. **Crop Research Operations Department:** Cassava, Yam, Cocoyam, Sweetpotato, Potato, Ginger, and Minor Root Crops Programmes.
2. **Research Outreach Department:** Farming System Research and Extension Programmes
3. **Biotechnology & Product Development:** Biotechnology, Product Development and Seed Technology Programmes.
4. **Agricultural Engineering & Mechanization Department:** Engineering Research, Irrigation and Farm Mechanization
5. **Planning Monitoring & Evaluation Department:** Planning, Project Monitoring & Evaluation, Budgeting, Statistic, Human Resources Development And Training.
6. **Research Support Services Department:** Computer Services, Meteorology, Irrigation And Water Management, Soils, Biochemistry, Genetic Resources, Plant Protection, Plant Breeding, Apiculture, Research And Engineering And Farm Mechanization.
7. **Information and Documentation Department:** Library Services
8. **Finance And Account Department:** Accounts and Stores
9. **Administration Department:** Registry, Pensions, Medical Clinic, Estate Redevelopment and Management, Security, Guest House and Personnel.

2.3 Partners

NRCRI over the decades has partnered with many Institutions and Organisations, some of which include;

1. International Institute of Tropical Agriculture, Ibadan.
2. International Food Policy Research Institute
3. International Centre for Tropical Agriculture (CIAT) Colombia
4. International Atomic Energy Agency (IAEA), Vienna, Austria
5. International Plant Genetic Resources Institute (IPGRI) Rome
6. Brazilian Agricultural Research Corporation (EMBRAPA)
7. International Potato Centre (CIP), Peru
8. Donald Danforth Plant Science Centre (DDPSC), USA
9. Whitefly IPM Project (Sweet potato) funded by DFID
10. National Centre for Genetic Resources and Biotech. Devt. (NAGRAB)
11. Nigeria Agriculture and Biotechnology Programme (Cassava Transgenic Research)
12. Root and Tuber Expansion Programme (RTEP)

13. National Special Programme on Food Security (NSPFS)
14. Pre-emptive Project on East Africa Cassava Mosaic Disease (CMD)
15. Raw Materials Research Development Council (RMRDC) Abuja
16. Niger Delta Development Commission (NDDC)
17. Nigeria National Petroleum Corporation (NNPC) - ethanol production
18. Nigeria Liquefied Natural Gas (NLNG)
19. Agricultural Development Programmes (ADPS)

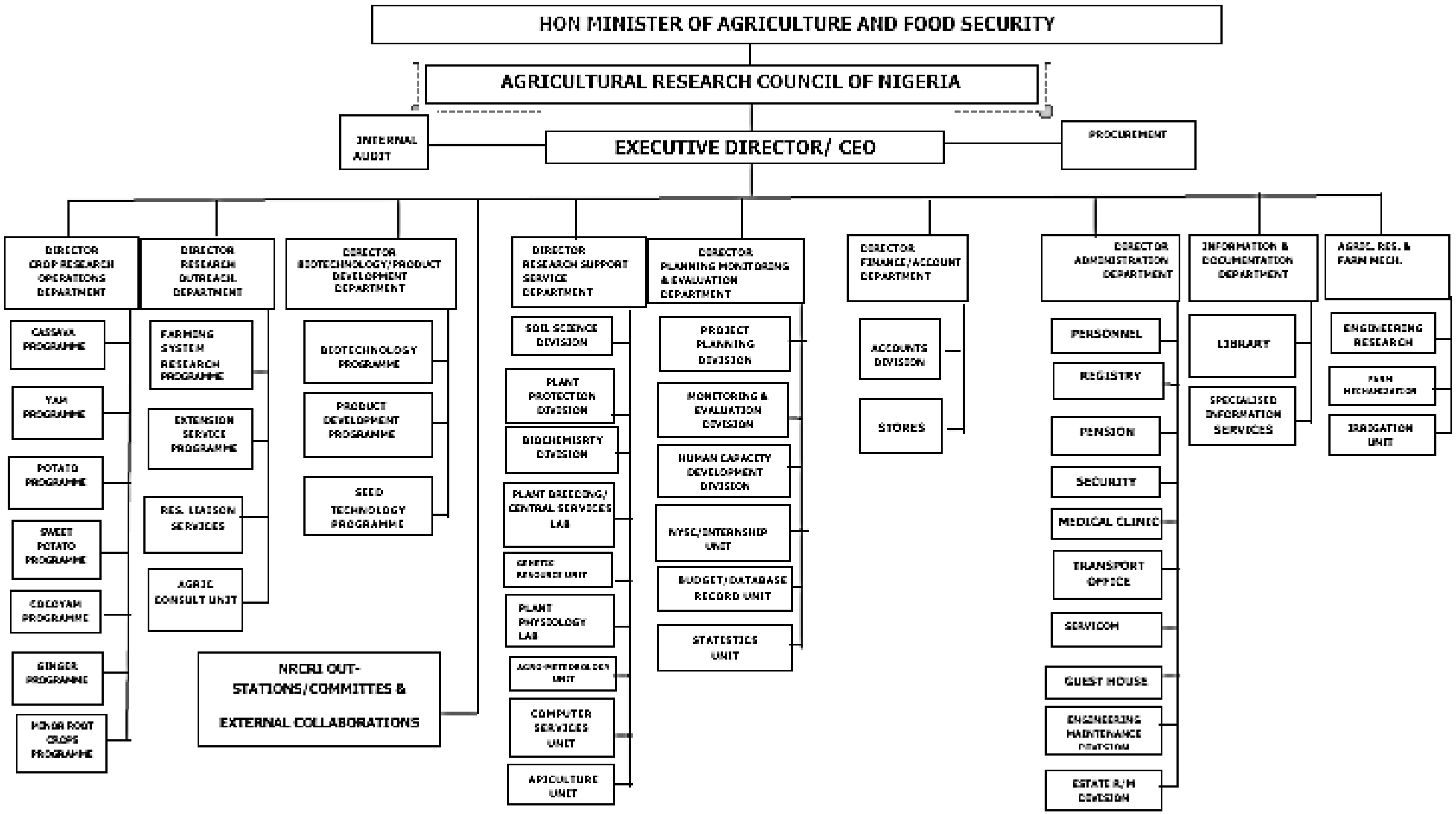
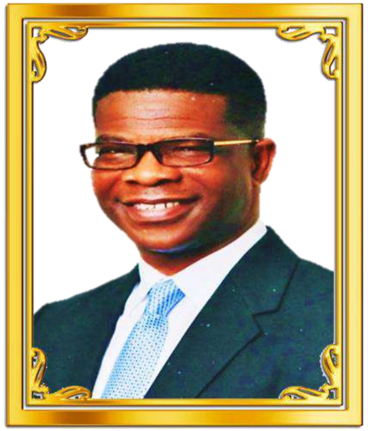


Fig. 4: Organizational Chart, NRCRI, Umudike

2.4 Present and Some Past Executive Directors/Directors of NRCRI, Umudike



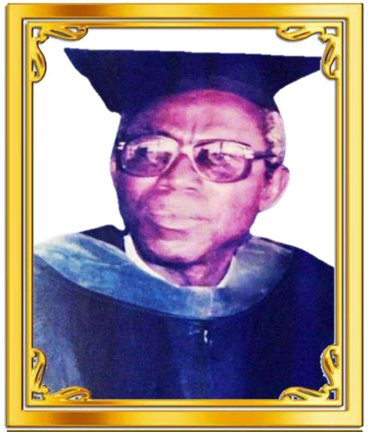
Prof. Chiedozie N. EGESI
Executive Director NRCRI Umudike
(November 2022 to present)

Prof. Ukpabi J. UKPABI
Executive Director NRCRI
Umudike (June 2017 – May 2022)

Dr. Julius C. OKONKWO
Executive Director NRCRI Umudike
(July 2012 – July 2017)

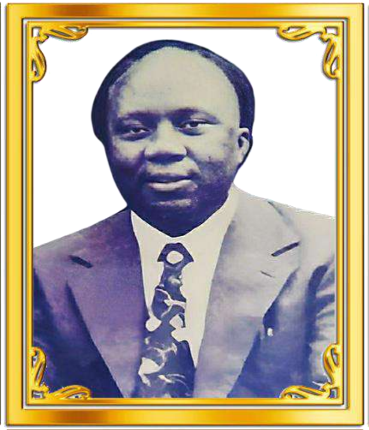
Dr. Kenneth I. NWOSU
First Executive Director/CEO
NRCRI Umudike
(December 2002 – Oct. 2011)

Dr. Michael C. IKWELLE
Director NRCRI Umudike
(Nov. 1998 – 2002)



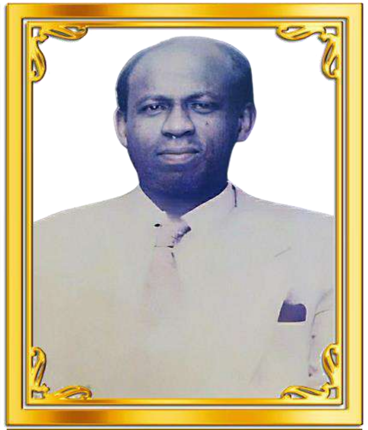
Dr. Obinani Ogbonna OKOLI
Director NRCRI Umudike
(January 1994 – Nov. 1998)

Dr. L.S.O. ENE
Director NRCRI Umudike
(May 1981 – Feb. 1994)



Dr. Benerad E. ONOCHIE
Director NRCRI Umudike
(July 1976 – May 1979)

Dr. C. H. OBIHARA
Director NRCRI Umudike
(1st June 1975 – 20th Nov. 1975)



Chief N. A. NWOSU
Pioneer Director NRCRI Umudike
(March 1972 – April 1974)

2.5 Establishment of Sub-Stations

The Institute maintains 6 sub-stations spread across the root and tuber crops producing areas of the country. They are located in:

- Kuru, Plateau State
- Otobi, Benue State
- Igbariam, Anambra State
- Nyanya, Karu, Nassarawa State
- Maro, Kaduna State
- Iresi, Osun State

These outstations are spread across the Major root and tuber belt of Nigeria (South-east, South-west and North-central).

2.5.1 Nyanya Sub-Station, Nassarawa State

NRCRI Nyanya outstation was established in the year 2000 at Nyanya along Abuja-Keffi road with a temporary office at Karu Local Government Secretariat. The main purpose for the establishment of the outstation is to have a representation of the Institute at the Federal Capital Territory to serve as a technology development and transfer centre in the Guinea savanna agroecology of Nigeria. The station started effective research and other farm activities in 2005 with its research station relocated to the present site at Jidna in 2008 with a total land area of 12.5 hectares

Heads of Nyanya Sub-station

Dr Godwin Ogbonnaya Chukwu, a soil scientist was the pioneer Head of the station, a position he held from 2000 to 2005. Dr Nnamdi Abel Onunka, another soil scientist succeeded Dr Chukwu until 2009. Dr Jude Njoku, a Systems Agronomist was appointed to head the outstation in 2009 until 2013 when Dr Edward Ngozi Nwaogu (soil scientist) took over the sub-station. Dr Nwaogu was posted back to NRCRI headquarters in 2017, paving the way for Dr Innocent Nwokomma Onyekwere (Soil Scientist) who became the Head of Station. Dr Innocent Onyekwere superintended over the outstation until October 2022, when the current Head of station, Dr Justin Enyinnaya Ewuziem (Agric. Economist) took over. The Sub-Station has a total staff strength of 71.

Strengths

The location of the sub-station, close to the Federal Capital Territory Abuja in the Guinea savanna agroecology coupled with the recent posting of very senior research officers to strengthen and position the outstation to carry out research on climate adaptation of root and tuber crops in Nigeria is the best strategic initiative of the present Executive Director-Prof. Chiedozie Egesi. This is in line with the vision of the ED to upgrade the sub-station to a centre of excellence in climate adaptation of root and tuber crops in Nigeria. The outstation is currently housing some research studies on cassava nutrient uptake, fertilizer studies in sweetpotato, Multi-location trials of new mutant lines of ginger, training of rural women and youths on value addition technologies developed by NRCRI and Economics of dry season farming of ginger using furrow irrigation. At the moment, the outstation is not receiving enough funds that will enable it to carry out required research activities.

2.5.2 Maro Sub-Station, Kaduna State

Introduction

Maro is a community in Kajuru Local Government Area of Kaduna State, Nigeria located on longitude 9º 59'N and 10º 55' N and Latitude 7º 34'E and 8º 13'E. The Local Government Area shares boundaries with Igabi LGA to the north, Chikun LGA to the West, Zangon Kataf LGA and Kachia LGA to the Southwest and South respectively. The inhabitants are predominantly petty Traders, farmers and Hunters. National Root Crops Research Institute, Maro Station, Kaduna State was established with a mandate to assist in carrying out research that will improve agricultural practices, especially for Ginger production and equally serve as a gateway for farmers to gain knowledge. The Station is the only one in the North Western part of Nigeria established in July 2004 with its intended office structure to be built in Maro Village but due to some challenges encountered. In May 2005, the office was temporarily relocated to Maraban Kajuru in Kajuru LGA under the great financial support of Late Senator Mukhtar Aruwa who was representing Kaduna Senatorial Zone 2.

Leadership

In the Eighteen (18) years the station since it commenced operation has experienced a series of different leaderships with Mr. Ene as its pioneer Head of Station (HOS); In the year 2006, Mr. Mafulul M. I. (Superintendent) assumed the position of Acting head of Station for a period of seven (7) years, followed by Late Mr. E.A. Dung (Research Officer) of blessed memory. After his demise in 2016. Mr. Victor Dabel (Research Officer) assumed the position of HOS for 3 years and Mr. Anothony Danbaba Kude (Research Officer) for a period of 2 years. In the year 2019, Mr Thomas Dalyop (Research Officer) assumed the position of new HOS and served in that capacity for less than a year. In the month of November 2019. Mr Idris Bala Macido (Superintendent) was appointed as the new head of the Station and served in that capacity for a period of Three (3) years. Dr Ali Saleh (Research Officer) succeeded him as the current Head of the Station from 4th October 2022.

Infrastructure

The Maro Station has a Metrological station that was set up in 2014 under the leadership of the Late Mr E.A Dung with the help of the Head of the Metrology Station in Jos. Which is used to generate weather data useful to support research work. The station office building occupied a plot of land measuring 300m^2 x 300m^2 at Maraban Kajuru, Kajuru LG, Kaduna State with Six (6) Offices complex, a Toyota Hilux van, a Borehole, 2 Tractors, a Diesel-electric generator. The station has a manpower capacity of 25 Staff with farmland size of 791,765.50m^2 (79.18 hectares) located at Maro Village, Kajuru LGA, Kaduna State, and another hired farmland measuring 250,000m^2 (25 hectares) located at Iburu Village, Kajuru LG, along Kaduna – Kachia Road, Kaduna State used for its Research.

2.5.3 Iresi Sub-Station, Osun State

In line with the Agricultural Transformation Agenda (ATA) of the administration of former President of Nigeria His Excellency, Dr. Goodluck, Ebele Jonathan (GCFR); the foundation laying ceremony of National Root Crops Research Institute, Iresi Sub-station, Osun State was laid on September 6, 2014. Consequently, the Iresi community allocated about 221 hectares of farmland on which experiments and activities on root and tuber crops will be sited. It is expected that the Institute will proffer solutions to farming systems problems of farmers in South-West Nigeria. It will also have multiplier effects on the livelihoods of the neighbouring states and communities by providing employment opportunities for the people of the zone. However, it is imperative to appreciate the thoughtfulness of the Institutes Governing Council and the Internal Management Committee for achieving this great feat.

Leadership

1. Dr. Akinpelu, Ayodele Oladipo (6th September 2014 to 2017)
2. Dr. Afuape, Solomon Femi (2017 to October 2022)
3. Dr. (Mrs) Akinbo, Oladunni Kofoworola (2nd October 2022 to date)

The outstation has a total staff strength of 23.

Strengths

The location of the NRCRI Iresi Sub-station coupled with the recent posting of the research officers to strengthen work in the station.
The Outstation is currently carrying out these field activities:

1. Maintenance of dry season sweetpotato vines production in the nursery for the 2023 cropping season.
2. Maintenance of 2023 yam production field.
3. Maintenance of cocoyam multilocations trial at the NRCRI, Iresi Outstation.
4. Maintenance of 2023 sweetpotato experimental field.
5. Evaluation of fertilizer use in sweetpotato as planting materials in the savannah transition ecology of Iresi Southeastern Nigeria.
6. Maintenance of 2023 sweetpotato production field.
7. Maintenance of 2023 ginger experimental field. Evaluation of Improved ginger lines for yield stability and selection for ginger varietal development in Nigeria.
8. Maintenance of 2023 cassava experimental field.

2.5.4 Kuru Sub-Station, Plateau State

Introduction

The National Root Crop Research Institute at Umudike, Abia State, has a substation devoted to potatoes. The Sub-station has the mandate for Potato Research (Potato Irish) and a few other minor root crops. In 1976, the Kuru, Jos South of Plateau State-based Potato Research Program began operations. It was founded in 1975. The objective was to launch Nigeria's rapid expansion of potato research and production. Under the direction of Dr. B. E. Onochie (Director, NRCRI), the station was created with the goal of addressing issues related to the crop's (potato's) climatic adaptation. Low tuber yields and inadequate supplies of the potato crop to Nigerians. Prior to the foundation of the Potato varietal studies were already underway at Ta-Hos in Riom Local Government, Saminaka, and Zaria in Kaduna State before the station at Kuru was established. These trials were supported by the Institute of Agricultural Research, Samaru, Zaria in 1967.

Leadership

The Programme has witnessed a good number of Coordinators that headed the station beginning from Dr O. P. Ifenkwe, Dr. J. C. Okonkwo, Dr. F. O. Anebunwa, Dr. E. C. Nwuzor, Dr C. O. Amadi, Dr D. Lenka, Mr T. Y. Dalyop, Mr A. K. Danbaba, Mr S. S. Kahya and presently, Dr C. O. Nwadili. Each of the Coordinators made some level of progress to the programme as can be observed in the Annual reports of NRCRI beginning from 1976 to date. The Potato Programme of NRCRI is one of the most successful Potato Research Programmes in Africa. Since its inception in 1975, the programme has made significant achievements in research, leading to increased potato production, improved food security, and increased income for farmers in Nigeria and other parts of the world

2.5.5 Otobi Sub-Station, Benue State

Introduction

Otobi Sub-station of National Root Crops Research Institute is one of the Sub-stations spread across Nigeria. It was established in 1976 as an experimental and production site for root and tuber crops. Otobi Akpa which is the site of the sub-station is a town in Otupko Local Government of Benue State, adaptable to the North Central Agro-ecological zone. The station has an estimated land mass of 256 Hectares.

Leadership

The sub-station from inception to date has been headed by nine (9) Heads of sub-station (HOS). Mr J.O. Okafor,1976 -1984; Mr. J.C Ogbonnaya, 1984 -1987; Dr. J.C. Okonkwo, 1988 -1990; Dr. T.O Ezulike, 1991 -1996; and Mr. B. E. Ukpokwu, 1996 -2007. Others are Mr. P.K. Akuma, 2007 -2009; Dr. M.H. Tokula, 2009 -2017; Dr. H.A. Etudaiye, 2017 -2022 and Dr C. O. Okereke, 2022 to date, with staff strength 33 (Thirty three) persons.

Activities

Among the numerous activities conducted in the station include the following: Next Generation Cassava Project (Nextgen) Advance Yield Trial, Uniform Yield Trial, Preliminary Yield Trial (AYT, UYT, PYT respectively); Programme for Emerging Agricultural Leaders (PEARL) Cassava Project; Harvest Plus Cassava Project, Building a Sustainable; Integrated Seed System for Cassava (BASIC) Trial, Alliance for Green Revolution in Africa (AGRA) Innovate Trial; Nationally Coordinated Research Programme for Yellow and White material; Nationally Coordinated Research Programme for Yellow and White material; Five hectares of foundation seed cassava by Umudike seed company, cocoyam multi-location trial, ETF ginger trial and Cassava Confined Yield Trial.

2.5.6 Igbariam Sub-Station, Anambra State

Introduction

National Root Crops Research Institute, Igbariam Sub-Station was previously located in Ugwu-Oba, Oji River of present Enugu State before it was moved to Igbariam, present day, Anambra East Local Government Area in 1979. The Station is charged with conducting research into the genetic improvement of root and tuber crops, disseminating information on the latest findings (innovations) on root and tuber crops through its extension arm, and training farmers on crop improvement and good agricultural practices. The Station is situated on 102ha of land.

Leadership

Since its inception the following have been Heads of Station; Ogbonna .O., Dr. Ikeorgu, J.G., Dr. Orkwor, G.C., Dr. Anselem Udealor, Mr. Awo Nwankwo, Mr. Obiekwe Alex, Mr. Abazie, A.C., Dr. Obasi, M.N., Dr. Okoye, B.C., Dr. Ogbonna .M., Dr. Abojah, F.N and presently, Dr. Ikoro Anyim Ikoro.

The Station is comprised of the following Units; Research, Administration, Accounts, Technical, Library and Information, and Estate Management.

2.6 Research Organization: 1973

Research work on the station continued to be organized along discipline lines till May 1973 when the first step was taken to establish nucleus research teams and research programmes on the major root crops that concern the station. In the new organization, a team of scientists of various academic disciplines working under a team leader, are assigned to one crop such as yam, cassava or potato. These scientists working co-operatively and simultaneously on all the given problems of the crop are expected to provide all the information required to assemble a comprehensive package of farm practices designed to maximize the production of the crop concerned. Essentially the new organization is designed to bring all efforts of a team of scientists working on that particular programme to isolate problems of production and provide the information required to assemble a comprehensive recommended farming practice designed to maximize both the quality and production of the crops concerned.

2.6.1 Laboratories

The laboratories which were severely damaged and looted during the Nigerian civil war, were gradually reactivated in 1973; Structural repairs to buildings and renovations were completed. Water and electricity supplies were fairly regular and a number of equipment on order were received. Although the laboratories have not been brought up to the pre-war level in respect of equipment, facilities are available for work in the following areas: Agronomy, Animal Pathology, Chemistry and Soils, Plant Breeding/Cytology/Physiology, Plant Protection, and Statistics.

2.6.2 Library

The station Library is organized into two units, namely the research and the teaching units. The Research unit has a large stock which includes standard textbooks, reference books, scientific journals, Government publications, reports, pamphlets, and the Nigerian daily newspapers. The School unit has a stock which is largely made up of textbooks and reference materials. Both units were air-conditioned with comfortable chairs and tables for reading. As of 1973, plans are on hand to build a new Library with modern facilities for research and teaching.

Fig. 5: Research Reference Library: 1973

2.6.3 Engineering Workshops

Two workshops exist as at 1973, one at the Research and the other at the School. The one located at the Research is used at present as a maintenance workshop and has a wide range of equipment for servicing plants and machinery used in the station. The school workshop is used for training and also has a variety of machinery and equipment for training in crop handling, processing and storage, as well as for training in field cultivation and survey.

2.6.4 School of Agriculture

The School of Agriculture was established in October 1955, to provide broad agricultural in-service training for sub-professional technical staff needed for research, extension and agricultural development schemes of the various governments and agricultural institutions in Nigeria. It also equips serving agricultural staff with further knowledge and skills necessary for more efficient performance of their duties and for the assumption of higher responsibilities. In addition to the regular courses, the School runs various intensive short courses for farmers or their nominees in poultry, piggery, vegetable gardening, rubber tapping and processing, farm machine operation and tractor driving. Candidates for the three regular courses must be Federal, State Government or other Agricultural Institution/Agency employees who would then be nominated for the in-service course by their employer. The School does not entertain requests for admission directly from individual candidates. Farmers and their nominees are admitted into the farmer-trainee courses on the recommendation of the officer in charge of Agricultural Extension services in the particular farmer's Division, Council, or local Administration area. The School assumed a full national outlook since the 1st of April, 1972, when it was taken over by the Federal Government as part of the Federal Agricultural Research and Training Station, Umudike. The School operates on 81 (202 acres) of the 409 hectares (1007 acres) occupied by the Federal Agricultural Research and Training Station. The School farms comprise l1 hectares (27.5 acres) of arable land, 4 hectares (I0 acres) of vegetable garden and crop nurseries, about 2 hectares (5 acres) of tree crop plantations, and 40 hectares (IO0 acres) of pasture land.

In 1992, the Institute’s Federal College of Agriculture was directed to relocate to Ishiagu, Ebonyi State, and its premises were taken over by Michael Okpara University of Agriculture, Umudike. In 2006, the Institute and its Federal College of Agriculture came under the supervision of the Agricultural Research Council of Nigeria (ARCN), Abuja; an agency under the FMAFS (Federal Ministry of Agriculture and Food Security).

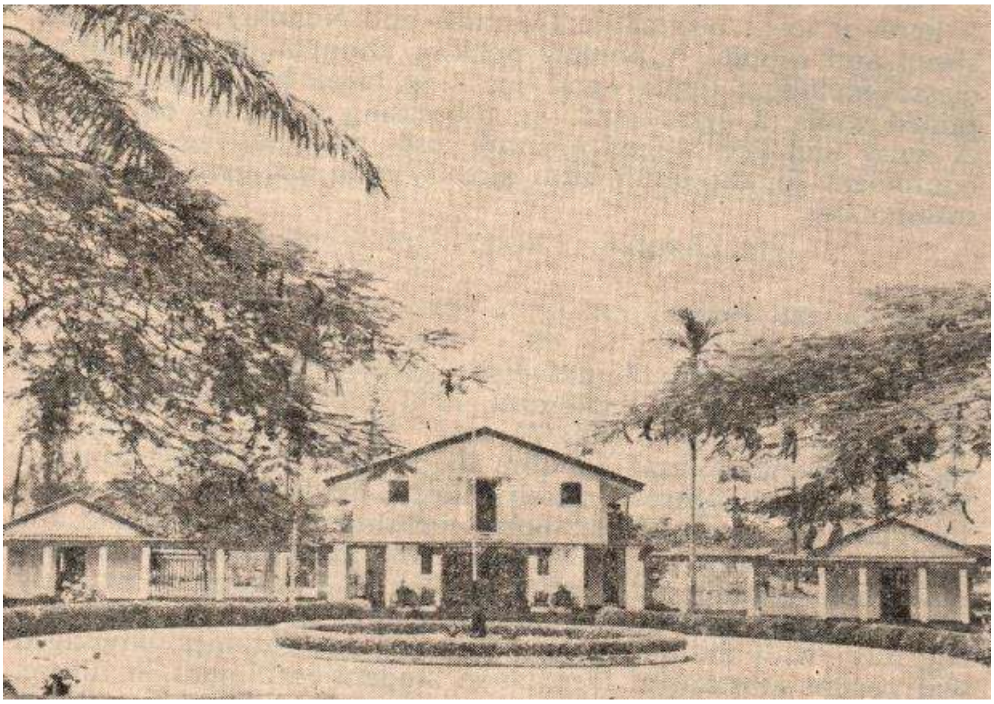


Fig. 6: Front View of the Federal School of Agriculture Umudike: 1973

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CHAPTER 03

EARLY RESEARCH STUDIES AND FINDINGS: 1923-1972

3.1 Early Experiments and Findings: 1923-1959

Most of the early experiments on the farm were conducted with the object of finding a system of cropping which would include green manures in order to maintain and, if possible, improve the fertility of the soil. One such experiment was a six-year trial rotation set up in 1924. This rotation was planned to test the cropping capacity of the soil without eventual loss of fertility by including a three-year green manure crop (Mucuna), followed by yams, maize and cassava. This rotation was then compared with the local system of a four-year bush fallow followed by a two-year cropping. Results obtained showed that whereas the soil fertility of local plots was just as high as it had been at the start, that of the continuously farmed plots had fallen practically to nil.

Cover Crops

As a result of the poor knowledge of cover crops, it was necessary first to discover a good cover crop (often a legume) which can be established readily, provides complete or nearly complete cover for the soil, enriches the soil and is capable of re-establishing itself after other crops had been taken off the land. *Mucuna utilis* and *Dolichos lablab* were among the early covers used in the early experiments conducted between 1924 and 1927.

Between 1928 and 1932, mucuna which had proved superior to Dolichos was tested against Centrosema, Calopogonium and Crotolaria. After test cropping with yams, maize and groundnut, it was concluded in 1932, that Crotolaria had a greater residual effect than all others included in the trial. Both Mucuna and Centrosema made very poor growth and produced patchy covers. They also died back during the rains and were replaced by weeds. On the other hand, Calopogonium provided the best cover and consequently deposited the greatest amount of plant material on the surface although it failed to give as much residual effect as Crotolaria.

Between 1934 and 1935, the search for a suitable cover crop continued with the inclusion of *Tephrosia candida* and *Mimosa invisa*. From this search, it was concluded that;

i. Although initial growth was rather slow, Tephrosia formed excellent cover, and early sowing was suggested.
ii. Calopogonium which grew faster and covered the soil, had little merit in the maintenance of soil fertility.
iii. Mimosa produced good cover only in good soils.

Organic Manures

Between 1937 and 1938, experiments conducted with farmyard manure and compost gave the following results:-

i. Farm-yard-manure (FYM) and compost gave increased yield responses.
ii. FYM and compost in combination with lime, where necessary, gave higher yield responses than without lime.
iii. 10.0 tons/ha (4 tons per acre) of either FYM or compost appeared to be the most economical rate.
iv. FYM was better than compost in crop yield response.

Lime

In the early 1940s, when the price of farm produce was low and there was virtually no demand, it was not considered an economic proposition for farmers around Umudike to apply lime or other fertilizers to crops, especially maize.
From experiments on maize, the following results were obtained:

i. Liming increases yield.
ii. Dressings of 1.3 tons/ha (q ton per acre) are adequate, and higher dressings tend to depress yield.
iii. Liming has to be applied 2 to 3 months before planting time for the crop to benefit.

A few other experiments carried out using yams and cassava as test crops gave a strong indication that a small dressing of lime l .3 tons/ha. (½ ton per acre) would have little or no effect on yields.

3.2 Experiments and Findings: 1960-1972

These experiments were carried out between 1960 and 1972 and were mostly on fertilizers, farming systems, varieties, and cultural practices.

Fertilizer Experiments (N.P.K.)

Fertilizer experiments through the years have indicated high responses in the yield of various crops due to fertilizer application. The Umudike soil appears to be particularly deficient in potash and nitrogen. Occasionally responses to phosphate have been obtained. Rates of application vary with crops and soils. In general, nitrogen is applied in the form of sulphate of ammonia placed a few centimetres away from the seedlings. The optimum rate for yam and cassava is around 280 kg/ha. (250 Ibs. per acre) and for maize around 336 kg/ha. (300 Ibs. per acre) Potash can be applied either in the form of muriate of sulphate. But for cassava, the sulphate form is preferred. The optimum rate for yams and cassava is around 233 kg/ha. (208 lbs per acre), while for maize, the optimum rate is around 126 kg/ha. (112 lbs. per acre), and application is by ring placement.

There is a possible interaction between nitrogen and potash; the nature of this interaction is such that nitrogen tends to give better results at the k1 level than at the k2 level.

Phosphate is usually applied as superphosphate at a dressing of about 3 l 2 kg/ha. (278 lbs. per acre) for both yam and cassava, and at 126 kg/ha. (112 lbs. per acre) for maize. The current standard fertilizer practice in the station is the application of a compound granular fertilizer N. P. K 10. 10. 20 at the rate of 336 kg/ha. (300 Ibs. per acre) for either yams or cassava.

Cropping System Experiments

The experiments which commenced in 1962 were designed to find out the minimum effective duration of a bush/stylo fallow, with and without the application of fertilizers and lime; the most effective fertilizer regime for stylo fallow, whether it is best to apply fertilizer to the fallow, the crop or both or neither; the herbaceous cover which has the greatest soil fertility regenerative ability and also the greatest livestock best-carrying capacity; the livestock b e s t suited to the farming systems advocated; the crop sequence in a rotation and the effect of the rotation-yams (1st year), maize i.p.w. cowpeas f.b. cassava (2nd year) and cassava continued (3rd year), on the building-up of posts diseases.

Unfortunately, the farming system experiments were disrupted by the civil war. Nevertheless, the following results were obtained before the war:-

i. Lime and fertilizers were necessary to boost yields under a system of fallow. Following stylo cover, the effect of fertilizers was more marked than the effect of fertilizers following bush fallow.
ii. In the crop sequence trials in general, each crop gave its best yield only when it succeeded in bush fallow cut and burnt in the year of cropping. Where the fallow was cut down a year before to rot down and residues burnt, in the year of cropping, yields were reduced.
iii. Where yam succeeded yam, the yield was significantly reduced by 67.5%; maize succeeding maize also resulted in a significant reduction in yield of 82.7%, and cassava succeeded by cassava. gave a significant reduction in yield of 59.8%.
iv. The fertilizer regime in stylo fallow gave an indication that it was better to give the fertilizer directly to the crop rather than to the fallow.
v. The fallow management involving cutting and carrying away of fallow materials as livestock feeds and returning at cropping time, their nutrient equivalent in the form of farm-yard manure, gave the most satisfactory result.
vi. In a small mixed farm holding, like the one used in the trial, sheep appeared to be a more convenient class of livestock. It was easy to manage.

Variety Trials

a) Maize: N.S. I and Western yellow, are the most promising varieties of all those tried in recent years. They are regarded as recommended varieties for the station. With fertilizers, N.S.1 yields higher than Western yellow but without fertilizer, Western yellow out-yields N.S.1.
b) Cassava: For many years, GCH 7 has had a yield potential of 13-23 tons/ha. (5 to 9 tons per acre) was regarded as the recommended variety for the station. Recent trials have now shown varieties 60506, 60447 and 5310 I as the most promising in that order and their yield potential is between 20-33 tons/ha. (8 to I3 tons per acre).
c) Rice: The following swamp varieties are recommended: I.R.5; SML/40/10; I.R.8 in place of MASS 2401 which was formerly regarded as the standard variety. The currently recommended varieties have yield potentials of between 3363 and 4708 kg/ha. (3000 and 4200 lbs. paddy per acre). Among the upland varieties, OS6, E 425 and R 66 are regarded as promising with yield potentials, of 2242 - 2803 kg/ha. (2000-2500 Ibs paddy per acre).
d) Yams: Work is in progress. No clear statement can yet be made. But early work here showed that Jioku, the yellow yam (*D. cayenensis*) was best suited to the soil conditions at the farm. At present, the variety known as Jiaga, white yam, (*D. rotundata*) is regarded as the most popular and does well when heavily manured with PYM/Compost at I5tons/ha. (6 tons per acre) and fertilizers (10.10.20) at 336 kg/ha. (300 lbs. per acre).

Cultural Trials

Over the years, cultural trials gave results which led to the following standard practices now in use on the farm:

a) Maize: Following early rains, 91.4 cm. (3ft) ridges are made and 2 seeds are sown per hole, spaced 30. 5 cm (I ft) apart on the ridge. A week after germination, the crop is thinned to one plant per stand. This gives an optimum plant population of 35864/ha. (14520 per acre). Harvests start from late June to early July.
b) Yams: Usually planted around mid-March, and spaced 61.0 cm (2 ft) on 121.9 cm. (4 feet) ridges using setts of 227¬340 gm (8-120zs.). Harvests start from October to November.
c) Cassava: Usually planted between early April and early September. Spacing is either 91.4 cm. (3 feet) on 121.9 cm. (4 feet) ridges or 121.9 cm. (4ft) on 91.4cm. (3-feet) ridges, the length of cutting is 229 mm - 305 mm (9" to 12") and about one-third of the cutting is pushed into the ground in a slanting position at an angle of about 45°.

*Early Varieties***:** Harvests start after a period of 6 months.
Late Varieties: Harvests are started after a period of one year.

CHAPTER 04

BIOTECHNOLOGY RESEARCH PROGRAMME: ACHIEVEMENTS

4.1 Introduction

The mandate for the Institute among others includes the genetic improvement of root and tuber crops such as cassava, yam, sweetpotato, cocoyam, potato, sugar beet, ginger and other minor root crops. These crops have genetic bottlenecks that impact on capacity for genetic improvement of these crops. Issues such as poor sexual reproduction due to historic vegetative propagation, long growing cycles, and lack of desirable traits in particular cultivars necessitate the use of biotechnology approaches for the benefit of resource-poor farmers. The broad research goals of the programme include producing improved varieties of root and tuber crops in terms of yield, resistance to diseases and various abiotic factors, improved nutritive and post-harvest qualities and possible elimination of undesirable traits from our mandate crops.

The Biotechnology Programme of NRCRI was established in the year 2009 with the aim of accelerating the improvement of root and tuber crops using biotechnology tools. The program research scope cuts across molecular breeding, bioinformatics, molecular diagnostics, invitro technologies and genetic modification technologies including genetic engineering and genome editing. The program from inception has attracted various collaborations with international partners proffering interventions in breeding, diagnostics and seed systems. Interventions geared towards accelerated breeding of root and tuber crops include genomic innovations (tools) for accelerating cassava breeding, profiling food quality attributes of root, tuber and banana for end-user preference, biofortification of cassava for improved accumulation of essential vitamins and micronutrients such as pro-vitamin A, Iron and Zinc, developing new cassava varieties recalcitrant to biotic and abiotic stresses, improved starch accumulation, yield and nitrogen-fixing potentials in cassava. Interventions for seed systems include building an economically, sustainable, integrated cassava seed system as well as developing seed system innovations for vegetatively propagated crops. The program is also contributing towards surveillance and developing diagnostic approaches for plant viral disease in West Africa.

The Biotechnology Programme has three main laboratories including a Cell and Tissue Biology facility that serves also as a germplasm repository. The programme also has a Molecular Biology laboratory for molecular breeding and attached to this is a Disease Diagnostic component for viral and pathological research. The third laboratory is the Trait Profiling facility which conducts phenotyping of root crops for important quality traits such as beta carotene, dry matter, starch quantity and quality among others.

The Programme has five major projects of research including Molecular Breeding and Diagnostics, Genetic Modification, In vitro Conservation and Tissue Culture Techniques, Fermentation and Microbial Biotechnology and Bioinformatics and Communication in Biotechnology where the focus is on protocol, technology and trait development.

(a) Molecular Breeding and Diagnostics

Research activities include molecular breeding through marker-assisted breeding, marker-assisted recurrent selection and genomic selection using SSR and SNP markers for biotic stress, abiotic, productivity and food quality traits. The Trait Profiling laboratory supports the phenotyping of root and tuber crops for important quality parameters. Disease Diagnostics research involves the development of viral and other diseases using molecular tools for identification, monitoring and early warning systems and understanding of the basis for resistance to major diseases.

(b) Genetic Modification

Research activities include the development of plants using biotechnology approaches. Confined field trials and biosafety research and compliance in the root and tuber crops are among activities that are being conducted. The programme has a biosafety level 2 screenhouse and a modern confined field trial site for contained and confined research and regulatory trials with biotechnology products.

(c) In vitro Conservation and Tissue Culture Techniques

Research activities include the use of cell and tissue biology in the improvement of crops with such actions as micropropagation, embryo rescue, phytosanitation through meristem tip culture, massive production and distribution of clean planting materials to farmers and development of low-cost technologies for cell and tissue biology. Other activities such as in vitro conservation of root and tuber crops are an activity in development.

(d) Fermentation and Microbial Biotechnology

Research activities include research into the development of fermentation products using root and tuber crop substrates. It also involves the manipulation of useful microbes in the improvement of root and tuber crop productivity.

(e) Bioinformatics and Communication in Biotechnology

Research activities are in development and they include the development of crop databases such as www.cassavabase.org and breeding management system (BMS) and data storage. Development of genomic libraries and data analysis of genetic data are also in development. Electronic data capture for all field and laboratory activities is being implemented for better efficiency and improved accuracy in data handling. Due to the need to give appropriate information on the benefits and risks of biotechnology, the programme is developing communication briefs on different aspects of biotechnology.

4.2 Achievements

The biotechnology program over the years has been able to achieve the following:

a. **Establishment of functional state-of-the-art laboratories** for molecular biology, tissue culture, semi-autotrophic hydroponic and genetic transformation (Fig. 7).

Figure 7: Sections of Biotechnology Laboratories

b. **Training and capacity building** for scientists to work in this field spanning from hands-on training, bachelors, masters and PhDs.

c. **Breakthroughs in AgriGenomics**

i. Development of three cassava varieties; Game Changer, Obasanjo and Hope (high yielding, virus resistance & drought tolerant) using Genomic Selection and prediction in collaborations with partners Cornel University, IITA & others
ii. Developed Virus Resistance Cassava biofortified with Iron and zinc in partnership with Donald Danforth Plant Science Center & other partners
iii. Identification of candidates genes associated with CMD resistance, CGM resistance, Leaf pubescence and stay green using Genomic Wide Association Studies (GWAS) in partnership with Cornel University, IITA & others
iv. Developed Genetic map for drought tolerance in Cassava using KASPar SNPs in partnership GCP(COP) project

UMUCASS 47: TMS13F1160P0004 (GAME CHANGER)

UMUCASS 48: TMS13F1343P0022 (OBASANJO-2)

UMUCASS 49: NR130124 (HOPE)

Figure 8: Newly released cassava genotypes developed through molecular breeding

Figure 9: Confined Field Trial for Virus resistant cassava stacked with iron & zinc

d. Breakthroughs in In-vitro technologies

i. Developed genetic transformation protocol for farmer-preferred cassava varieties in partnership with VIRCA Plus & CASS Project
ii. High-through put multiplication system for root & and tubers using semi-autotrophic hydroponic (SAH) in partnership with IITA and other partners
iii. Developed protocol & and systems for disease cleaning & and elimination in root & and tuber crops Partners in partnership with IITA and others
iv. Developed protocols and systems for high ratio multiplication of yam nuclear seeds using Temporary Immersion Bioreactor (TIBs) in partnership YIFSWA Project.

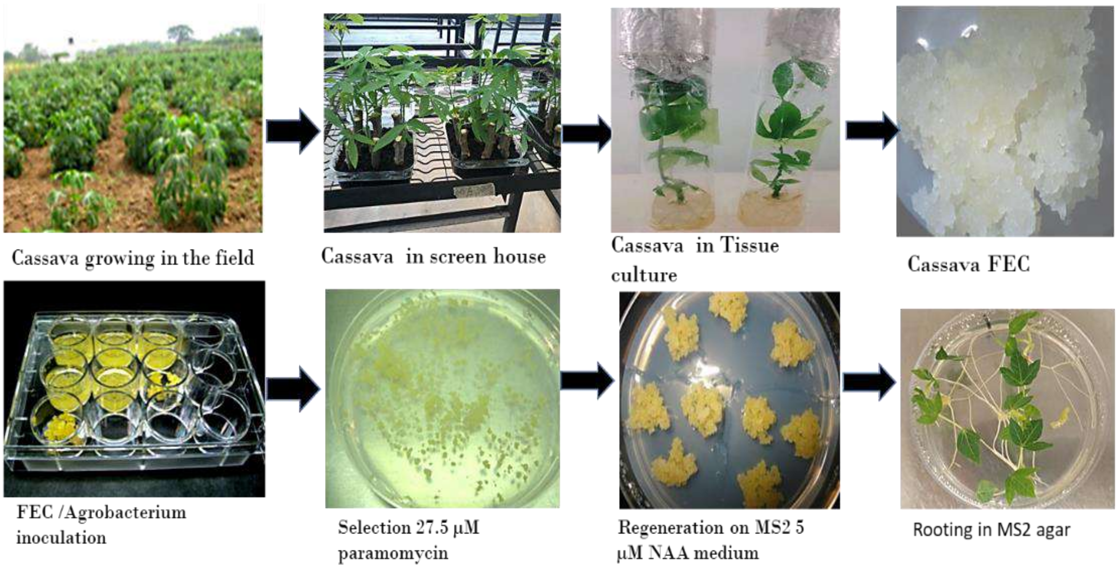

Figure 10: Protocol for the production of transgenic cassava with novel traits

Figure 11: Facility for the rapid multiplication of vegetatively propagated crops

Figure 12: Protocols & systems for disease cleaning & elimination in root & tuber crops

Figure 13: Protocol for high ratio multiplication of yam nuclear seeds using Temporary Immersion Bioreactor

e. Breakthrough in Trait-profiling

i. Developed protocol for use of Near Infra-red spectrophotometer for predicting cassava dry matter content, carotenoid starch, amylose and total titratable acidity in partnership with CIRAD and others

ii. Developed mid-throughput protocols for profiling textural properties of RTB products with texterometer (ready-to-eat cassava fufu and Eba) in partnership with CIRAD and others

iii. Developed SOP for characterizing the retting ability of cassava genotypes using a hand-held penetrometer in partnership with CIRAD and others

iv. Developed protocol for evaluating easy peeling of farmer-preferred cassava cultivars in partnership with CIRAD and others

Figure 14: Protocol for the use of Near Infra-red spectrophotometer for predicting of cassava dry matter content, carotenoid starch, amylose and total titratable acidity

Figure 15: Mid-throughput protocols for profiling textural properties of RTB products with texterometer (ready-to-eat cassava fufu and Eba)

Figure 16: Protocol for characterizing the retting ability of cassava genotypes using a hand-held penetrometer and Protocol for evaluating ease of peeling of farmer-preferred cassava cultivars

4.3 Conclusion

NRCRI's R&D programmes are characterized by a continuing integration of the novel crop improvement strategies, and molecular breeding (including genetic transformation). The Institute collaborates actively with international agricultural research centres and several advanced laboratories and participates in several multi-country projects. NRCRI, with its recent inception of a confined field trial of genetically modified cassava, has become the first institute in Nigeria to be accredited.

CHAPTER 05

SEED TECHNOLOGY RESEARCH PROGRAMME: ACHIEVEMENTS

5.1 Introduction

Seed Technology Programme of the National Root Crops Research Institute, Umudike came into existence in the year 2012 and is the newest addition to the Institute. Seed Technology Programme past and present Coordinators include Dr E.C. Nwachukwu (2012-2014), Dr N. A. Onunka (2014- 2017), Dr M. Tokula (2017- 2020), Dr (Mrs) Ebeniro C. N. (2020) and Dr Korieocha, D. S. (2021 to date). The role of the Seed Technology Programme is inherent in the mandate of the Institute as it is a platform designed for the production of high-quality seeds in Root and Tuber Crops. Progress in agriculture depends on the production and distribution of quality seeds and best-yielding varieties with desirable characteristics; Seed technology takes care of this. The term "seed" is used to denote botanical seeds, tuber, roots or other plant parts. Good seeds/panting materials naturally imply freedom from diseases, insects and pests as well as other physiological qualities. Other aspects of seed technology include; production, processing, certification, testing, storage, entomology, pathology and marketing. The National Root Crops Research Institute, Umudike has strategically positioned and upgraded root and tuber crop production nationally by offering improved varieties of crops that address food security issues; through in-depth research and application. The role of the seed technology programme is therefore to consolidate and ensure the availability of these products to the end users.

The specific objectives of the programme include to;

1. develop an effective seed programme for the production of quality seed in root and tuber crops
2. collaborate with breeders in commodity crop programmes within the Institute and National Seed Council to produce breeders, certified and foundation seed in root and tuber crops
3. develop an effective agronomic and cultural practice for the production of quality seed in root and tuber crop
4. develop good management and control measures for diseases and pests in root and tuber crop seed production
5. apply modern Agricultural biotechnology and other techniques for rapid cleaning and multiplication of seeds in root and tuber crops.
6. develop an effective post-harvest management of seed in root and tuber crops. The seed technology programme is a multidisciplinary platform that requires the collaborative effort of all scientists across the commodity crop programmes of the institute.

5.2 Achievements

a) Planting of improved varieties of cassava on 0.5ha land area at Igbariam, Anambra State, Umudike, Abia State and Otobi, Benue State.
b) Establishment of pilot plots for certified foundation seeds in all the Agroecological zones for supply to out-growers.
c) Capital development on key areas of seed technology, seed certification, seed storage, processing, seed testing and evaluation for research staff of the programme.
d) Identification of seed companies that are involved in improved seed yam production.
e) Improved seeds of root and tuber crops were made available to some seed companies, village seed entrepreneurs and farmers.
f) Weed management: use of Aclonifen/Isoxaflutole (Lagon 5 +5 sc) and the rate of 0.95kg ai/ha implemented with Glyplusate (post-emergence) at rate 0.65 kgai/ha at 10 and 14WAP.
g) Another study showed that the use of 12.5cm of cassava stem (seed) gave the same yield as the 25cm length. The implication is that the cost of production occasioned by the high cost of planting material can be reduced by the use of this 12.5cm length and in turn, will enhance productivity.
h) Collaborating with institutions like the National Agricultural Seeds Council (NASC) Abuja. The presence of the South-East region office located within the Institute ensures that compliance with the production of certified quality seeds is achieved.
i) Detection of CMD by molecular methods, buttresses the need for technologies that aid the elimination or mitigate the spread of diseases.
j) Part of the national mandates of the National Root Crop Research Institute (NRCRI)Umudike is the development of improved and cost-effective technologies for the genetic development of high-yielding, disease-resistant sweet potato seeds with high seed purity, and ensuring that there is an all-year round availability of such seeds to farmers. In response to this mandate of the Institute, The Roots and Tuber Crop (RTCs) Programs has recorded some measure of achievements resulting in:
   - Breeding and release of new varieties
   - The production of RTCs Seed in Tissue Culture Laboratory
   - Currently NRCRI maintains good stock of RTC varieties in the TC Lab

Fig. 17: Tissue Culture Laboratory: NRCRI

Training on sweetpotato seed production

NRCRI has also embarked on capacity building of both staff, farmers and students on production of quality sweetpotato seed as business. Fig. 1 show some pictures of training conducted on quality seed production within the country. We have conducted capacity trainings of sweetpotato seed entrepreneurs in the following various aspects of Sweetpotato production and utilization:

- The use of net tunnels
- Whatever you want to know about sweetpotato
- Farm records and book keeping
- Diseases identification and control
- Field inspection
- Tripple 'S' Technology
- Rapid vine multiplication etc

NRCRI has ensured that all the released varieties of sweetpotato seed were promoted and known to the farmers and end users- we target the audience through:

- Schools
- Field days – Rural Communities • Market etc.
- Radio Jingles
- Fliers
- Sweetpotato production guide – extension research programme etc.

Fig. 18: Training of DVMs (Decentralized Vine Multipliers) across States in Nigeria

Fig. 19: Awareness Creation on OFSP Seed and Root Production in Schools

5.3 Efforts made by NRCRI to formalize the Sweetpotato seed System

Fig. 20: Stakeholders meet on how to formalize the Sweetpotato Seed System

The highlight of the meeting was to harmonize the sweetpotato seed nomenclature and standard seed protocol.

Estimation of Cost and Price of Sweetpotato Basic and Commercial Seed in Nigeria

The Program has been able to estimate the unit cost of production of basic seed (screenhouse and net tunnel) @ N4.7 and N2.4 respectively. The price of basic seed has been established @ N500 (screen house) and N300 (net tunnel) using real-time costing and cost route approaches.

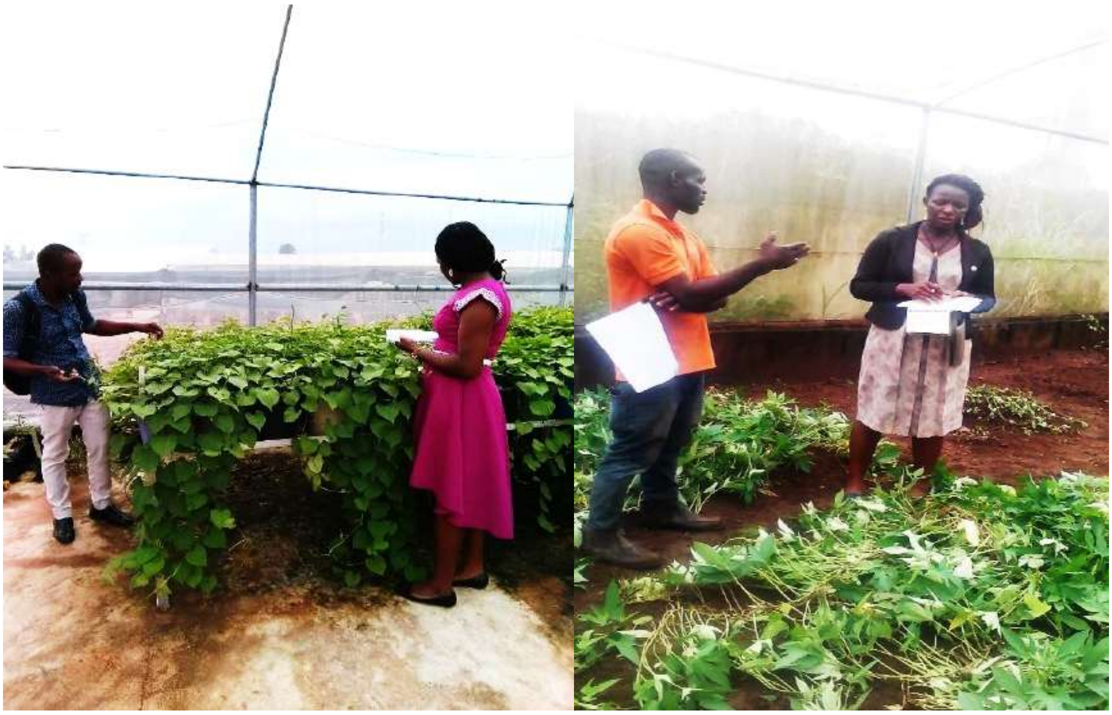

Fig. 21: Real time costing of sweetpotato seed production (Okoye et al., 2018)

Development of Sweetpotato Seed Business plan

With the support of SASHA 11 project, the Program was able to develop a sweetpotato seed business plan for both small and medium seed investors in Nigeria. The business plan components include:

- Seed multiplication calendar
- Micro recording sheet
- Marketing strategies for sweetpotato seed
- Pricing strategies
- SWOT analyses
- Cost structure

Sustainability of Sweetpotato Seed

NRCRI has finally sustained sweetpotato seed production through establishment of Revolving Fund (RF) account with NRCRI commercial Venture account where all the proceeds from sales are used to take care of the recurrent cost of production.

Building An Economically Sustainable Integrated Cassava Seed Systems (Basics Project; Asumugha *et al*., 2018)

A comprehensive data collection of VSEs in Abia, Akwa Ibom, Cross Rivers, and Imo States was conducted from November 14-20, 2018 using 17 trained interns and junior researchers. The study aimed to understand commercial competence, volume of stems sold, and challenges faced by VSEs, and to inform necessary support for their business. A one-day training session was organized to prepare interns. All the 50 trained VSEs were visited and interviewed.

Fig. 22: Interns training at NRCRI Umudike

Table 1 shows that Cross River state had the least number of VSEs (11) who are predominantly men. In terms of female participation in the VSE programme, Cross River and Abia States recorded the lowest with 22.2% and 33.3% respectively. The predominant varieties supplied to the VSEs are, TME 419, TMS 30572, TMS 0505, TMS 0581 and Yellow root cassava varieties. Most of the VSEs ratooned from their farms to replant and expand the size of their farms. From the records, about 4578 bundles of cassava seed were sold against a projected 4000 bundles in 2018. Meanwhile, over 50% of the VSEs could not sell stems as a result of low demand and poor prices offered by buyers. Across the states, cassava seed prices recorded an average season price of ₦800 per bundle. This is lower than the prices recorded during the previous season (Tables 2 and 3).

Table 1: Distribution of VSEs by State and Sex

S/N	States	Males	Females	Total
1	Abia	9	3	12
2	Akwa Ibom	7	5	12
3	Cross River	9	2	11
4	Imo	10	5	15
	Total	**35**	**15**	**50**

Table 2: Distribution of cassava seed bundles sold by VSEs according to varieties

Varieties	Bundles sold	Percentage
TME 419	3377	73.8
TMS 0505	99	2.2
TMS 0581	171	3.7
UMUCASS 36	931	20.3
Total	**4578**	**100**

Table 3: Distribution of cassava seed bundles sold by VSEs by States

States	Bundles sold		Percentage
Abia	1640	TME 419 = 1160 TMS 0505 = 0 TMS 0581= 75 UMUCASS 36= 405	35.8
A/Ibom	1518	TME 419 = 1220 TMS 0505 = 52 TMS 0581= 153 UMUCASS 36= 93	33.2
Imo	1420	TME 419 = 1001 TMS 0505= 15 TMS 0581= 5 UMUCASS 36 = 399	31.0
Total	**4578**		**100**

5.4 Component Focus Going Forward

a) Strengthen VSE's access to the seed tracker & and VSE's social networks.
b) Linking the NIRSAL cooperatives to our VSEs for seed supply
c) Linkage with CBN ANCORPS Borrowers farmers who will get stems from VSEs while supplying roots to processors.
d) Advocacy/Liaising with CBN for our VSEs.
e) Clustering VSEs around processing plants in the States as well as input dealers.
f) Putting in place Innovation platforms for cassava stakeholders where VSEs will play a key role.
g) Exhibitions, Field days, Expos of VSEs products especially the vibrant ones & refresher trainings.
h) Encouraging VSEs to mentor others (Peer-to-peer mentoring 1:10).
i) Collaboration with CWM project, ACAI, ATASP-1 Outreach program

Fig. 23: Umudike Seed Foundation seed yam in storage

Fig. 24: Umudike Seed Screen House with one node yam vine

Fig. 25: Nwabudo seed yam farm, Amapu Ntigha Abia State

Fig. 26: NRCRI Screen houses

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CHAPTER 06

PRODUCT DEVELOPMENT RESEARCH PROGRAMME: ACHIEVEMENTS

6.1 Introduction

The Product Development Programme (PDP) is one of the three programmes under the Biotechnology and Product Development Department out of the five departments in the National Root Crops Research Institute (NRCRI). The programme handles the processing of NRCRI mandate crops after harvesting. Root and tuber crops are highly perishable due to the high moisture content of most of these crops. Hence, a need to process them to a more storable state (improved shelf life) after harvest. Also, some of the crops contain anti-nutritional compounds that require to be removed before consumption. PDP research covers the processing of biofortified crops using appropriate processing methods that ensure retention of the fortified crops, such as pro-vitamin-A fortified crops which includes yellow root cassava, orange fleshed sweetpotato and other biofortified crops. Value addition to all NRCRI mandate crops is a key schedule of PDP. This has been the focus of the programme for many years and they have had huge success in this line. The programme researched making innovative products of RTCs and to the credit of the Institute, one such innovative product was patented by the Federal Ministry of Science and Technology in 2019. More of such are on the way. PDP is involved in research and training activities into processing, preservation, storage and utilization of the Institute's mandate crops among these activities is participation in the exhibition of RTCs-based products both at National and International programmes. Worthy of mentioning is the unique way PDP handles all students posted to programmes from high institutions for Industrial Training (IT). The students are been taught how to process NRCRI mandate crops into value added products. Also, PDP organizes fortnightly seminar presentations by grouping the IT student and giving topics related to their course of studies to make presentations. This has gone a long way in helping the student to do their school seminar presentation and project writing. Some of these students PDP for I T do engage in the food business after the training.

6.2 Programme Structure

For the effective running of PDP, the programme is divided into units, which include: The kitchen/innovative food sales centre; Food Research Laboratory; *Gari* processing unit and Cassava processing unit. The kitchen/innovative food sales centre. This where food developed are been processed from fresh crops or intermediate (Various flours) into Ready-To-Eat (RTE) products and these are been displayed at the sales centre located within the institute for general populace patronage at a customer-good price. The food Laboratory is a research laboratory where researchers conduct their research on RTCs to develop various food forms and evaluate their sensory acceptance test, shelf-life etc. In the *Gari* processing unit cassava roots are been processed into high quality *gari*, High Quality Cassava Flour, Instant fufu flour, cassava chips and processing of other RTCs into either RTEs, but mostly intermediate products. The Cassava processing unit conducts the processing of cassava into various food forms mostly intermediate products. The use of higher equipment. However, this unit has been run by the private sector for many years.

6.3 Milestone Achievements of the Product Development Programme

PDP is one of the strong arms of NRCRI because of its contributions to the successes recorded in the Institute over the years. Among these numerous contributions include:

1. Pioneered the development of new food forms/products from cassava in Nigeria (Oji, 1989) and cocoyam Mbanaso and Akomas (1986).
2. Development of 28 value-added food forms of Sweetpotato (Aniedu and Oti, 2007).
3. Development of over 26 value-added products cassava (recipes) (Aniedu and Oti, 2008).
4. Development of over 22 value-added products of Cocoyams (Aniedu and Oti, 2009).
5. Development of over 24 value-added products of Wateryam (Aniedu and Oti, 2011).
6. Development of numerous food forms of minor root crops such as Hausa potato, turmeric, Amora (Omodamiro *et al*., 2021) (*Tacca leontopetaoides*), etc.
7. Development of different food forms of American Yam Bean roots. Various fortifications of root and tuber crop food with underutilized and less known crops e.g. African Yam bean, soybean, Bambara nuts, etc.
8. Determination of physicochemical properties and food uses of NRCRI mandate crops
   Production of drinks from Orange fleshed Sweetpotato and the utilization of Sweetpotato leaves as vegetables. (Omodamiro *et al* 2011, Omodamiro *et al*., 2017, Omodamiro *et al*., 2023)
9. Training of over women/youth/farmers on value addition innovations to farm produce in over 250 communities/Organizations across Southeast, South-south, North-central and other parts of Nigeria. Impact and adoption studies of training in value-added innovations in root/tuber crops 5 States of Nigeria.
10. The programme conducts training of Master Bakers in Nigeria in conjunction with the Federal Ministry of Agriculture & Rural Development on 20% HQCF inclusion in breading making and in setting standards for the operations of HQCF production in the country.
11. The programme in conjunction with the Extension Services Programme, promotes the activities of the Institute through the exhibition of innovations developed by NRCRI, Umudike during World Food Days (at Abuja and Abia State), Field Days, trade fairs, etc. It is important to note that in all the exhibitions, NRCRI, Umudike had taken the first position or adjudged one of the best food exhibitors.
12. The programme is also involved in the dissemination of the Institute's activities to farmers through radio, print media and T. V. programmes in international, national and local media activities.
13. The students/groups/individuals visit the programme on educational tours.
14. The programme generates revenue for the Institute through the sales of value-added products of root/tuber crops and processing activities open for public patronage.

6.4 Achievements in Innovative New Products

The programme under the leadership of Dr. Rachel Majekodunmi OMODAMIRO as the Coordinator developed many new root and tuber crops-based products. Among these commercial potential products include:

Turmeric and ginger-based products

Turmeric activated tea (enhanced curcumin bioavailable turmeric tea)
Turmeric non-activated tea (turmeric tea without curcumin enhancer)
Turmeric Green Tea
Ginger Green Tea

Plate 1: Turmeric green tea, Non activated turmeric tea and Activated turmeric tea respectively

Plate 2: Ginger Green Tea; Activated Turmeric Tea; Non activated Turmeric Tea and Turmeric Green Tea respectively

Orange Fleshed Sweetpotato (OFSP) based Products

Plate 3: Orange Fleshed Sweetpotato based fruity drinks

Some Orange Fleshed Sweetpotato (OFSP) based Ready-To-Eat Snack

Plate 4: OFSP Crunchy snacks; OFSP Jam; 30% OFSP bread, 20% HQCF: 30% OFSP: 50% Bread, OFSP 40% Cake

6.5 Achievements in Patency

Product Development Programme has been able to patent one of her innovative root and tuber crops-based products (Nutritive Turmeric Enriched *Gari*). More products are undergoing patency registration and will soon be released.

Plate 5: NRCRI Patented product: Nutritive Turmeric Enriched Gari

6.7 Achievements in newly developed Technologies

High-Quality Amora Industrial Starch

D. dumentorum Flour (Yammy) for swallow

Cassava fibre Tiger nut cookies

OFSP crunchy snacks

Plate 6: Some newly developed Technologies from amora, yam, cassava and OFSP

6.8 New Branded Product Packaging / Presentation

The Product Development Programme greatly improved her product packaging by using standard food grade and attractive packaging materials such as PET//MET: PE/MET etc materials

Orange Fleshed Sweetpotato fortified Cookies

Turmeric-fortified 100% Cassava strips

Amora/wheat chin-chin

OFSP crunchy snacks

Cookies

Ginger flavour Coco yam chips

New look of NRCRI OFSP Fruity Drinks

OFSP fortified flour for swallow

Instant Cassava Flour for swallow, packaged in food-grade polyethylene bag

Plate 7: Branded Product Packaging

6.9 Some Recent (Under 5 years) Processing Technology Developed

Plate 8: Processing Of Fresh Amora Tuber into High-Quality Amora Starch (QAS)

Plate 9: Sun Drying using net tunnel: Net box tunnel (solar dryer) developed to dry food material with acceptable microbial load according to NAFDAC and SON standards

6.10 Improvement in Product Display at NRCRI, Annual In-House Review

Fig. 27: Day one exhibition of innovative root & tuber crops (RTCs) based products, at the 2023 External In-House review meeting, April 2023

Fig. 28: Day two of the 2023 External In-House Review meeting. Director Biotechnology and Product Development Dr. T. J. Onyeka, viewing displayed RTCs-based products

Plate 10: Displayed innovative Ginger Green Tea, Activated Turmeric Tea, Non-Activated Turmeric Tea, and Turmeric Green Tea respectively, at the NRCRI 2023 Annual external in-house review

Fig. 29: The Honorable State Minister for Science and Technology, Chief Henry Ikechukwu Ikoh applauds the Product Development Programme

The Honorable State Minister for Science and Technology, Chief Henry Ikechukwu Ikoh applauds the Product Development Programme *displayed RTCs value added products, accompanied* by the ED Prof C. Egesi other dignitaries Dr Mrs Tessy Madu and other management staff, at the the2023 external in-house review. The exhibition attracted some private companies seeking to partner with the institute among these is SASADECO farms, Ebonyi State.

6.11 Participation in National Programmes

Product Development Programme participates yearly in national programmes such as World Food Day, Feed Nigerian Summit, and AGRICON Conference & Expo etc.

❖ **Feed Nigeria Summit**

The showcase of NRCRI's innovative and existing products at the 2022 Feed Nigeria Summit was well appreciated by the participants. The Hon. Minister for the Federal Ministry of Agriculture and Rural Development appreciate NRCRI's potential in exportable innovative products.

Fig. 30: Hon. Minister for FMARD and entourage admires NRCRI Innovative potential exportable foods, accompanied by the ED NRCRI Prof C Egesi at the 2022 Feed Nigeria Summit, Abuja

- **Exhibition of NRCRI products at 2022 Exhibition show organized by the Federal Ministry of Agriculture and Rural Development (FMARD) held at National Centre for Asbestos-Related Diseases (NCARD), Jos. October, 2022.**

Fig. 31: The Executive Secretary ARCN, Prof. Hamidu Sharubutu admiring NRCRI Value added products

Fig. 32: Senate Chairman, Committee on Agricultural and Rural Development commenting on export potentials of NRCRI innovative products

Fig. 33: Sweetpotato farmers and special guests admiring orange fleshed sweetpotato 40% cake

❖ Testimony of an Outstanding National Performance

Cocoa Research Institute of Nigeria (CRIN) documented our technology's outstanding exhibition performance titled *Exhibition Galore for NRCRI production technologies & Value Added Products* in her Institutes Newsletter. At the Institute's exhibition stand at the National Centre for Asbestos-Related Diseases (NCARD) in Jos, Nigerians appreciated the array of NRCRI Value Added Products and Technologies. Kudos to Dr.

(Mrs.) Rachel Omodamiro and Dr Adanma Amaefula for a good outing as the NRCRI stand was the cynosure of all eyes. The Executive Secretary of the Agricultural Research Council of Nigeria, (ARCN), Prof. Garba Hamidu Sharubutu (mni) was very impressed with the quality of NRCRI value-added products.

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Fig. 34: Executive Secretary, ARCN, Prof. Garba Hamidu Sharubutu (mni) admiring NRCRI technologies (CRIN 2022)

- **In 2021 and 2022 NRCRI showcased potential exportable products from root crops at the 2nd and 3rd AGRICON Conference and Expo held at International Conference Centre, Federal Capital Territory, Abuja.**

Fig. 35: NRCRI exhibits value-added products at the 2nd and 3rd AGRICON Conference and Expo held in 2021 and 2022 respectively

❖ 2022 World Food Day Exhibition

NRCRI received many schools among other visitors, at World Food Day 2022.

Fig. 36: Students from Keffi Secondary School listening to the NRCRI team on the economic potentials of RTCs through value addition at NRCRI stand at the World Food Day 2022

Fig. 37: AWARD of Second Position at the 2022 World Food Day Exhibition, and presentation of Award to the ES Agric. Research Council of Nigeria (ARCN) Prof. Garba Hamidu Sharubutu using the background of display of NRCRI export potential products at the ARCN museum

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CHAPTER 07

CASSAVA RESEARCH PROGRAMME: ACHIEVEMENTS

7.1 Introduction

Origin, History and Development

Cassava originated from Latin America and was introduced into Africa and Nigeria by the Portuguese traders and explorers from Fernando-Po to Warri in the then Mid-Western Nigeria in the late 18th Century (Muoneke and Njoku, 2008). It later spread to Lagos, Badagry, Abeokuta and Ijebu in the early 19th Century by slaves returning from the West Indies and Sierre Leone who settled in these towns (Agboola, 1979). These returnees processed cassava into gari, lafun and iwa-panya (roast and eat) for food. Cassava and cassava products were later introduced into Eastern Nigeria along the Coast towns of Calabar and Yenagoa by traders from Western Nigeria. Thus, cassava may have been introduced in Nigeria to different regions about 330 years ago (Agboola, 1979).

However, cassava improvement and development started in 1940 with the collection and introduction of superior germplasm for improved yields and resistance against pests and diseases (Umunah, 1977). Based on a two-year selection of the collected germplasm, the first cassava hybrid called Gold Coast Hybrid (GCH 7) or 37065 emerged in 1942. This variety had an average yield of 9t/ha with an improvement of 28% in yield over local varieties (Umanah, 1977 and Okeke, 1988). A further selection of locally available cassava germplasm in 1953 gave rise to another superior cassava hybrid popularly called Oloronto or 53101. This was recommended to farmers in Southwestern Nigeria.

In 1954/55, modern cassava research and development started at the Federal Department of Agricultural Research (FDAR), Moor Plantation, Ibadan, when a Plant Breeder was assigned to the cassava improvement programme. With the provision of a Breeder, more collections were made locally and from foreign countries. Some of the germplasm acquired from foreign countries include *Manihot glaziovii* from Puento Rico; *Manihot melonohasis* and *Manihot saxicola* from Amani in East Africa. Crosses of these cassava varieties, 53101 and 42074 etc., led to the development and release of cassava hybrids such as 60444, 60:06 and 60447 in 1967. The attributes of these early-developed varieties are shown in Table 4.

Table 4: Recommended pests and diseases resistant cassava varieties and their qualities

Variety	Yield/acre	Mean increase over local variety (%)	Starch content at 15-18 months (%)	HCN content (mg/100g)
Gold Coast (GCH 7)	8.9	28.0	23.0	182.0
53101	13.6	64.5	30.0	185.0
60444	16.3	95.3	25.30	162.0
60506	15.4	78.0	30.0	162.0
60447	15.0	55.1	25.30	189.0

Source: Umanah (1977)

Shortly after the inception of NRCRI Umudike in 1973, the Institute developed and released some resistant and high-yielding cassava varieties namely: NR 41044, NR 8082, NR 8083, NR 8212, NR 8267 and NR 8233. Also, in collaboration with IITA, Ibadan more cassava varieties have been released to date.

The Cassava Research Programme is among the pioneer commodity crop programmes established since the inception of the institute in 1973. The mission of the programme as the branch of the institute is to improve the Cassava crop and its cultivation for production, industrial uses and income generation. The programme has a core mandate to conduct research on varietal-developed Cassava genomes that produces root crop with high yield, disease and pest resistance suitable for multi-purpose end users through conventional and marker-assisted breeding (MAS) techniques. The programme as an organ of the Institute is also responsible for the promotion of cassava along the value chains through the development of the best-fit production packages for different agro-ecological sections to optimize yield on farmers' fields. It also works in collaboration with the sister Post Harvest Research. To bring research findings into the limelight, Extension Services are integrated into the cassava programme to promote, popularize and disseminate relevant research findings developed by the Institute through the use of different strategic teaching methods. However, the Extension Service Programme in the Cassava program is designed specifically to popularize and promote the activities in the Cassava Programme through the establishment of different information circulating channels to the end users who are the core target of the breeders. Research efforts of the programme in partnership with local and international partners have brought a modest increase in the national average yield on farmers' fields from (9-11t/ha) to (15-25t/ha), making Nigeria the World's largest producer of Cassava.

Breeding research objectives on the cassava root crop among others include:

a. High fresh root yield, dry matter and starch contents.
b. Resistance to major cassava pests- cassava mealy bugs (CMB), cassava green mite (CGM) and diseases- cassava mosaic disease (CMD), cassava bacterial blight (CBB) and cassava anthracnose disease (CAD).
c. Compatibility with intercrops with legumes, cereals, vegetables and other crops in intercropping systems.
d. Extended in-ground reduced storage cyanogenic potentials.
e. Early maturity (8–10 months after planting)
f. High Carotene and protein-based varieties
g. Drought tolerant varieties

To Achieve the Aims and Objectives of the Cassava Programme, National Root Crops Research Institute, Umudike works in Collaboration with the following Institutions:

a. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria: a major collaborating institution in the development of improved cassava varieties, pre-emptive management of a severe form of CMD, Cassava Enterprise Development, HarvestPlus as it relates to beta carotene in cassava roots and Integrated Pest Management of whitefly- transmitted viruses of cassava and sweetpotato
b. Donald Danforth Plant Science Centre (DDPSC), St. Louis, Missouri, USA in the area of genetic engineering to elevate resistance in farmers' preferred cassava varieties which are highly susceptible to CMD, and screening of farmers' preferred varieties for possible bio-engineering to improve the protein content of cassava tubers, reduce cyanogenic potential and to delay the deterioration of cassava tubers after harvest.
c. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia with a focus on the use of simple low-cost marker technology to pyramid useful genes for delayed post-harvest physiological deterioration of cassava in addition to maintaining resistance to the major pests and diseases.
d. International Atomic Energy Agency (IAEA), Vienna, Austria for the conduct of research on the use of radiation to produce desirable mutants of cassava varieties.
e. Alliance for Green Revolution in Africa (AGRA) funding drought tolerant cassava improvement and availability in Nigeria.
f. Generation Challenge Programme (GCP) provides funds for many projects on cassava improvement in Africa including NRCRI, Nigeria.
g. Raw Material Research Development Council (RMRDC), Abuja, Nigeria on research for early maturing (8–10 months after planting) cassava varieties
h. National Centre for Genetic Resources and Biotechnology (NAGRAB), Abuja Nigeria: in the area of genetic engineering for cassava variety development.
i. Cornell University, Ithaca NY, USA: on the Next Generation Cassava Breeding (NEXTGEN Cassava) project which aims to significantly increase the rate of genetic improvement in cassava breeding to unlock the full potential of cassava. The project implements and is empirically testing a new breeding method known as genomic selection that relies on statistical sampling, predicts cassava performance before field testing, and dramatically accelerates the breeding cycle.
j. West Africa Agricultural Productivity Programme (WAAP): in funding multiplication of breeder and foundation seed stock for distribution to farmers.
k. African Agricultural Technology Foundation (AATF): funding and partnership in the execution of the Cassava Mechanization and Agro-Processing Project (CAMAP) in two pilot states in Nigeria.

7.2 Achievements

Synergies between NRCRI and IITA had led to the release of 46 improved cassava varieties to farmers in Nigeria including six beta carotene (Pro-Vitamin A) varieties and six early maturing varieties. The cultivation of these improved cassava varieties by farmers in Nigeria has placed Nigeria as the world-leading producer of cassava. In light of this, NRCRI Umudike in collaboration with IITA has recorded the following achievements:

1. Development of best-fit agronomy packages to optimize yield on farmer's fields without adverse effects on soil substrate and environmental hazards. These include choice of stem cuttings as planting material, appropriate plant spacing for different cropping systems, use of appropriate fertilizer regimes and cost-effective weed management.

2. Development of cultural control measures for pests and diseases of cassava such as termites, cassava green mites and CMD.
3. Identification of transgenic cassava plants with elevated resistance to CMD, Vit. A, Fe and Zn under screen house condition at DDPSC, U.S.A. The plants are undergoing testing under field conditions in Nigeria.
4. Exotic germplasms with desirable traits such as PPD, protein, beta-carotene etc., have been introduced from the centre of primary diversity to NRCRI for introgression and evaluation.
5. The programme has been playing an active role in the Cassava transformation agenda of the Federal Government as a major key player in the multiplication and distribution of improved planting materials, demonstration farms, development and evaluation of cassava varieties for High Quality Cassava Flour (HQCF), distribution of input to farmers through the Growth Enhancement Scheme (GES) and provision of technical services to farmers.
6. Promoted and disseminated the Institute's new research findings and varietal release on cassava varieties through print media such as newspapers, magazines, the establishment of demo farms, result demonstrations, individual contact, farmers, as well as the Institute's own News bulletin.
7. Establishment and use of demonstration plots with improved production practices to showcase prototype on-farm evidence of various technologies developed by the Institute for teaching myriads of students, farmers and other visitors that visit the Institute.
8. Exposed and sensitized youths and farmers to the latest research findings of the Cassava Programme through guided tours to NRCRI farms, laboratories, and engineering and exhibition units.
9. Integrated, updated, upgraded and strengthened the knowledge and skills of farmers on improved agricultural, innovation, Production and post-harvest technologies through ad-hoc training, Adopted Villages/Schools Outreaches and Out-grower Schemes.
10. Creating marketing Channels and Extension Delivery for newly improved cassava varieties and processed cassava Products. These include the development of a Market Information System (MIS) on root and tubers to guide stakeholders.
11. Adoption and Impact assessments of NRCRI disseminated newly improved cassava technologies.
12. Organized training for over 6,000 women & youths on improved processing and value addition to root and tuber crops in the Institute's Rural/Women Empowerment Programme.
13. Facilitation of dissemination of improved cassava technologies through the adopted villages and Schools outreach projects established in different communities and secondary schools in Nigeria with the support of WAAPP in 2013 multiplication of cassava and yam seeds for distribution to farmers.
14. Conducted several trainings of subject matter specialists of the ADPs, extension agents, farmers and other root crops entrepreneurs on improved cassava production, processing, utilization and business.
15. A two-week training programme for cassava seed entrepreneurs (CSEs), 2021, for value chain development among youths in nine States (Enugu, Kogi, Nassarawa, Anambra, Benue, Ebonyi, Niger, Ogun and Taraba) by NRCRI, Umudike in partnerships with FGN/FAD/VCDP at the library complex, Umudike. Trained 120 youths from nine states to become cassava seed entrepreneurs.
16. NRCRI Umudike, organized a two-day intensive training workshop for more than 60 farmers. Theme: Commercial Seed Entrepreneurship (CSE) and Good Agricultural Practices for Cassava.

17. PIND/BASICS-II. Workshop initiative on the “foundation for partnership initiatives in Niger Delta for Building an Economically Sustainable Integrated Cassava Seed System (BASICS-II) organized by NRCRI, Umudike and Kolping Society of Nigeria, Abia State.

Fig. 38: NRCRI Cassava Demonstration Farm

Fig. 39: Screen house: Cassava

Fig. 40: NRCRI 2020 released cassava variety: HOPE (NR130124)

Fig. 41: NextGen Cassava Breeding project sponsored by BMGF

Nine high pro-vitamin A Cassava varieties released in Nigeria

Year of Release	Genotype	Yield (t/ha)	DMC (%)	PVAC (µg/g)
2012	UMUCASS 36	26.6	24.8	8.2
2012	UMUCASS 37	29.0	26.3	6.4
2012	UMUCASS 38	20.0	28.5	5.7
2014	UMUCASS 44	36.4	36.0	10.8
2014	UMUCASS 45	34.0	40.2	11.7
2014	UMUCASS 46	32.0	33.0	10.9
2022	UMUCASS 52	51.7	35.3	16.9
2022	UMUCASS 53	51.6	33.3	15.6
2022	UMUCASS 54	45.8	30.6	15.7

***Highlight of Achievements** Cont'd*

- *In 2012, 3 pro-vitamin A cassava varieties were released – UMUCASS 36, 38 and 39.*
- *In 2014, another 3 pro-vitamin A cassava varieties were released UMUCASS 44, 45 and 46.*
- *In January 2022, additional 3 pro-vitamin A cassava were released- UMUCASS 52 (Headmaster), UMUCASS 53 (Security) and UMUCASS 54 (No-hunger).*
- *We provide some incentives to farmers like Agro inputs such as seeds, fertilizers and herbicides. For example, from 2014-2021, an estimated 900,000 Nigerian households received pro-vitamin A cassava planting varieties from NRCRI.*
- *Released of cassava varieties: Umucass 47, 48, 49, 50, 51....(support by NextGen Cassava Breeding Project)*

Fig 42: Highlights of Pro-Vitamin A Cassava varieties released in Nigeria

Fig. 43: Some food products from Pro-Vitamin A Cassava Varieties

Fig. 44: Picture taken with Executive Director of NRCRI (Dr. J.C. Okonkwo), Dr Damian, Genetic Resource Unit staff, cassava programme staff and IT students during PPD evaluation training exercise on Monday, 27th July 2015 at Pearl Cassava Breeding Project Building, NRCRI, Umudike, Abia state, Nigeria

Table 5: Cassava Research Improvement at NRCRI Umudike

S/No	Project Title	Duration
1	Generation Challenge Programme (GCP)	2005-2013
2	Alliance For a Green Revolution in Africa (AGRA), Cassava1	2009-2012
3	Alliance For a Green Revolution in Africa (AGRA), Cassava2	2016-2019
4	International Atomic Energy Agency (IAEA)(Mutation Breeding	2005-2010
5	HarvestPlus (Cassava Breeding)	2008-2015
6	Program for Emerging Agric Research Leaders (PEARL) Cassava	2016-2020
7	BioCassava Plus	2005-2015
8	Community of Practice (CoP) on Cassava	2008-2013
9	CARGS-ARCN (Cassava Breeding)	2010-2013
10	CARGS-ARCN (Genetic Resources-Cassava)	2010-2013
11	Fed Min of Trade & Investment (Cassava)	2006-2012
12	NextGen Cassava Breeding Project (phase 1 & 2)	
13	West Africa Virus Epidemiology (WAVE) Cassava	
14	BASICS (Cassava)	
15	Cassava Weed Management Project	
16	African Cassava Agronomy Initiative (ACAI)	
17	Agric Transformation Agenda Support Program (ATASP1&2)	
18	West Africa Agricultural Productivity Project (WAPP1&2)	
19	Many others and even some in pipeline	

7.3 Some Milestones achievements in Collaboration with the Product Development Programme

1. NRCRI sponsored by RTBfoods Umudike, completed and submitted the Gendered food mapping reports on *Fufu* and *Gari-Eba*; reported on the Participatory processing diagnoses with processors and consumer testing studies on *Fufu* and *Eba*.

2. The Institute also achieved and approved the SOP for optimizing *Fufu* processing and preparation as well as the descriptors and scale for the descriptive sensory evaluation. NRCRI, Umudike also collaborated with CIRAD to conduct a proof of concept study to ascertain the biophysical properties that influence the retting ability of different cassava varieties during *Fufu* fermentation.

3. NRCRI Umudike developed the SOP for predicting dry matter (DM) and amylose content of wet *Fufu* mash using the ASD portable hand-held NIRS. Calibrations for predicting dry matter and starch yield of *Fufu* were also developed by the institute.

4. NRCRI, Umudike further processed and characterized *Fufu* quality traits of 91 clones from PYT (Preliminary Yield Trial); Umudike and Ubiaja, 70 clones from NCRP (Umudike and Otobi) and 29 clones from Uniform Yield Trial (UYT cy1a and cy1b

population); (Umudike and Otobi) planted in different agro-ecological zones in Nigeria.

5. NRCRI, Umudike also published an article titled Quality Attributes of *Fufu* in South-East Nigeria: Guide for cassava Breeders in the Special Edition IJFST https://doi.org/10.1111/ijfs.14875.

6. NRCRI, Umudike in conjunction with IITA produced the SOP for optimising processing and sample preparation of *Eba*. The descriptors and scale for carrying out the descriptive sensory evaluation of *Eba* were developed by IITA and NRCRI, Umudike. In conjunction with IITA, NRCRI produced the SOP for optimising instrumental texture analysis of *Eba.*

7. NRCRI, Umudike developed SOPs for the determination of the dry matter and amylose content of unmilled and milled *Gari* using the ASD hand–held NIRS. The institute collaborated with other partners to ensure the publication of an article titled Fom cassava to *gari*: Mapping of Quality Characteristics and End-user Preferences in Cameroon and Nigeria in the Special Edition of IJFST. https://doi.org/10.1111/ijfs.14790

8. In 2003, NRCRI, Umudike introduced Cassava Cooking Banana and Cocoyam cooking Banana Composite flours for snack making (Cake and chin-chin). However, Oti and Etudaiye of NRCRI, Umudike, also produced Cassava-Cocoyam composite flour for instant *Fufu* from Cassava Varieties like NR 930255, 30199, 87184, 8212, 930061, 84292, 930127, TMS 96/0304 and TMS 71762.

9. In the year 2004, NRCRI, designed and fabricated a cassava chipping machine. Introduced a Fabricated drying root and tuber chips/slice; a dryer for temperatures lower 60^{o}C.

10. In 2005; fabricated a hydraulic jack cassava presser, the starch recovery facility used for processing. Worked on 28 improved cassava varieties (NR8082, 30572, TMS 4(2) 1425. Inclusive were 25 newly selected CMD resistant genotypes from IITA in collaboration with NRCRI; to produce *lafun* and starch, 16 samples (TMS 94/0039, 98/0002, 92/0057, 98/2101, 96/1089, 99/3037, 99/21 23, 98/006, TMS 96/1565, NR 8082, TMS95/0166, TMS4 (2) 1425, TMS94/0026 TMS 94/0561 and TME 419 was selected for *lafun* and *amala*.

11. 2006; designed and fabricated a dewatered cassava pulp pulverizer/sifter (2kg/min) capacity for prototype. Screened and selected some varieties for high dry matter, starch and gari yield respectively (TMS 30572, NR 87184, TMS 82/0058 TMS 98/0002 TMS 98/0581, and TME 419.

12. 2008; used cassava starch from TME 419 to produce a gelling agent in medium preparation in place of agar for *in vitro* micropropagation. Further TME 419, TMS 97/0162 and TMS 98/0505 as gelling agents for *in vitro* multiplication of ginger.

13. 2009; Processed and used starch from nine cassava varieties as a gelling agent alternative and medium for in vitro propagation of cassava. Produced value-added products from HQCF from β-carotene cassava genotypes.

14. 2010; Cassava starches produced and used as a gelling agent substitute for *in vitro* propagation of yam.

15. 2012; released TMS 98/2132 (Umucass 42) and TMS 01/1206 (Umucass 43) for high fresh root yield, high dry matter and excellent food forms. Discovered that vitamin A-rich cassava root meal can replace up to 50% of maize for the production and growth performance of broilers. Produced salad cream from yellow root cassava that has seven weeks shelf life. Predicted a model that uses a centrifuge to replace the manual method of dewatering cassava.

16. 2013; produced ethanol from 3 varieties of cassava with TMS 98/0505 and the highest ethanol production.

17. 2014; buttressed the point on paper bags as effective in long-term storage of cassava flour to maintain microbial stability and other attributes and recommended a plastic bucket for carotenoid retention.
18. 2016; recommended that farmers and feed millers include 40%pro-vitamin A cassava-rich meal in the diet of laying hens.

19. 2018; successfully fed pigs with 50% cassava replacement with maize.

20. 2019; recommended soaking sun drying for roots and sun drying for chips for production of dried cassava chips used in producing other cassava-based products and livestock feed production respectively. Produced turmeric fortified *gari*. Recommended soaking and sun drying as methods of processing cassava roots into chips and improving their mineral levels except for Zn in TMS 01/1368 and Na in TMS 98/0505.

21. 2020; discovered that the nutrient uptake rate of cassava under West Africa conditions can be achieved at 4MAP under non-water limiting conditions. This provided insight into optimizing the timing of nutrient application and management for maximum yield response.

Table 6: Some Released Improved Cassava Varieties from NRCRI Cassava Programme and Collaborators

S/N	Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Outstanding Characteristics/ Potential Yields
11	NICASS 11	NR-8208	NGME 96-11	NRCRI, Umudike	NRCRI, Umudike	High yielding
12	NICASS 12	NR-8083	NGME 96-12	NRCRI, Umudike	NRCRI, Umudike	High yielding
13	NICASS 13	NR-83107	NGME 96-13	NRCRI, Umudike	NRCRI, Umudike	High resistance to pests and diseases.
14	NICASS 14	NR-8082	NGME 96-14	NRCRI, Umudike	NRCRI, Umudike	Very high-yielding and resistant to pests and diseases.
15	NICASS 15	TMS-50395	NGME 96-15	IITA Ibadan	IITA Ibadan	High biomass
16	NICASS 16	NR-8212	NGME 96-16	NRCRI, Umudike	NRCRI, Umudike	High yielding
17	NICASS 17	NR-41044	NGME 96-17	NRCRI, Umudike	NRCRI, Umudike	High yielding
25	NICASS 25	NR 87184	NGME 06-25	NRCRI, Umudike	NRCRI, Umudike/RMRDC, Abuja	Early maturing, high yielding, suitable for food and industry (34.6t/ha)
26	NICASS 26	TMS 92/0057	NGME 06-26	IITA	IITA/NRCRI Umudike	Fairly suitable for mixed cropping, high yielding, suitable for food and industry (37.7t/ha)
26	NICASS 26	TMS 92/0057	NGME 06-26	IITA	IITA/NRCRI Umudike	Fairly suitable for mixed cropping, high yielding, suitable for food and industry (37.7t/ha)

S/N	Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Outstanding Characteristics/ Potential Yields
27	NICASS 27	TMS 92/0326	NGME 06-27	IITA	IITA, NRCRI Umudike and RMRDC Abuja	Early maturing, suitable for mixed cropping, high yielding, suitable for food and industry (39.5t/ha)
28	NICASS 28	TMS 96/1632	NGME 06-28	IITA IITA	IITA NRCRI IITA, NRCRI Umudike	Fairly suitable for mixed cropping, high yielding, suitable for food and industry (43.2t/ha)
29	NICASS 29	TMS 98/0002	NGME 06-29	IITA	IITA, NRCRI Umudike and RMRDC Abuja	Early maturing, fairly suitable for mixed cropping, high yielding, suitable for food and industry (48.4t/ha)
30	NICASS 30	NR 93/0199	NGME 08-30	NRCRI, Umudike	NRCRI, Umudike	Very suitable for food and industry
31	NICASS 31	TMS 96/1089A	NGME 08-31	IITA	IITA, NRCRI Umudike	Contains moderate level of beta-carotene, high yielding, suitable for food and industry
32	UMUCASS 32	NR 01/0004	NGME-10-32	NRCRI, Umudike	NRCRI, Umudike	Early maturing, moderately suitable for intercropping, high yielding, suitable for food and industry and tolerance to drought. (48.4t/ha)
33	UMUCASS 33	CR 41-10	NGME-10-33	CIAT, Colombia	NRCRI, Umudike	Very suitable for intercropping, early maturing, high yielding, suitable for food and industry and tolerance to acidic soils. (46.4t/ha)
34	UMUCASS 34	TMS 01/0040	NGME-10-34	IITA, Ibadan	NRCRI, Umudike	Moderate branching that can smother weeds, early maturing, high yielding,

S/N	Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Outstanding Characteristics/ Potential Yields
						suitable for food and industry. (51.7t/ha)
35	UMUCASS 35	TMS 00/0203	NGME-10-35	IITA, Ibadan	NRCRI, Umudike	Suitable for smothering weeds in sole cropping, early maturing, high yielding, suitable for food and industry. (43.3t/ha)
36	UMUCASS 36	IITA TMS 1011368	NGME-11-36	IITA, Ibadan	NRCRI, Umudike	High beta carotene, high yield, suitable for *gari* and f f it bl f hi h*fufu*, suitable for high quality cassava flour. (46.5t/ha)
37	UMUCASS 37	IITA TMS 1011412	NGME-11-37	IITA, Ibadan	NRCRI, Umudike	High beta carotene, high yielding, suitable for *gari* and *fufu*, broad adaptation. (59.1t/ha)
38	UMUCASS 38	IITA TMS 1011371	NGME-11-38	IITA, Ibadan	NRCRI, Umudike	High beta carotene, suitable for *gari* and *fufu*, suitable for high quality cassava flour. (39.3t/ha)
39	UMUCASS 39	NR 03/0211	NGME-11-39	NRCRI, Umudike	NRCRI, Umudike	Early maturing, high yielding, high starch yield, suitable for high quality cassava flour. (42.5t/ha)
40	UMUCASS 40	NR 03/0155	NGME-11-40	NRCRI, Umudike	NRCRI, Umudike	Early maturing, high yielding, suitable for *gari* and *fufu*, tolerance to drought. (53.7t/ha)
41	UMUCASS 41	CR 36-5	NGME-12-41	International Centre for Tropical	NRCRI, Umudike	High starch yield, high dry matter, erect plant type suitable for intercropping and

S/N	Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Outstanding Characteristics/ Potential Yields
				Agriculture (CIAT), Cali, Colombia.		dense population in plantations and suitable for *gari* and *fufu*. (42t/ha)
42	UMUCASS 42	IITA TMS I 982132	NGME-12-42	IITA, Ibadan	IITA, Ibadan, NRCRI, Umudike	High root yield, high dry matter and moderate carotene content. (49.5t/ha)
43	UMUCASS 43	IITA TMS I011206	NGME-12-43	IITA, Ibadan	IITA, Ibadan, NRCRI, Umudike	High root yield, high dry matter content, drought tolerance (leaf retention in the dry season), and suitability for high quality cassava flour due to low fibre content and high starch of dry roots. (53t/ha)
44	UMUCASS 44	NR 07/0220	NGME-14-44	NRCRI, Umudike	NRCRI, Umudike/IITA, Ibadan	High beta carotene content and high yielding. (36t/ha)
45	UMUCASS 45	IITA TMS I 07/0593	NGME-14-45	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High carotene content and high yielding. (34t/ha)
46	UMUCASS 46	IITA TMS I 07/0539	NGME-14-46	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High carotene content and high yielding. (32t/ha)
47	UMUCASS 47 (GAME CHANGER)	TMS13F1160P0004	NGME-20-47	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High starch, dry matter content and high fresh root yield. (39.2t/ha)
48	UMUCASS 48 (OBASANJO-2)	TMS13F1343P0022	NGME-20-48	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High starch, dry matter content and high fresh root yield and good for flour. (38.7t/ha)

S/N	Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Outstanding Characteristics/ Potential Yields
49	UMUCASS 49 (HOPE)	NR130124	NGME-20-49	NRCRI, Umudike	NRCRI, Umudike/IITA, Ibadan	High fresh root yield. Excellent *gari* and *fufu* quantity and quality. (40.1t/ha)
50	UMUCASS 50 (BABA-70)	IITA-TMS-IBA00070	NGME-20-50	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High fresh root yield. Excellent *gari* and *fufu* quality. (37.5t/ha)
51	UMUCASS 51 (POUNDABLE)	TMEB693	NGME-20-51	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	Poundable, mealy, low cyanogenic potential and high dry matter. (26t/ha)
52	UMUCASS 52 (HEADMASTER)	IBA154810	NGME-22-52	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High fresh root yield, high dry matter content and elevated level of total carotenoid content.35.97 t/ha
53	UMUCASS 53 (SECURITY)	IKN130010	NGME-22-53	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High fresh root yield, high dry matter content and elevated level of total carotenoid content. 30.22 t/ha
54	UMUCASS 54 (NO-HUNGER)	IBA164773	NGME-20-54	IITA, Ibadan	IITA, Ibadan/NRCRI, Umudike	High fresh root yield, high dry matter content and elevated level of total carotenoid content. 29.78 t/ha

NRCRI Cassava Programme Present Research Interests going forward

a. Increasing the protein content of cassava tubers
b. Selection for high beta carotene content in cassava tubers
c. Delay in post-harvest deterioration of cassava tubers
d. Development of early maturing varieties
e. Screening and breeding for resistance against CMD, CBB, CAD, CMB, etc
f. Breeding of varieties for good nutrition and that are drought resistant Development of best-fit production packages for intensive production that is socially, economically and ecologically friendly.
g. Encouragement of cassava-based industries for starch, flour, ethanol etc.
h. Research focusing on the removal of weak links along the value chain.
i. Research focusing on the nutritive values of cassava leaves for human and animal consumption.
j. Sensitization, monitoring and early warning system against Cassava brown streak disease (CBSD).

Training and Awareness Creation on Cassava Virus Diseases Management, Good Agricultural Practices, Processing and Exhibitions

NRCRI WAVE Training on the use of Plant Village App Nuru for Cassava Virus disease Diagnosis

Dr Okoye, B.C. and Trainees during the ATASP-I training on Prospects for Gari, Starch and High Quality Cassava Flour (HQCF) Production, Anambra State

NRCRI WAVE Country Director – Dr. C. K. Nkere in on-farm training on Plant Village Nuru app for cassava disease diagnosis

Dr Udemezue J.C. with Anambra State FADAMA CARES Farmers Umueje Community, Anambra State

Dr. Damian Njoku showcasing cassava products at exhibition fair

NRCRI ED-Prof Egesi, C. explaining the importance of Pro-vitamin A cassava to humans to the former Minister of State for Science & Innovation (Chief Ikoh) during his official visit to NRCRI Umudike, Febr. 2023

Fig. 45: Some Training and Awareness Creation on Cassava Virus Diseases Management, Good Agricultural Practices, Processing and Exhibitions

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CHAPTER 08

YAM RESEARCH PROGRAMME: ACHIEVEMENTS

8.1 Introduction

Yams (*Dioscorea spp*) are among the oldest food crops believed to have originated in the tropical areas of three separate continents; Africa, South-East Asia and South America. In West Africa, man began to gather yams for domestic use as early as 50,000 BC. Yam is not only a vital staple food but is considered *king* crop, having great ethnic as well as agricultural importance in West Africa, where much ritual has developed around its production and utilization. Various preparations of yam are still the choice food of millions during ceremonies and festivals and it is an indispensable bride price in Nigeria. Yam is an important crop for millions of rural poor producers, processors, and consumers in many countries in the world, particularly in West and Central Africa (WCA). It is estimated to provide millions of people with an average of 200 kcal per day. It is also clearly a major source of revenue for many rural poor people including a good proportion of women as producers, processors, and traders. The goal of NRCRI's yam research has been to enhance the adoption of improved technologies by farmers, and thus contribute to a sustainable increase in productivity of yam-based systems.

The programme dates back to the 70s with historic research leadership pioneered by Drs Ene, Okoli, Igwuilo, Nwinyi, Igbokwe, Orkwor, Ikeorgu and Nwachukwu. Our success today dates back to the very foundation they established and their scientific insights. The programme has thus evolved including the following pathways;

1. Expand the demand for yams (increased number and diversity of end-products from yams, better understanding of product profiles, markets and consumption patterns)
2. Increase productivity of yam cultivation (increased yield, lower storage losses, and lower costs of production)
3. Contribute to enhanced capacity for research on yams
4. Promote partnerships with other stakeholders in yam research and development
5. Promote awareness of the opportunities and challenges of the yam sector and progress being made in research for development
6. Engage in policy dialogue towards increased support for the Yam sector

8.2 Research Focus

1. Agronomy, breeding and crop improvement – The main goal under this focus is to increase yam productivity whilst reducing production costs and environmental impact by developing and deploying end-user preferred varieties with higher yield, greater resistance to pests and diseases and improved quality in Nigeria.

2. Integrate d soil, crop, and pest management in yam systems – we focus on sustainable management of yam crops in terms of crop health, soil fertility and production profitability. We apply knowledge from breeding, farming systems, physiology, and soil fertility management among others for yam cultivation.

3. Post-harvest- We investigate on yam product diversification and increased market opportunities. We prioritize trait preferences with key stakeholders (including producers, retailers, processors and consumers). We evaluate gender impact on value chains, considering demographic and lifestyle trends. We focus on understanding of different traits and food product preferences by different social groups and value chain actors.

4. **Policies, institutions and markets** – The research on policies, institutions and markets seeks improvement in outcomes of improved food security, poverty reduction, enhanced nutrition and health as well as sustainable management of biological resources. Our research contributes to technology adoption and sustainable intensification, cross-cutting gender initiatives and capacity strengthening, we address issues on ex-ante adoption of novel technologies and value chain analysis.

We target poverty reduction and increased food security through the development of relevant and sustainable technologies for stakeholders involved in root and tuber crops. NRCRI, in partnership with collaborators, has released 35 (Table 7) yam varieties in Nigeria.

Table 7: List of 35 released yam varieties in Nigeria

S/N	Variety name	Original name	Collaborating Scientists	Outstanding Characteristics	Year of release/regist.
1	TDR 89/02677	TDR 89/02677	Dr. S.K. Hahn, Dr. R. Asiedu , Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, cream tuber parenchyma, 25% tuber dry matter content.	2001
2	TDR 89/02565	TDR 89/02565	Dr. S.K. Hahn, Dr. R. Asiedu ,Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, cream non-oxidizing parenchyma, 35% tuber dry matter	2001
3	TDR 89/02461	TDR 89/02461	Dr. S.K. Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good as cooking and pounding qualities, cream parenchyma, 26.7% tuber dry matter.	2001
4	TDR 89/02665	TDR 89/02665	Dr. S.K. Hahn, Dr. R. Asiedu , Dr. G.C. Orkwor	Stable yields very good cooking and pounding qualities, cream non-oxidizing parenchyma, 35.3% tuber dry matter	2003
5	TDR 89/01213	TDR 89/01213	Dr. S.K. Hahn, Dr. R. Asiedu, Dr. G.C. Orkwor	cooking and pounding qualities, white non- oxidizing parenchyma, tuber dry matter = 29.8%	2003
6	TDR 89/01438	TDR 89/01438	Dr. S.K. Hahn, Dr. R. Asiedu ,Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, tuber dry matter = 29.3%	2003
7	TDR 95/01924	TDR 95/01924	Dr. S.K. Hahn, Dr. R. Asiedu, Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, tuber dry matter = 32.8%	2003

S/N	Variety name	Original name	Collaborating Scientists	Outstanding Characteristics	Year of release/regist.
8	DRN 200/4/2	DRN 200/4/2	E. C. Nwachukwu	High yielding, pests and disease tolerant, very good for fufu, frying and boiling. (35t/ha)	2008
9	TDa98/01176	TDa98/01176	R. Asiedu, C.N. Egesi	High yielding, pests and disease tolerant, good for pounded yam, frying and boiling, suitable for both rainy and dry seasons yam production. (26-30t/ha	2008
10	TDa98/01168	TDa98/01168	R. Asiedu , C.N. Egesi	High yielding, pests and disease tolerant, good for pounded yam frying and boiling. (24-28t/ha)	2008
11	TDa98/01166	TDa98/01166	R. Asiedu & C.N. Egesi	High yielding, pests and disease tolerant, good for pounded yam, frying and boiling, suitable for both rainy and dry seasons yam Production. (26-30t/ha)	2008
12	TDr 95/19158	TDr 95/19158	R. Asiedu	High yielding, pests and disease tolerant, very good for yam, fufu, frying and boiling. (29.4t/ha)	2009
13	TDr 89/02602	TDr 89/02602	R. Asiedu, J.G. Ikeorgu and E.C. Nwachukwu	High yielding, pests and disease tolerant, very good for yam, fufu, frying and boiling. (31.5t/ha)	2009
14	TDr 89/02660	TDr 89/02660	R. Asiedu, J.G. Ikeorgu and E.C. Nwachukwu	High yielding, pests and disease tolerant, very good for yam, fufu, frying and boiling. (31t/ha)	2009
15	TDa 00/00194	TDa 00/00194	. Asiedu, C. N. Egesi and J. G. Ikeorgu	High yielding, pests and disease tolerant, good for pounded yam, frying and boiling. (37.5t/ha	2009

S/N	Variety name	Original name	Collaborating Scientists	Outstanding Characteristics	Year of release/regist.
16	TDa 00/00104	TDa 00/00104	R. Asiedu, C. N. Egesi and J. G. Ikeorgu	High yielding, pests and disease tolerant, good for pounded yam, frying and boiling. (30t/ha)	2009
17	UMUDa-4	TDa 00/00364	R. Asiedu, C.N. Egesi & J.G. Ikeorgu	High yielding, good for Amala, pounded yam, frying and boiling. (33.3t/ha)	2010
18	UMUDr-17	TDr 95/19177	R. Asiedu, E.C. Nwachukwu	High yielding under dry season yam cropping system. (30t/ha)	2010
19	UMUDr-18	TDr 89/02475	R. Asiedu, E.C. Nwachukwu & J.G. Ikeorgu	High yielding, pests and disease tolerant, very good for yam fufu, frying and boiling. (31t/ha)	2010
20	UMUDr-20	TDr 98/00933	Lopaz, A., Maroya, N Asiedu, R., Nwankwo, I.I.M., Eke-Okoro, O.N., Ikeorgu, J.G. and Ikoro, A. I.	Potential yield (39.8t/ha)	2016
21	UMUDr-21	99/Amo/064	Nwachukwu, E.C., Nwankwo, I.I.M., Eke-Okoro, O.N., Ikeorgu, J.G. and Ikoro, A	Potential yield (43.9t/ha)	2016
22	Obiaoturugo	Obiaoturugo	Nwankwo, I.I.M., Eke-Okoro, O.N., Ikoro, A. I. and Ikeorgu, J.G	High yielding. (27.78t/ha	2016
23	Amola	Amola	Nwankwo, I.I.M., Eke-Okoro, O.N., Ikoro, A. I. and Ikeorgu, J.G.	High yielding. (21.6t/ha	2016
24	Hembakwasa	Hembakwasa	Nwankwo, I.I.M., Eke-	High yielding. (29.94t/ha	2016

S/N	Variety name	Original name	Collaborating Scientists	Outstanding Characteristics	Year of release/regist.
			Okoro, O.N., Ikoro, A. I. and Ikeorgu, J.G.		
25	Ekpe	Ekpe	Nwankwo, I.I.M., Eke-Okoro, O.N., Ikoro, A. I. and Ikeorgu, J.G.	Early maturing and high yielding. (23.21t/ha)	2016
26	Alushi	Alushi	Nwankwo, I.I.M., Eke-Okoro, O.N., Ikoro, A. I. and Ikeorgu, J.G.	High yielding. (27.6t/ha)	2016
27	UMUDa-27 (Aku abata)	TDa1100201	Obidiegwu J.E., Nwachukwu E.C., Oselebe H., Asfaw A., Asiedu R., Lopez-Montes A., De Koeyer D., Adebola P	Slow rate of oxidization (browning) and high dry matter content. (35t/ha	2019
28	UMUDa-28 (VaYam)	TDa1100316	Obidiegwu J.E., Nwachukwu E.C., Oselebe H., Asfaw A., Asiedu R., Lopez-Montes A., De Koeyer D., Adebola P.,	Non-browning after processing, excellent boiling and pounding quality. (34t/ha)	2019
29	UMUDr-29 (Super)	UMUDr-29 (Super)	Obidiegwu J.E., Oselebe H., Asfaw A., Asiedu R., Lopez- Montes A., De Koeyer D., Adebola P., Agre P.,	Slow rate of oxidization (browning) and high dry matter content. High yield (22t/ha)	2020
30	UMUDr30 (Nagode)	TDr1000048	Obidiegwu J.E., Oselebe H., Asfaw A., Asiedu R., Lopez- Montes A., Adebola P., Agre P	Slow rate of oxidization (browning) and high dry matter content., high yield(24t/ha)	2020

S/N	Variety name	Original name	Collaborating Scientists	Outstanding Characteristics	Year of release/regist.
31	UMUDa 31 (Wonder)	TDa1100432	Obidiegwu J.E., Oselebe H., Asfaw A., Lopez-Montes A .,Obidiegwu J.E., Asfaw A., Oselebe H.,., Agre P., Dekoeyer D., Adebola P., Asiedu R	Slow rate of oxidization (browning) and high dry matter content, high yield, excellent boiling and pounding quality. (43t/ha)	2020
32	UMUDr32 (Favorite)	TDr1100497	Obidiegwu J.E., Oselebe H., Asfaw A., Asiedu R., Lopez- Montes A., Adebola P.	High dry matter, high tuber and flour yields, high starch, slow rate of oxidation, excellent sensory properties. (32.7t/ha)	2022
33	UMUDr33 (Blessing)	TDr1401220	Oselebe H., Asfaw A., Asiedu R., Lopez-Montes A., Adebola P., Agre P	High yield (33t/ha), high dry matter (36.4%), Good boiled and pounded yam quality	2023
34	UMUDr34 (Sunshine)	TDr1400158	Obidiegwu J.E., Oselebe H., Asfaw A., Asiedu R., Lopez- Montes A., Adebola P., Agre P	High yield (33t/ha), high dry matter (36.4%), excellent boiled and well pounded yam quality	2023
35	UMUDa35 (Delight)	TDa1100374	Oselebe H., Asfaw A., Asiedu R., Lopez-Montes A., Adebola P., Agre P	High yield 45.7(t/ha), high dry matter (33.3%), and high flour yield (26.4%)	2023

This feat is a testament to our multi-disciplinary approach to addressing our demand-driven problems. The multidisciplinary team includes staff and consulting experts in the following disciplines: genetics and breeding, biotechnology, plant physiology, entomology, food science and nutrition, environmental science, gender, biochemistry, agronomy, bioinformatics and statistics. We draw our strength from the interactions that lie at the core of the yam research team and training programs. In addition, NRCRI boasts of established infrastructures like fields, multi-site stations in diverse agroecologies, offices, laboratories, yam barns, and a yam screen house. NRCRI has delivered project deliverables through her intervention in multi-consortium and international project collaborations on Yam. Some of these collaborations include;

INCO-Yam Project sponsored by the European Union under the INCO-DC (International Cooperation with Developing Countries) is the first regional project on yam (1998-2003) that addressed the issues of post-harvest technologies, consumption, processing, preservation, and marketing of both fresh tubers and dried yam chips. The project identified 13 food forms of yam and the frequency of their consumption in Nigeria. INCO-Yam equally identified over 300 cultivars of food yam grown in Nigeria. The best food forms of these cultivars were determined.

IFAD-PA Yam project enhanced food security while improving the income of resource-poor farmers by facilitating access to new but proven technologies to boost production. The project addressed the development of a sustainable system for the multiplication and distribution of improved planting materials, the development of an integrated pest management system, including biological control to reduce the incidence of disease and pests, strengthening of on-farm adaptive research while increasing the availability of new cropping, storage and processing techniques and empowering of resource-poor farmers, particularly women, to ensure that they have unimpeded access to improved technologies

Promotion of Seed Yam Production Using the Yam Minisett Technology project deployed the most rapid multiplication methods to produce seed yams that were made available to farmers, thus ensuring a higher significance of yams in food security. The project was based on the principle that high-quality seed yams of improved varieties can exert tremendous positive influence on field productivity and storability of yam tubers as sources of nutrients for the initial growth of the crop, free from major pests and diseases

Yam Improvement for Income and Food Security in West Africa Modest Achievements (YIIFSWA): The project time frame was from February 2012 to July 2016 (Phase 1) and July 2016 to December 2021(Phase 2) with Dr. J.G Ikeorgu (Phase 1) and Dr. O.N. Eke-Okoro (Phase 2) as the team leaders. The problem tackled was scarcity of improved seed yams, high cost of seed and clean seed yams for production, high yields with desired utility attributes and establishment of a formal seed yam system in Nigeria.

Empowered small- holder ware yam farmers with the seed of improved yam varieties for increased productivity resulting in increased income, developed a functional and sustainable seed system that delivers sufficient quantities of high-quality seed of improved varieties to farmers at the right time and at prices that encourage adoption, raised the awareness of the economic impact of the yam sector for increased investment and prioritization from national, regional and international programs as well as the private sector and empowerment of women to profitably participate in the commercial yam seed value chain within the context of the appropriate socio-cultural system.

8.3 Modest Achievements

a. Release of two improved yam varieties (UMUDr/020 and UMRDr/021) in October 2016.
b. Registration of five top yam landraces (Obiaoturugo-UMUDr/022; Amola-UMUDr/023; Hembakwasi-UMUDr/024; Ekpe-UMUDr/025; Aloshi-UMUDr/026).
c. Establishment of Aeroponics sysyem of clean seed yam multiplication.
d. Establishment of a Bioreactor system for the production and multiplication of clean seed yams.
e. Availability of three improved yam varieties-TDr 89/02665 (Asiedu); TDr 95/19177(Kpamyo) and TDr 95/01176(Swaswa) for farmers in large numbers.
f. Release of 20,000 improved and clean seed yams to Seed Companies for mass production for the take-off of commercial yam seed system in Nigeria.
g. Training and establishment of yam farmers as Out-growers in Nigeria.
h. Training of ten staff of NRCRI Umudike
i. Infrastructural support (Aeroponics and Bioreactor systems/laboratories) for Umudike Seed Company for sustainability.

AfriCrop Project – Yam evolution and domestication funded by Agence Nationale de la Recherche (ANR, project AFRICROP ANR-13-BSV7-0017-(2014 – 2015), this project facilitated our understanding of the origin and history of agriculture in sub-Saharan Africa. We investigated the domestication of African yam (*Dioscorea rotundata*), a key crop in early African agriculture. Using whole-genome resequencing and statistical models, we showed that cultivated yam was domesticated from a forest species. We infer that the expansion of African yam agriculture started in the Niger River basin. This result, alongside with the origins of African rice and pearl millet, supports the hypothesis that the vicinity of the Niger River was a major cradle of African agriculture.

Basic Research for Enabling Agricultural Development (BREAD): Development of genomic resources in water yam (*Dioscorea alata* L.) for accelerated breeding and improvement (20015-2019) provided a genomic foundation for the development of improved varieties of water yam by (1) producing an annotated, chromosome-scale genome sequence for *Dioscorea alata*, and interpreting this sequence through annotation and comparative analysis, (2) producing an integrated genetic map for *D. alata* via the analysis of map crosses segregating for disease-resistance and quality traits important for farmers, and (3) characterizing the global collection of *D. alata* cultivars, enabling more efficient use of the existing genetic diversity in this species. The primary impact of this project will be the accelerated pace of breeding improvement in water yam, a crop that is a staple in West Africa and other tropical regions of the world. The use of genome-enhanced breeding approaches like marker-assisted selection and genomic selection promises to speed up the breeding cycle by allowing the definition of desirable genotypes, and the introduction of rapid cycles of selection for genotypes.

The AfricaYam project focused on improving yam productivity whilst reducing production costs and environmental impact by developing and deploying end-user-preferred varieties with higher yield, greater resistance to pests and diseases and improved quality in West Africa. In Phase I of the project (2014- 2019) a strong and active yam breeding community of practice (YCoP) was built, improved physical infrastructures, improved data collection and management, and enhanced capacity of yam breeders and technicians. Yam target environments were re-defined for varietal testing, selection and breeding. The project also generated ample genetic and genomic resources as well as established the YamBase and associated statistical tools that can be utilized for

Genomic Selection and implementation. Building on these successes **AfricaYam, phase II** (2019-2023) focused on modernizing the yam breeding programs in West Africa for more efficient and effective development and deployment of end-user preferred varieties with higher yield, greater resistance to pests and diseases and improved food quality in line with well-defined product profiles. It entailed the implementation of breeding strategies for the delivery of improved varieties that were superior and eventually replaced some of the current popular varieties in the production system. AfricaYam II expanded resources for applied breeding to obtain higher-quality data and maximized our ability to improve varieties. We identify traits preferred by farmers and end-users and incorporate these in product profiles, to ensure that breeding is demand-driven and inclusive. The AfricaYam phase II will facilitate the development of next-generation yam varieties for traditional and emerging products/markets, the development of new resources and approaches for yam improvement and the leveraging of emerging breeding methods and tools to expedite yam genetic gain and optimization and improved efficiency of NRCRI yam breeding program.

RTBfoods (Yam 2019-2023) defined key user-preferred quality traits for a range of RTB food profiles (boiled and pounded yam) that were further linked with the biophysical and functional properties of yam food products. Laboratory-based methods to assess these properties in a quantitative manner were established. A core value of the project was the integration of key user traits into breeding and variety deployment.

RTB breeding (Yam-2023- 2024) Though plant breeding is a proven approach to develop varieties tailored to meet customer needs, to achieve success a relentless market-driven stance, constant modernization to increase genetic gains delivered on farmer's fields, and links with seed systems to accelerate the adoption of novel varieties are of essence. RTB Breeding, a BMGF investment is focused on progressively streamlining and mainstreaming modern breeding approaches in RTB crops, aiming to increase genetic gains delivered on farmer's fields, achieve progress towards developing effective and efficient CGIAR-NARS breeding networks in RTB crops and quickly transition from a "one crop" mindset towards a shared one, fostering and incentivizing cross-crop, cross-center and cross-national programs collaborations to better serve farmers.

Some highlights of the program

1. The minisett technique of seed yam production developed by the International Institute of Tropical Agriculture (IITA) and National Root Crops Research Institute of Nigeria in the late 1970s was aimed at improving the availability of seed yam. It involves cutting tubers into minisetts of 25–100g, with each containing part of the cortex and periderm. The minisetts are treated in a mixture of fungicide and insecticide before planting to produce small whole seed tubers. The minisett technique increases the multiplication ratio to about 1:30, and the seed size tubers produced are planted to obtain ware yam tubers.

2. Three possible plant population densities have been successfully established at the NRCRI. These are;

a. A single row per ridge at 25cm intra-row spacing and one meter inter-ridge spacing (40,000 plants/ ha)
b. A double row on a ridge at 50cm intra-row spacing and one meter inter-ridge spacing (40,000 plants/ ha)
c. A double row on a ridge at 25cm intra-row spacing and one meter inter-ridge spacing (80,000 plants/ ha)

3. Sequence diversity shows a lack of geographical association between isolates from Ghana and Nigeria.
4. YMMV isolates from Ghana and Nigeria fall within four of the 11 monophyletic groups
5. The CT-RT-LAMP assay is suitable for the detection of YMV in both leaf and tuber tissues
6. Detached-leaf severity in the laboratory and greenhouse whole-plant severity, lesion size, and spore production can effectively discriminate yam genotypes into distinct phenotypic groups of anthracnose resistance responses
7. Development of anthracnose and yam moasaic virus tolerance varieties
8. Use of a diverse collection of *C. gloeosporioides* populations from a wide range of sources for screening for durable resistance
9. Development of molecular tools (QTL mapping) to aid identification of anthracnose resistance in *D. alata*
10. Pathogenic potential of *S. bradys* in the field determined
11. Establishing that yam is highly mycorrhizal and associated with a wide range of AMF
12. Critical period of weed interference between 10 and 22 weeks.
13, Determinants of seed and ware yam markets available for a policy guide

Some recently released Yam Varieties

Older leaves: cordate, dark green petiole

Younger leaves: cordate, pale green, anti-clockwise vines

Tuber cross section: Creamy white fleshed

Tuber: light brown skin, smooth, small corm, cylindrical shape, no roots, or spines

Fig. 46: UMUDr33 – Blessing

Younger leaves: Dark green. Petiole: Dark green, none serrated edge, Anticlockwise vine

Older leaves: Pale green

Tuber: Creamy white flesh

Tuber: Dark brown skin, hairy and spiny skin, Cylindrical shape

Fig. 47: UMUDr34 – Sunshine

Younger leaves: Cordate, pale green petiole

Older leaves: Cordate, green, anti-clockwise vines

Tuber cross section: Creamy

Tuber: brown skin, rough, small corm cylindrical shape, no roots, or spines, hairs present

Fig. 48: UMUDa35 – Delight

Fig. 49: On-farm inspection of released yam varieties

CHAPTER 09

COCOYAM RESEARCH PROGRAMME: ACHIEVEMENTS

9.1 Introduction

Cocoyam Research Programme is one of the seven crop-based programmes at the National Root Crops Research Institute, Umudike. Cocoyam was recognized as a major crop by the defunct Biafran government in 1969. Effective research on cocoyam started in Nigeria in 1976, when it became one **o**f the mandate crops of the Institute charged with the study and holistic improvement of important root and tuber crops in Nigeria. Cocoyam (*Colocasia esculenta* (taro) and *Xanthosoma mafafa* (tannia) are cultivated mainly for their corms and cormels. It ranks third in importance after cassava and yam among the root and tuber crops cultivated and consumed in Nigeria. However, it is popularly called the 'Nigeria's Giant Crop' because it is nutritionally superior to other roots and tubers in Nigeria and the gigantic size of variety NXs 003. Nigeria is the largest producer of cocoyam in the world with an annual production of 3.2 million metric tonnes, equivalent to 25.94% of world production and 33.76% and 701.2% of total output of cocoyam in Africa and West Africa respectively. The crop is popularized through cocoyam rebirth. The Cocoyam (giant crop) choir thrills the audience with three Cocoyam songs composed by Dr. Godwin O. Chukwu during important agro and cultural events.

9.2 Programme Objectives

(a) to develop new genotypes, improve and promote landraces with highly desirable food and industrial qualities; (b) to develop and promote genotypes with high aesthetic values for landscaping and environmental management; (c) to multiply healthy planting materials for dissemination to farmers; (d) to develop low-input, socially acceptable, environmentally sound and economically viable technologies; and (e) to develop environmentally-friendly strategies for the control of pre-and post-harvest pests and diseases.

The Cocoyam Crop: Cocoyam is an ancient tuber crop that belongs to the *monocotyledonous family* of *Araceae*. More than 500 million people in over 100 countries globally consume cocoyam as a staple crop. Cocoyam is divided into two groups namely; Tannia which is *Xanthosoma sagittifolium* (Fig. 50) and Taro which is *Colocasia esculenta* (Fig 2). *Xanthosoma sagittifolium* comes in different shapes, sizes and flesh colours. There are white-, purple- and yellow-fleshed tannia. The tannia is characterized by large sagittate leaves, a large main corm and several cormels which are mainly used as carbohydrate food. The corm and cormels are the main sources of starch in many countries.

Fig 50: Tannia (Xanthossoma species)

Colocasia esculenta called Taro (Fig 51) is characterized by round-shaped corm and peltate, cordate leaves which may be round with thick elongated large succulent petioles. The corms may be of different sizes and shapes. There are different kinds of Taro. The upland and swamp taro. Some varieties of Taro also grow well in freshwater swamps.

Fig 51: Taro (Colocasia Species)

At the National Root Crops Research Institute (NRCRI) Umudike the following cocoyam landraces of *Xanthosoma Species* are in the cocoyam germplasm: NXs/001 = white-fleshed, NXs/002 = Purple Fleshed, NXs = Yellow fleshed cocoyam. *Colocassia Species* in the cocoyam germplasm include NCe/001 = 001, NCe/002, NCe/003, NCe/004, NCe/005, NCe/006, NCe/007, NCe/008 and NCe/009.

Cocoyam research: The pioneering members of the Cocoyam Research Programme since 1923 have made huge steps as far as cocoyam research is concerned. The availability of enough land for research, the presence of supporting research scientists and the establishment of laboratories, screen houses and tissue culture laboratories including marketing channels for cocoyam products have given the Cocoyam Research

Programme an advantage in the research sector of the National Root Crops Research Institute (NRCRI), Umudike. Not many farmers in Nigeria are making the transition to become cocoyam producers these days but this could suddenly change - depending on changes in political interests or official regulations on new market opportunities, or even on increased pressure by communities interested in cocoyam farming. In the case of renewed interest in cocoyam cultivation, the vast knowledge, experiences, technologies and new varieties developed by the Cocoyam Research Programme will be of great importance to aspiring cocoyam farmers.

9.3 Research Achievements

Technologies developed (Culled from Chukwu *et al*., 2012)

***Growing cocoyam under shade*:** Research on cocoyam cultivation technologies suggests that open fields are optimal for clonal cultivation, as demonstrated by experiments at NRCRI. Cocoyam thrives better in open fields, with higher photosynthetic efficiency, ensuring higher yields than under shade, according to Chukwu (2012).

Fig. 52: Growing cocoyam in open fields

Cocoyam trial under weed/plant organization: Chukwu (2012) found that cocoyam, a tuber crop, effectively competes with weeds in natural conditions, making it a crucial food security crop. All cocoyam species refuse weed smothering, indicating its giant nature. However, initial weeding is necessary for open-field cultivation.

Lack of Planting Materials: Cocoyam production faces challenges due to scarcity and high cost of planting materials, limiting land, breeding materials, and materials for consumption, processing, and marketing, resulting in reduced production volume.

Solution: This challenge has been reduced greatly by the development of *Goken* multiplication technology (Chukwu *et al*., 2009) for very rapid multiplication of cocoyam corms and cormels. This technology uses cocoyam planting materials weighing 7 g, in addition to sustainable soil. They are called micro cormels when whole cormels are used and micro setts when cut setts are used. In the gocken technology, the seed rate ranges from 0.35-0.45 t/ha as against 1.0-1.4 t/ha used in the then popular minisett technology. The development of gocken technology has rendered minisett technology obsolete. In the gocken technology, mean total corm + cormel yield could range from 7.34 - 15.5t/ha; mean seed harvest multiplication ratio (SHMR) ranges from 19.0 - 39.0, while available yield could vary from 89.5-94.7 %. Economic analysis showed that the benefit-cost ratio was 4.24:1.0, indicating that the technology is profitable by returning 4.24 to every N1.00 spent (Fig. 53)

Fig 53: Microsett and micro cormel technology. Source: Chukwu et al., (2009). Source: Chukwu et al. (2009a)

Low Genetic Base: The narrow genetic base of cocoyam, with nine landraces at NRCRI, Umudike, hampers the development of new genotypes. Despite research on root and tuber crops in Nigeria since 1924, there are no improved cocoyam varieties, highlighting the need for further development.

Solution: Among the impacts of cocoyam rebirth is a significant increase in the genetic base of cocoyam held at the NRCRI, Umudike. It increased from nine in 2007 to fourteen in 2009 (Table 8), representing a 55.6% increase. Three varieties (two landraces and a hybrid) were introduced from Cameroon. The landraces (NCe 007 and NCe 008) belong to the *Colocasia* species while the hybrid cocoyam (NXs 004), belongs to the *Xanthosoma species*. Two landraces (NCe 009 and NCe 0010) belonging to the *Colocasia species* were collected in Nigeria.

Table 8: Cocoyam Germplasm held at NRCRI Umudike in 2007

Xanthosoma species	Colocasia species
NXs 001	NCe 001
NXs 002	NCe 002
NXs 003	NCe 003
	NCe 004
	NCe 005
	NCe 006
Increase in 2009	Increase in 2009
NXs 004 (hybrid)*	NCe 007*
	NCe 008*
	NCe 009**
	NCe 010**

**Introduced from Cameroon. ** Introduced from Nigeria*

Low Soil Fertility: The decreasing soil fertility in Nigeria's root crop belt is a significant challenge for the sustainable cocoyam programme. The major cocoyam zone is characterized by acidic, deep, highly permeable Ultisols with multi-nutrient deficiencies. High demographic pressure, urbanization, and ecological problems contribute to soil erosion, reducing agricultural land and fallow periods. However, pockets of fertile soils exist, but cocoyam is scarcely cultivated in these areas.

Solution: The twin problems of scarcity of good agricultural land and low soil fertility can be solved by agricultural intensification based on sound soil fertility management. Among the strengths of cocoyam rebirth is the development of low- external- input and sustainable soil management that guarantee good crop growth and higher total (corm+ cormel) yield in the open field.

Disease and Pest Problems: Among the biotic problems in cocoyam production, the cocoyam root rot blight complex (CRRBC) is a serious threat to *Xanthosoma species*. Symptoms of this disease include chlorosis (yellowing), stuntedness, loss of vigour and death. In severe cases, there could be total crop failure (Fig. 54).

Fig 54: Xanthosoma Cocoyam Root Rot Blight Complex (CRRBC)

Cocoyam blight, a devastating disease affecting Colocasia cocoyam farmers in Nigeria, causes leaf spots to coalesce, leading to leaf distortion, tissue necrosis, and even crop death in severe cases (Fig. 55).

Fig. 55: Taro leaf blight disease

Currently, the *Xanthosoma* cocoyam is resistant to the Leaf Blight Complex Disease (LBCD).

Solution: Currently, no effective control measure is available to tackle these diseases. In the interim, the use of healthy planting materials, early planting, and sustainable soil health management through integrated plant nutrient management to boost crop growth and immunity against disease are recommended. Breeding for resistant *colocasia* genotypes is ongoing in the cocoyam breeding programme.

Lack of Effective Storage: Lack of good storage reduces the shelf life of harvested cocoyam corms and cormels, a major challenge for Nigerian farmers, processors, and marketers. Conventional storage methods, such as barn-heaping and inside pits, are ineffective due to high losses from pathogens. This reduces total revenue and threatens reliance on cocoyam as a food security crop during economic downturns. Sprouting also leads to high physiological losses.

Solution: The National Root Crops Research Institute (NRCRI) in Umudike, Nigeria, has developed a sustainable and effective method of storing cocoyam called the "gocing" barn. This method, derived from Dr. Godwin Ogbonnaya Chukwu's contribution to improved storage technology, involves a half wall, wire netting, and adequate ventilation. The store is maintained at 60-80% humidity and 20-28°C temperature. The gocing barn can prevent a 10%-25% loss in cocoyam storage compared to 33-85% losses due to rot in local barns. Some varieties, like NCe 002 and NCe 003, can be stored for up to six months without significant loss.

Low-Value Addition to Cocoyam: In Nigeria, cocoyam corms and cormels are consumed in various forms, including boiled, fried, porridge, roasted, and "ikpankwokwo." The leaves are used in soups, porridge, and "ikpankwokwo." To maintain their health, they are stored in gocing barns with appropriate environmental conditions and cultural management. Some varieties can be stored for up to six months without significant loss. More research is planned to expand the range of cultivars.

Solution: The launch of the cocoyam rebirth has stimulated the interest of researchers in diversifying the uses of cocoyam through value addition. Aniedu and Oti (2009) produced a bulletin on cocoyam-based recipes. Apart from cocoyam-based foods that are not confectionery, such as cocoyam wraps, ikpanikpon, cocoyam fufu, cocoyam pudding, achicha, and ofeolugbu, the production of the following cocoyam-based confectioneries is discussed in the bulletin: They include: Cocoyam chin-chin Cocoyam strips Cocoyam crisps Cocoyam Queen's Cake, Cocoyam doughnuts Cocoyam muffins, 10% cocoyam bread, 20% cocoyam bread, cocoyam fritters, cocoyam shortbread, cocoyam balls, and cocoyam drop scones The concept of value addition to cocoyam was expanded beyond tangible, physical items, as listed above, to encompass intangible value (psychological satisfaction). The introduction of cocoyam songs and music is a new dimension of value addition. The societal value attached to the value-added products of cocoyam (crisps, chips, flour, etc.) (Fig. 56) is catalyzed by the cocoyam songs, as evidenced by the way people scramble for these products after listening to the song. Cocoyam songs influence emotions by motivating workers and promoting cohesion among them. It reduces the tedium of physical and mental stress in agricultural research and production. The song also promotes physical and spiritual health, higher efficiency of labour, and total productivity. This justifies the intermittent shouting of the cocoyam slogan "Cocoyam Rebirth for Food Security and Empowerment!" and the integration of the cocoyam song in the cocoyam rebirth initiative.

Fig. 56: Cocoyam flour and chips
Photo credit Chukwu, Okoye and Nwosu, 2012

Apathy (lack of interest in the crop): The greatest challenge facing cocoyam is the lack of interest by stakeholders. Scientists who are expected to solve identifiable challenges are, hitherto, not showing appreciable interest in cocoyam research. This accounted for the low generation of new technologies and the protracted and perennial nature of some of the challenges. Similarly, consumers are biased against cocoyam. Cocoyam is erroneously perceived as an inferior crop to yam, cassava, rice, sweet potato and potato, meant for the poor and produced by indigent rural women. On the contrary, cocoyam is the richest in protein and mineral contents and highest in digestibility among the carbohydrate-based foods mentioned above. In addition, it is a medicinal crop for the management of diabetes.

Solution: NRCRI Umudike is implementing a campaign to raise awareness about the nutritional benefits of cocoyam compared to other crops. The campaign includes seminars, workshops, and training on improved cocoyam production and processing. The Cocoyam Consumption Awareness Campaign (COCAWAC) was launched in 2009, allowing staff and children to enjoy cocoyam again. The campaign also aims to promote the use of cocoyam corms, a healthier alternative to yam tubers and promotes security and empowerment.

Cocoyam Song: Dr. G. O Chukwu created two Cocoyam songs to address apathy towards Cocoyam. Music, as discussed by Father Anselm Adodo, promotes physical, emotional, and spiritual health by influencing blood circulation, metabolism, muscular energy, respiration, blood pressure, and emotions. In some American companies, music can improve concentration and productivity. The Cocoyam Research Programme Choir, "The Giant Crop Choir," entertained the monitoring team during a 2009 field monitoring, leading to increased productivity. The choir was sponsored by Dr. K. I. Nwosu, who promised to sponsor the choir for the 43rd Annual Conference of the Agricultural Society of Nigeria (ASN). The choir's music has been included in the ASN's program and has been invited to perform at various events, such as the 24th Annual Research Extension Farmer Input Linkage System (REFILS) Workshop at NRCRI, Umudike.

Cocoyam slogan: Cocoyam, a popular crop in Nigeria, has been promoted through slogans, T-shirts, and caps, and its versatility in producing flour, doughnuts, chips, and crisps has been highlighted. This has led to numerous organizations and communities collaborating in the Cocoyam Rebirth Initiative, which has resulted in increased efficiency and productivity. Dr. Nwosu, a prominent figure in the initiative, sponsored the Giant Crop Choir to attend the 43rd Annual Conference of the Agricultural Society of Nigeria (ASN) in Abuja, and the choir has been invited to perform at various events.

Cocoyam Goes to School: Another method of increasing awareness of the nutritional value of cocoyam is to arouse the interest of young children in the crop and to inculcate in them a love for agriculture. The Collaborative School Cocoyam Project in Primary Schools and with Farmer Cooperatives is tailored to satisfy this desire.

9.4 Achievements in Genetic Improvement of Cocoyam Research Programme of NRCRI, Umudike (Culled from Amadi *et al*., 2012)

Cocoyam improvement studies at NRCRI commenced in 1972 and by 1976 a collection of 94 accessions was assembled to provide a broad genetic base for breeding (Arene and Ene, 1987).

Germplasm Collection and Classification: Within the first 5 years (1972-1976) of the commencement of cocoyam improvement at NRCRI, a collection of 94 accessions were assembled to provide a broad genetic base for breeding (Arene and Ene, 1987). Twenty-two of these accessions belonged to 3 main groups of *Xanthosoma species* locally called “Okorokoro” (yellow tuber flesh), “Ede ocha” (white tuber flesh), and “Ede uhie” (pink tuber). The remaining 72 accessions belonged to 3 groups of *Colocasia* species locally called “Cocoindia” (with a central corm and satellites of smaller cormels), “Isi okpo” (with excessively large corms and one or two tiny cormels), and “Anyamanya” (with corms and cormels not distinguishable in size but form uniform conglomerates) (Okonkwo, 1975; Mbanaso, 1992). More recently, in 2005, 103 accessions of cocoyams were collected during the in-country germplasm collection of cocoyams in Southern Nigeria. Sixty percent (60%) of these were *Colocasia esculenta* while 40% were *Xanthosoma mafaffa cultivars.* Wider genetic diversity exists among *C. esculenta* cultivars than among *X. mafafffa* cultivars (Mbanaso *et al*, 2005). These are all landraces (Chukwu *et al*., 2011) as shown in Table 9.

Table 9: *Colocasia* and *Xanthosoma* Cultivars in the Nigerian Cocoyam germplasm

Acccession Number	Local Names*
Colocasia esculenta	
NCe 001	Cocondiya
NCe 002	Ede ofe green
NCe 003	Ede ofe purpe
NCe 004	Ede ofe giant
NCe 005	Ukpong
NCe 006	Gyana
NCe 007	Iboko green
NCe 008	Iboko pink
NCe 009	Ede oba
NCe 010	Akiri
NCe 022	Akpahuri
Xanthosoma mafaffa	
NXs 001	Ede ocha
NXs 002	Ede uhie
NXs 003	Ede Okorokoro
NXs 004	Hbrid

*Source: Chukwu, et al 2012): Local names are variable depending on the locality**

Currently, there are 11 *Colocasia* and 4 *Xanthosoma* cultivars in the Nigerian cocoyam germplasm (Table 2). These are all landraces except one *Xanthosoma* hybrid introduced from Cameroun (Chukwu *et al*., 2011). Wide variability in plant characteristics was found to exist among local cultivars with yield ranging from 3-13 t/ha for *X. sagittifolium* and 3-25 t/ha for *C. esculenta*) (IITA, 1973).

Cytogenetics of Cocoyam: Knowledge of the cytogenetics of a crop is critical to the understanding of its breeding behaviour. Earliest reports from NRCRI, cited a range of chromosome numbers for *C. esculenta*: X=12, 2n=24, 48; X=14, 2n=28,42 and *Xanthosoma* : X=?, 2n=48 (Ene, 1977). Ekanem and Osuji (2006) reported 2n= 42 for *Xanthosoma sagittifolium* cultivars locally known as ‗Ede Ocha'(NXs 001), ‗Ede Uhie'(NXe 002) and ‗Ede Okorokoro'(NXs 003); and 2n = 24 for four cultivars of *Colocasia esculenta* namely: (NCe 001), ‗Ede Ukpong'(NCe 005), ‗Ede Gyana'(NCe 006) and ‗Ede Ofe'(NCe 003). Other chromosome numbers 2n = 22, 26, have also been reported for *C. esculenta*. However, the most commonly reported results are 2n = 28 or 42 (Onwueme, 1999). The variation in chromosome numbers reported in *C. esculenta* is probably due to the erratic behaviour of the chromosomes during cell division. This may also be responsible for the polymorphism exhibited by the species.

Evaluation of Landraces: Evaluation of elite landraces of *C. esculenta* and *X. mafaffa* to determine their adaptability to selected agroecological zones has been carried out. Results reported by Mbanaso, *et al*. (2004) indicated that *Colocasia* cultivar NCe 001 gave the highest yield across the locations. A previous report (IITA, 1973) indicated that wide variability in plant characteristics exists among local cultivars with yield ranging from 3-13 t/ha for *X. sagittifolium* and 3-25 t/ha for *C. esculenta.* Findings of evaluation of the landraces for suitability for target value-added products are summarized in Table 10.

Table 10: Evaluation of cocoyam landraces for suitability for target value-added products

Landraces	Target product	Source
Colocasia esculenta		
NCe 001		
NCe 002		
Mgbidicameroon	Cocoyam flour (Soup thickener)	Ijeoma (1983)
T3-185-70/307		
Nimbo		
Akupe		
NCe 001	Cocoyam chips	
NCe 001	Cocoyam Frizzle	Mbanaso (1986)
NCe 001	Cocoyam fries	
Xanthosoma mafaffa		
NXs 001	Cocoyam chips	
NXs 001	Cocoyam Frizzle	
NXs 001	Cocoyam fries	Mbanaso, (1986)
NXs 002	Cocoyam chips	
NXs 002	Cocoyam Frizzle	
NXs 002	Cocoyam fries	

Evaluation of Exotic Genotypes of *Colocasia:* Fifteen exotic cultivars of taro, obtained from the International Network on Edible Aroids (INEA) as part of an EU-funded project on "Adapting Clonally Propagated Crops to Climatic and Commercial Change," and some local cultivar were evaluated in 2013 and 2014 at Umudike, located between latitudes 5°24' to 5°30' N and longitudes 7°31' to 7°37' E in the rain forest zone of Nigeria. Results reported by Amadi *et al*. (2015) indicate that most of the exotic cultivars were early maturing, four were intermediate while two (BL/SM/152, and BL/PNG/13) were late maturing. Most cultivars were susceptible to TLB; BL/PNG/13 was highly resistant while BL/SM/152 was immune. The late-maturing cultivars were highly resistant/immune to TLB while most of the early-maturing ones were susceptible thus suggesting a link between the genes for maturity and those for resistance to TLB. Cultivar differences in the number of corms, cormels and total yield (corms + cormels) per plant were significant in both years. Total yield and Corm/Cormels ratio of many exotic cultivars compared favourably with the locals. Nine cultivars were selected as promising based mainly on yield, physical appearance, resistance to TLB and lack of stolon (Fig. 57).

Fig. 57: *Exotic cocoyam genotypes*

Micro-propagation of Cocoyam: Tissue culture a tool in biotechnology provides a very rapid and phytosanitary method of multiplying planting materials. Micro-propagation of cocoyams has been going on for years at NRCRI Umudike to produce clean planting materials for elite cultivars. Recently, meristem explants have been used to produce disease-free planting materials. Mbanaso *et al*. (2006b) recommended as a cost-saving measure, the use of cassava starch sourced from 5 cassava varieties namely 97/0162, 92/0323, 82/0058, 96/0505, and 97/8082 to replace imported gelrite in the medium used for routine in-vitro multiplication of cocoyam.

Establishment of Dose Range for Induction of Mutagenesis: The first step in mutation induction by gamma radiation for in-vivo studies is to establish sensitivity, LD50 and dose range. Mbanaso and Nwachukwu (2008) recommended a dose range of 6.0-11.0Gy and 3.0-18.0Gy for the induction of mutagenesis in *Xanthosoma* and *Colocasia* cultivars respectively.

Induction of Flowering: Nigerian cocoyam cultivars often have infrequent flowering and fruiting under natural conditions. However, studies at NRCRI Umudike showed that gibberellic acid, N-fertilization, and sett size can improve flowering. Gibberellic acid (GA3) at concentrations of 1000- 1500 ppm induced flowering and fruiting in *Colocasia esculenta* and *Xanthosoma sagittifolium* cultivars. Three methods of GA3 application include treating field plants with 1,500 ppm, 1,000 ppm for seedbed plants, and treating first leaves. Treated plants produce normal flowers 2-4 months after treatment.

Hybridization and Seed Germination of Cocoyam (*Colocasia esculenta*): In 2013, the Nigerian cocoyam breeding team led by Dr. Amadi Charles successfully hybridized, produced true taro seeds (TTS), and developed seedlings from these seeds. They used fifteen exotic taro cultivars and four local cultivars in a crossing block at Umudike. Out of 109 crosses, 18.3% were successful, with nine crossings developing to maturity and producing seeds. The cocoyam breeding team is currently using a protocol for hybridization, seed extraction, and maintenance.

Fig. 58: Taro plant with flowers
Source: Amadi *et al*. (2012)

Other breakthroughs include:

1. Effective hybridization and generation of True Taro Seeds (TTS) for raising Cocoyam seedlings to broaden the genetic base of Cocoyam. These cocoyam genotypes are undergoing field evaluation and are resistant to Taro Leaf Blight (TLB).
2. Successful induction of Xanthosoma *sagittifolium Species* (White fleshed and Purple fleshed cocoyam cultivars that rarely flower) to flower.

3. The successful conduct of Multi-Location evaluation of Taro elite landraces of *C. esculenta* for official registration as “variety” for commercial cocoyam production and for export markets.
4. Assemblage of wild cocoyam relatives for gene introgression into elite cultivars for resistance to Taro Leaf Blight.
5. Use of Rice Mill Waste technology (at 8t/ha) for optimum suppression of root rot blight disease complex of Edeocha and Edeuhie (NRCRI, 2022).

Fig. 59: Cocoyam seedlings developed from true cocoyam seedlings and newly developed Cocoyam clones free from Taro leaf blight
Source: Cocoyam Field, 2023

9.5 Challenges and Way Forward

Cocoyam improvement efforts at NRCRI face challenges like narrow genetic base, crop complexity, erratic flowering, lack of fruiting and seed set by local cultivars, limited infrastructure, poor funding, and apathy. Strategies include broadening the genetic base, introducing new cultivars, and using GA3 for successful flowering. Adapting pollination and seed germination protocols from the South Pacific through the INEA network has also helped achieve hybridization, fruiting, and seed set. NRCRI Umudike's biotechnology program needs strengthening through equipment procurement and manpower development for cocoyam improvement. Prioritizing cocoyam research funding is crucial to tackle Taro leaf blight and endemic Cocoyam Root Rot Blight Complex. The Cocoyam Research Programme in NRCRI, Umudike, has effectively empowered smallholder farmers and increased market access through technology development. However, mechanisms for facilitating research opportunities, such as international germplasm exchange and organized international bodies, are weak. More attention is needed to capacity building in molecular breeding, germplasm management, varietal development, and information and communication tools. Investments in training and better documentation of lessons learned are also needed.

Conclusion

Cocoyam Research Programme has made tremendous efforts to enhance the productivity of the crop through technological development, awareness creation, post-harvest value addition and breeding of new high-yielding disease-resistant varieties. If the challenges facing this giant crop are addressed by relevant Government and Non-governmental bodies, cocoyam will be the number one nutritious and prestigious carbohydrate crop among roots and tuber crops and will command high economic commercial value with export potential.

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CHAPTER 10

SWEETPOTATO RESEARCH PROGRAMME: ACHIEVEMENTS

10.1 Introduction

The Sweetpotato Programme is one of the commodity-crop-based research programmes of the National Root Crops Research Institute, Umudike. It was established in the 1970s to focus on sweetpotato research. Specifically, it was established to conduct research into the genetic improvement, agronomy, storage, processing, utilization and socio-economics of the crop. In order to fulfil this mandate, the Programme is staffed with research scientists with requisite professional backgrounds in these thematic areas. After over 40 years of working on the crop, it is pertinent to highlight some of the tremendous research achievements of the Sweetpotato Programme which have transformed the crop from a poor man's crop with no commercial value, to the present nutritious cash crop status that farmers spend money to purchase its planting materials, and which the Federal Government of Nigeria and important International Non-Governmental Organizations promote as bio-fortified, vitamin A-rich food.

The Crop

Sweetpotato is a perennial root crop cultivated as annual. It is cultivated in over 100 countries, especially in the tropic and sub-tropic spheres of the world, growing across altitudes that span 0 – 2,500 meters above sea level (Karan and Sanil, 2021). While it is grown in more than 115 countries (FAOSTAT, 2019), it has assumed the status of an important food and nutrition security crop in many African countries including Nigeria. Sweetpotato is a climate-resilient crop that is adapted to many agroecologies. In Nigeria, sweetpotato grows in all agroecologies from the coastal high rainforest belt of the south to the arid sudan-sahel of the drier north, though at different intensities Anderson *et al*, 2012). With 3.94 million tonnes (FAOSTAT, 2021), Nigeria is currently the 3rd largest sweetpotato producer in the world and the 2nd largest producer in Africa after Tanzania. Sweetpotato utilization is diverse and mimics the dominant food culture of the different ethnic groups in Nigeria. Generally, sweetpotato is often boiled and eaten with sauce, fried and eaten alone or with fried eggs/sauce, cooked with beans, or cooked alone as porridge. Not a popular practice, it is at times used as a substitute for carrot in the preparation of 'fried rice'. Initially from the north (where sorghum, millet and maize are more popular) but now in the south also, sweetpotato is now used for *kunnu* (a fermented, non-alcoholic drink) production.

Sweetpotato production has increased due to factors that include the presence of varieties that produce high yields within short periods (3-4 months); the ability of the crop to grow across all agro-ecologies; its susceptibility to very few diseases; its ability to grow on marginal fields; its health benefits, especially the OFSP, etc. The development and release of varieties with different attributes have increased the range of choice for farmers, consumers and processors. Specifically, the release and promotion of the OFSP types for their health benefits has led to a sporadic increase in its cultivation and utilization, especially its adoption for provitamin A bread and snacks. The belief that it helps in the management of health challenges such as diabetes, night blindness, high blood pressure, etc. has increased its adoption for consumption by the health-conscious working class. Also, the works of NGOs, faith-based and community-based organizations such the Hellen Keller International and the Catholic Relief Service in promoting the cultivation and consumption of OFSP by pregnant women and lactating mothers in VAD-endemic areas of the country also contributed to the increase in OFSP production and consumption across the country.

Concept of Food System

A typical food system is a complex, holistic system that encompasses all the key aspects of food production, processing, distribution and consumption as an inter-related entity rather than a stand-alone unit. In effect, it reflects the entire value chain of a crop system from the farm to the table. Therefore, achieving a functional sweetpotato food system means the approach must encompass issues such as sustainable production, nutrition and health, collaboration and participation of multiple stakeholders, and the inter-relationships of all these factors in the delivery of sweetpotato to consumers in both processed and unprocessed forms, and the various innovations used to deliver the outcomes of food and nutrition must be knowledge and evidence (research) based.

10.2 Sweetpotato Food System Development in Nigeria: NRCRI Research Innovations and Outcomes/Achievements

The National Root Crops Research Institute, Umudike is a foremost non-for-profit, National Agricultural Research Institute (NARI) with the national mandate to conduct research on the genetic improvement, production, extension and product development of commercially important root and tuber crops (cassava, sweetpotato, yam, potato, cocoyam, ginger, turmeric and some other less-produced root and tuber crops). A significant aspect of the mandate of the Institute is the extension of actionable research findings to the various end-users through the instruments of the various states' Agricultural Development Programs (ADP), and through its direct training activities for farmers, processors and other end-users in critical skillsets. For the sake of focus, effective resource allocation and efficient monitoring and tracking of outputs, each crop was structured into a commodity crop programme, giving rise to the Sweetpotato Programme with its compliments of staff dedicated to improving the crop's genetics, production techniques, product development and knowledge dissemination. With the commencement of active research on sweetpotato in the 1970s, much focus and efforts have been devoted to the development of new sweetpotato varieties, the development of best agronomic practices that ensure high yield at low production cost, development of food forms and processing techniques that create products that meet consumers' needs, development of the seed system that ensures constant availability of high-quality planting materials for farmers to increase productivity, and the delivery of these innovations to farmers' fields and other end-users through the extension services. This paper highlights the various research innovations and achievements of the NRCRI on sweetpotato under the Food System principles that include sustainability of sweetpotato production, nutrition and health, resilience and adaptation.

Sustainable Sweetpotato Production

Sustainability as it relates to the sweetpotato food system entails the adoption of approaches that ensure that sweetpotato production activities are carried out in ways that ensure the continuous availability and affordability of the roots for processing and consumption. Sweetpotato production involves the recruitment of all factors of production (land, labour, capital, entrepreneur) to ensure high root yield per unit land area. The presence of production factors must however be merged with research-based innovative practices and inputs to deliver optimum root yield and other end-products. Sweetpotato root productivity begins with the use of high-quality planting materials (vines) of the right variety by farmers, the use of appropriate plant density, the application of the right quality and quantity of organic and/or inorganic fertilizers and the appropriate time of application, application of optimum weed control method(s) (chemical herbicides and/or manual weeding), and proper harvesting and post-harvest handling. Appropriate technologies for all of these have been developed by the Sweetpotato Programme and put together as informed, research-based innovations for varied end-users. Below are some of the developed innovations as tangible, actionable achievements:

Development of Improved Varieties and Functional Sweetpotato Seed System

Sweetpotato breeding: Development of new sweetpotato varieties

A robust seed system begins with the availability of product-profiled varieties. Without the availability of officially released crop varieties, a formal seed system cannot be developed as the Nigerian Seed Law of 2019 forbids the distribution of seeds of unofficial cultivars in a formal seed system. Attempts at developing sweetpotato varieties at the NRCRI, Umudike for the country began in the late 1970s when advanced genotypes developed at the International Institute for Tropical Agriculture (IITA) were collected and evaluated by the Institute. Through the 1980s and 1990s, while core sweetpotato population development and preliminary genotype selections were done by IITA, the NRCRI, Umudike's breeding efforts were focussed on germplasm collection from IITA and field evaluations and selection of promising genotypes from the collected germplasm (Ochuba *et al*., 1982; Ochuba *et al*., 1983; Ochuba and Akuma, 1984; Agbo *et al*, 1990, Nwauzor and Afuape, 2005).

The first decade of the 2000s witnessed attempts at population development at the NRCRI Headquarters with crosses made and F1 progeny populations developed and screened for root yield, important yield components, disease resistance and pest tolerance (Afuape and Nwachukwu, 2003; Afuape *et al*., 2004; Afuape *et al*., 2005; Afuape and Nwauzor, 2006 Afuape *et al*., 2007; Nwankwo *et al*., 2018). Also, as IITA lost its mandate on sweetpotato research to the International Potato Centre (CIP), Lima, Peru in the late 1990s, NRCRI, Umudike began a close collaboration with CIP on sweetpotato breeding. The first introduction of exotic sweetpotato germplasm with enhanced provitamin A (beta-carotene) content popularly called orange-fleshed sweetpotato (OFSP) was birthed by this collaboration. This enabled the Institute to incorporate a nutrition enhancement pipeline into its Sweetpotato Breeding Program. By the second decade of the 2000s, (2010 – 2020), the NRCRI Sweetpotato Breeding Program and the collaboration between the Breeding Program and CIP led to the official release of FOUR sweetpotato varieties to Nigeria's sweetpotato production system. *The first officially released sweetpotato in Nigeria was in 2012 when two varieties (King J – UMUSPO/1*, *an OFSP, and UMUSPO/2, a white-fleshed type) were released. In 2013, the third variety, Mother's Delight (UMUSPO/3) was released; while in 2018, the fourth variety, Solo-Gold (UMUSPO/4), was released.* The yield (t/ha) performance of the 2017 on-farm trials in seven states which was presented during the nomination and release of Solo-Gold is presented in Table 11. Also, the disease and sweetpotato weevil damage score, as well as the beta-carotene content estimates of the advanced lines involved in the on-farm trials are presented in Table 12 and Figure 60, respectively.Table 1: Fresh root yield (t/ha) of sweetpotato genotypes from on-farm pre-release trials in seven states in 2017 cropping seasons

Table 11: Yield (t/ha) performance of the 2017 on-farm trials in seven States

	Genotypes							
State	**Solo-Light**	**Solo-Gold**	MD/8164/24	Cent/Ex-Igb/ 20	Irene	**Namanga**	MD	Local Variety
Ebonyi	**6.55 (5)**	**9.31 (1)**	5.52 (6)	4.40 (7)	3.50 (8)	**8.90 (3)**	9.21 (2)	8.14 (4)
Kwara	**5.80 (6)**	**7.89 (2)**	6.20 (5)	5.54 (7)	4.40 (8)	**6.95 (3)**	10.0 (1)	6.90 (4)
Kaduna	**9.36 (6)**	**11.39 (3)**	8.20 (8)	9.80 (4)	9.25 (7)	**9.80 (4)**	16.16 (2)	17.75 (1)
Osun	**5.56 (7)**	**13.33 (3)**	6.66 (6)	5.22 (8)	7.79 (5)	**9.86 (4)**	13.72 (2)	15.28 (1)
Ogun	**15.04 (4)**	**19.22 (2)**	7.13 (7)	11.10 (6)	6.19 (8)	**14.28 (5)**	26.76 (1)	18.47 (3)
Taraba	**26.25 (2)**	**25.61 (3)**	4.21 (6)	14.79 (5)	4.17 (7)	**18.14 (4)**	26.83 (1)	n.a
Abia	**20.28 (4)**	**23.50 (1)**	15.20 (7)	11.92 (8)	15.35 (6)	**22.85 (2)**	18.50 (5)	22.10 (3)
Mean	**12.69 (5)**	**15.75 (2)**	7.59 (7)	8.97 (6)	7.24 (8)	**12.97 (4)**	**17.31 (1)**	14.77 (3)
Rank sum	**39**	**17**	52	51	57	**29**	**15**	19
Ave. Rank	**5.57 (5th)**	**2.43 (2nd)**	7.43 (7th)	7.29 (6th)	8.14 (8th)	**4.14 (4th)**	**2.14 (1st)**	3.17 (3rd)

**The smaller the average rank, the better the genotype.*
Source: Afuape et al. (2017)

Table 12: Mean severity scores for sweetpotato weevil (*Cylas puncticollis*) and sweetpotato virus disease (SPVD) under on farm trials in 2017

Varieties	**Sweetpotato Virus Disease severity (Severity Score= 1- 5)**	**Sweetpotato weevil damage (Severity Score= 1- 5)**
Solo-Light	1.0	1.0
Solo-Gold	1.0	1.0
MD/TIS 8164/24	1.0	1.0
Centennial/Ex-Igbariam/ 20	1.0	2.0
Irene	1.0	1.0
Local Variety	1.2	2.0
MD (Control)	3.0	3.0
Namanga	2.0	1.0

Sweetpotato virus disease and weevil severity rating: 1= no apparent damage; 2 = very little damage; 3 = moderate damage; 4 = considerable damage; 5 = severe damage.
Source: Afuape et al. (2017)

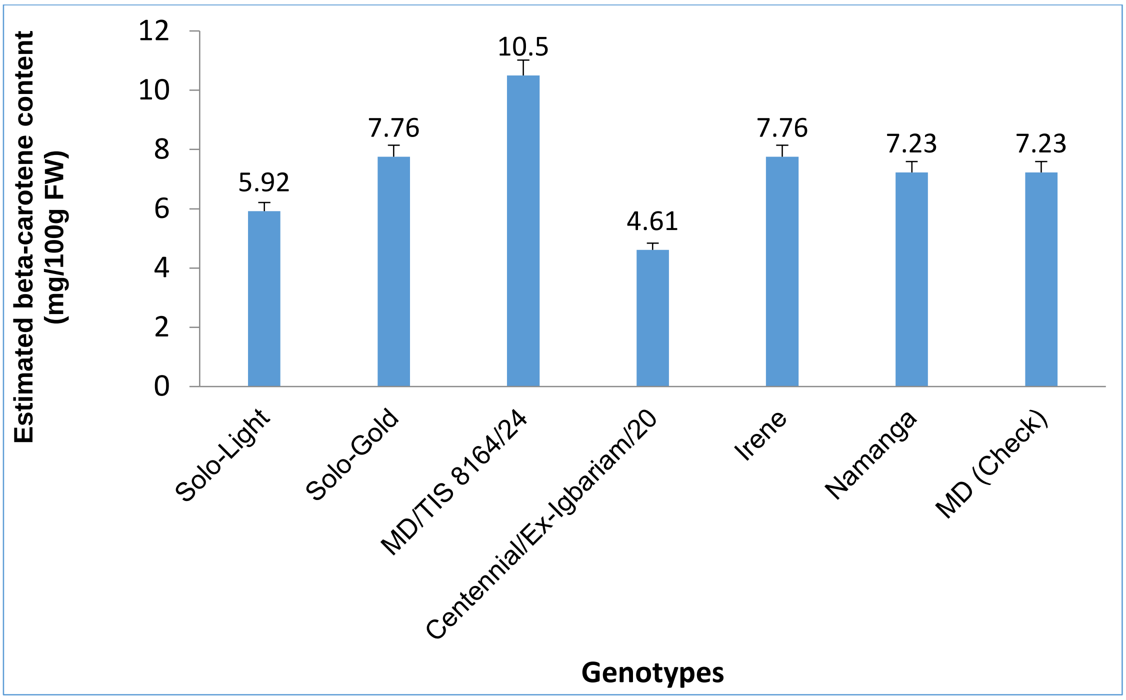

Fig. 60: Estimated mean beta-carotene contents (mg/100g FW) of each OFSP genotype as evaluated under multi-locational trials in 2016
Source: Afuape et al. (2017)

Three of the four officially released sweetpotato varieties are OFSPs (i.e. provitamin A-fortified sweetpotato types). The characteristics of the three OFSP varieties are presented in Figure 61.

King J (UMUSPO/1)	Mother's Delight (UMUSPO/3)	Solo-Gold (UMUSPO/4)
		
Attributes • High yielding • High dry matter • High SPVD resistance • Root maturity: 4 MAP • Light orange flesh • *Intermediate beta-carotene* • *Roots cracks at times*	**Attributes** • High yielding • High bulking rate • Root maturity: 3-4 MAP • High beta-carotene • Deep orange flesh • *Low dry matter* • *Susceptibility to SPVD*	**Attributes** • High yielding • High beta-carotene • Deep orange flesh • Root maturity: 4-5 MAP • High dry matter (>30%) • Resistant to SPVD • *Susceptibility to leaf spot*

Figure 61: Characteristics of the three OFSP varieties released at the NRCRI, Umudike. Note: SPVD = Sweetpotato virus disease; MAP = Months after planting

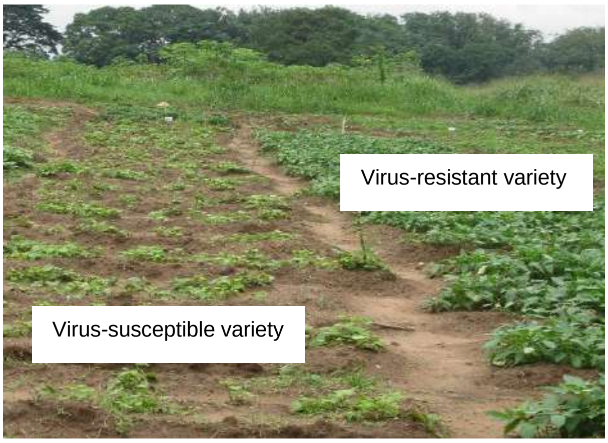

Fig. 62: Virus-susceptible and the virus-resistant variety developed by the Institute

The Sweetpotato Programme developed virus-resistant varieties to enable farmers in sweetpotato virus disease-endemic belts enjoy the economic and nutritional benefits of the provitamin A sweetpotato varieties (Figure 3). Picture shows a virus-susceptible and the virus-resistant variety developed by the Institute.

One major characteristic of the released varieties is their adaptation to all agroecologies, ensuring high root productivity in farmers' fields. **Therefore, the four new sweetpotato varieties represent innovations that will ensure sustainable sweetpotato production of farmer-preferred varieties in Nigeria.**

10.3 Sweetpotato formal seed system development

The end product of crop breeding is the release of new varieties, the seed of which serves as breeder seeds upon which other seed classes (Foundation and Certified seeds) depend. The released sweetpotato varieties, therefore, represent tangible research deliverables of the NRCRI sweetpotato breeding program that initiated the development of a robust formal sweetpotato seed system in Nigeria. Prior to the development of the new varieties, the sweetpotato seed system was mainly informal with the use of vine regrowth from the previous sweetpotato fields, or from friends, family members and other local sources**.** These vines are usually diseased, of poor genetic background, and of poor quality, leading to poor root yield and root quality. With the release of the first two OFSP varieties in 2012 and 2013, the Institute, in conjunction with CIP-SSA and the Federal Ministry of Agriculture and Food Security (FMAFS), worked to develop a number of improved practices and recommendations to enhance the production and delivery of the seed (vine) of the right variety in farmers' fields. Some of the innovations developed include the production of virus-clean Early Generation Seed (EGS), farm-gate quality vine conservation, rapid vine multiplication technique, etc.

i. Production of Early Generation Seeds (EGS) protocol and high-quality vines

The Institute and CIP, having realised the need for the production of high-quality planting materials as a critical factor to increase genetic gain in farmers' fields, began a collaborative work towards putting both infrastructure and expertise together to develop EGS which trained farmers can further multiply to produce Quality Declared Seeds (QDS) in 2015. Under the Federal Government-sponsored Rainbow Project, the NRCRI, and in conjunction with CIP, selected representative sweetpotato farmers from six states of the Federation were trained as Decentralised Vine Multipliers (DVMs) and also equipped with water pumping machines to enable them to produce QDS from EGS for sale to other farmers in their local communities. Having been saddled with the responsibility of producing sweetpotato EGS for Nigerian farmers, by 2016, the Institute started the production of EGS at the Headquarters. A typical early-generation sweetpotato seed is a virus-free, pathogen-clean tissue culture plantlets multiplied by micro-propagation or through the semi-autotrophic hydroponic (SAH) system that ensures highly vigorous vines. The clean planting materials are further multiplied in the screen house from where they are pruned and sold to sweetpotato vine producers (DVMs) as high-quality planting materials.

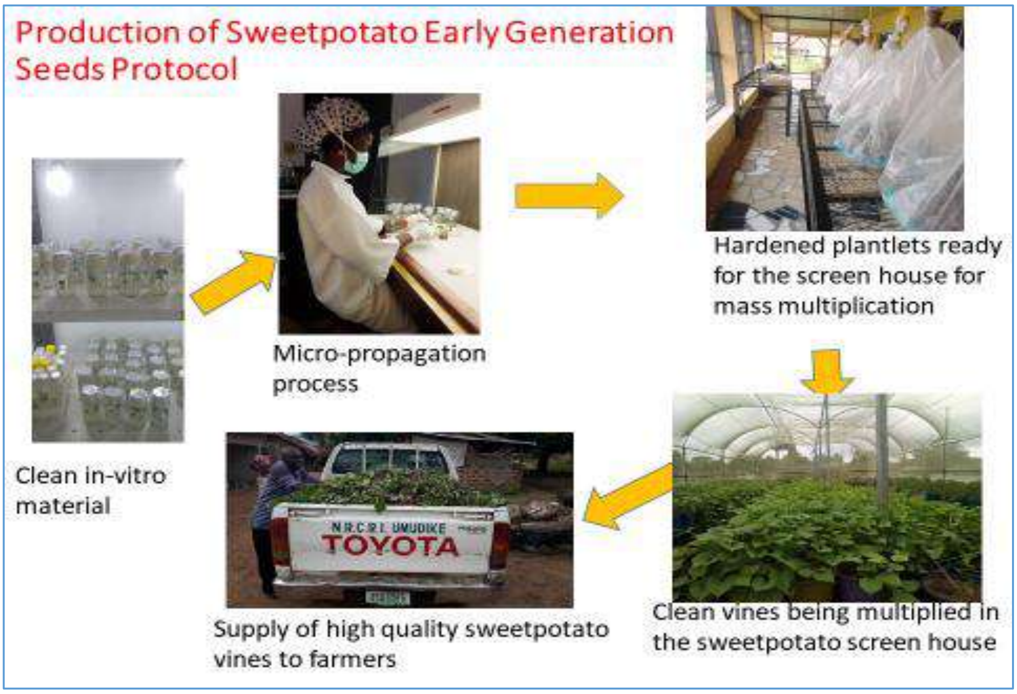

Fig. 63: Processes involved in the development of sweetpotato early generation seed (EGS)

Fig. 64: Early Generation Seeds being multiplied at the NRCRI, Umudike for sale to commercial sweetpotato vine producers across Nigeria

ii. **Farm-gate quality vine conservation**

For the conservation of high-quality vines on-farm, the NRCRI and CIP modified the CIP-developed Net-Tunnel seed conservation system by using locally-sourced cheap materials such as bamboo/bendable wood and net to produce mini net-tunnels (6 m^2) that can contain about 2 bundles (200 cuttings) of EGS. DVM farmers were then trained on net-tunnel construction and maintenance beside water sources on their farms.

Fig. 65: Training of Decentralized Vine Multipliers (DVMs) in sweetpotato vine production. Source: Okoye et al. (2018)

Fig. 66a: Net-tunnel under construction using locally-sourced (split bamboo) materials

Fig. 66b: Fully constructed bamboo net-tunnel ready to receive sweetpotato EGS

iii. **Field multiplication of seed by DVMs (Decentralized Vine Multipliers)**

For the production of high quality planting materials (also called Quality Declared Seeds), DVMs are expected to multiply virus-clean vines (EGS) collected from the NRCRI, Umudike or from their net-tunnels once on the field in virus-low environment to produce seed for sale. The seed developed from EGS by DVMs in an open field belongs to the seed class referred to as Quality Declared Seed (QDS). The seed field for the production of QDS ought to be certified by officers of the National Agricultural Seeds Council (NASC) before seeds are processed and marketed. However, this certification process is yet to be fully implemented as the Sweetpotato Seed Certification Protocol is yet to be completed and approved by NASC for use, and NASC sweetpotato Seed Certification Officers yet to be trained on its proper use. However, to ensure that quality is not sacrificed, DVMs have been trained on the following to ensure production of high quality planting materials:

- Use of all agronomic best practices to ensure optimum physiological growth of the plants on the field. The seed field could be on the flat beds or on ridges, especially for DVMs that are interested in the simultaneous production of vines and roots.
- The practice of negative selection whereby plants showing early symptom of sweetpotato virus disease are removed and buried or totally removed from the field or destroyed so as not to serve as source of inoculum.
- Sweetpotato seed field is usually planted at higher plant density except when the field serves dual purpose of root and vine production.
- When the soil is well-moistened, four-node vines are recommended. However, when atmospheric humidity is very high and planting materials are in short supply, two-node vines can be used, especially when pre-sprouted (Nwokocha *et al*., 1998) or inside the screen house or net-tunnels.
- Vines produced by DVMs on seed fields can only be pruned twice for sale or else subsequent seeds from the 3rd generation become progressively poor due to viral load accumulation.
- Vines for sale should be pruned 8 – 10 weeks after planting to maintain high vigour (Abimbola *et al*., 2019). However, for farmers interested in both root and vine production, vine harvesting 12 weeks after planting will not lead to significant root yield loss (Nwokocha *et al*., 2000).

10.4 Excellence in Sweetpotato Agronomy

Sweetpotato Best Agronomic Practices (SBAP)

While the use of improved varieties and quality seeds of such varieties is important for increased root productivity, equally essential is the adoption of Sweetpotato Best Agronomic Practices (SBAP) to complement the positive effects of the use of improved varieties and quality seeds. A suit of validated research innovations has been developed and extended to farmers as best agronomic practices. These include:

i. ***Land preparation*** – For a fallowed land, ploughing twice at two-week intervals (to allow the decay of buried plant materials in the soil before the second ploughing) followed by harrowing and ridging is the recommendation. On used land, one ploughing, harrowing and ridging should be good.

ii. ***Planting material preparation*** – vines meant for root production are usually cut 20 – 30 cm long. Okonko (1978) recommended 6-node cutting for root production. If vine availability is limited and the soil is well moist, vines could be pruned at 4-node length (Nwokocha *et al*., 1998). The vine at the top (apical) section is more vigorous and better than the middle section, while the middle section is more vigorous and better than vine cuttings from the base section (Ochuba and Akume, 1984). Vines cut and planted immediately have better yield than vines cut and stored for one week; one-week-old vine has a higher yield than two-week-old vines; and two-week-old vines are better than three-week-old vines (Ochuba and Akume, 1984).

iii. ***Plant spacing/density*** – For optimum root yield, spacing of 1m X 0,3m (i.e. on one ridge, plants are spaced 0.3m along the length of the ridge) has been the recommendation. This spacing gives 33,333 stands/ha.

iv. ***Fertilizer use-*** Basal fertilizer rate: A basal application of 400 kg/ha inorganic fertilizer NPK 15:15:15 is recommended for smallholder farmers who can't afford the cost of soil nutrient analysis. This recommendation does not apply to big farms that span many hectares. Soils of such large hectarage will be highly heterogeneous, requiring soil nutrient analysis and careful application of inorganic fertilizer due to soil needs to enhance productivity.

- Application method: ring method or side drilling method.
- Organic manure: Deep litter system poultry manure is the recommended organic manure source. The recommended rate is 1.6 tons/ha with 300kg/ha NPK 15:15:15 applied between 2-4 weeks after planting (Onunka, 2005).

v. ***Weed control*** – Weeding is one of the critical farming practices that affect root yield and root quality in a significant way. Proper weed control is critical for high productivity. Weed control can be by chemical (herbicide) and/or manual means.

- Chemical weed control: A combination of pre- and post-emergence herbicides as stipulated by the chemical producers have been found effective. For sweetpotato, all herbicides must be applied before planting as there is no selective herbicide for sweetpotato yet.
- Pre-emergence herbicide - While the herbicide type in use has been changing, currently, Lagon at 250 ml per 15 litre knapsack.
- Post-herbicide – For post-emergence weed control, glyphosate-based herbicides at manufacturers' recommended rate is usually effective.
- In order to minimize the use of herbicides, especially for smallholder farmers, a suite of integrated systems comprising the use of low concentration herbicides plus one manual weeding have been developed. These include:
- Use of S-metolachlor/terbutryne at 2.5 kg ai/ha + manual weeding at 8 weeks after planting (WAP) (Korieocha *et al*., 2011).
- Use of Atrazine/ metolachlor at 1.5 kg ai/ha + manual weeding at 8 WAP (Korieocha *et al*., 2013)
- Subsequent weed control can be manually done by roguing overgrown weeds/tall grasses.
- If weeding is by manual means, it should be carried out 4 weeks after planting depending on the growth state of the weed (Unamma, 1982) or at such time that the weed will not have competed with the crop for resources.

vi. ***Harvesting*** – Most of the sweetpotato varieties under cultivation were bred for maturity at four months after planting (MAP). Only Solo-Gold and King J may be extended to 5 MAP as they exhibit a slow bulking rate. Harvesting is usually done using a long wooden fork to carefully dig out the roots from the soil.

Fig. 67: A well-managed field that has adopted all the sweetpotato agronomic best practices for good field development

10.5 Economic studies and consumer behaviour

Some important studies that showed consumer behaviour for important decisions to be made in meeting end-user needs were carried out. Some of these research achievements and their importance are presented below:

i. **Cost-benefit analysis** showed that as much as ₦0.83k can be made as profit for every ₦1.00 spent on sweetpotato production in four months (Ogbonna *et al*., 2005). This is more than what can be made in cassava production, a 12-month crop.

ii. **Study to assess farmers' willingness to pay for early-generation seed and/or high-quality planting materials of sweetpotato**.

The study showed that most sweetpotato farmers were willing to pay as high as an average of ₦311 (range: ₦250 – N500) for a bundle (100 vine cuttings, each vine cutting between 20-25cm and minimum of 4 nodes) (Adesina *et al*., 2017). This finding was crucial to the commencement of commercial early-generation seed and QDS production. Today, many DVM farmers have increased their income from vine sales.

iii. **Identification of farmer-trait preferences for desirable cultivars**

This study was to serve as a bottom-top approach in identifying sweetpotato traits preferred by farmers and other consumers to guide the breeder in the efforts to develop acceptable new varieties for varied end-users. Identifying high root yield, large root size, and storability as key traits that must be considered in any sweetpotato variety, and finding out that taste and hard mouth-feel (dry matter) of boiled roots are key trait preferences for consumption will enable the breeder to focus in meeting both farmers and consumers' trait needs.

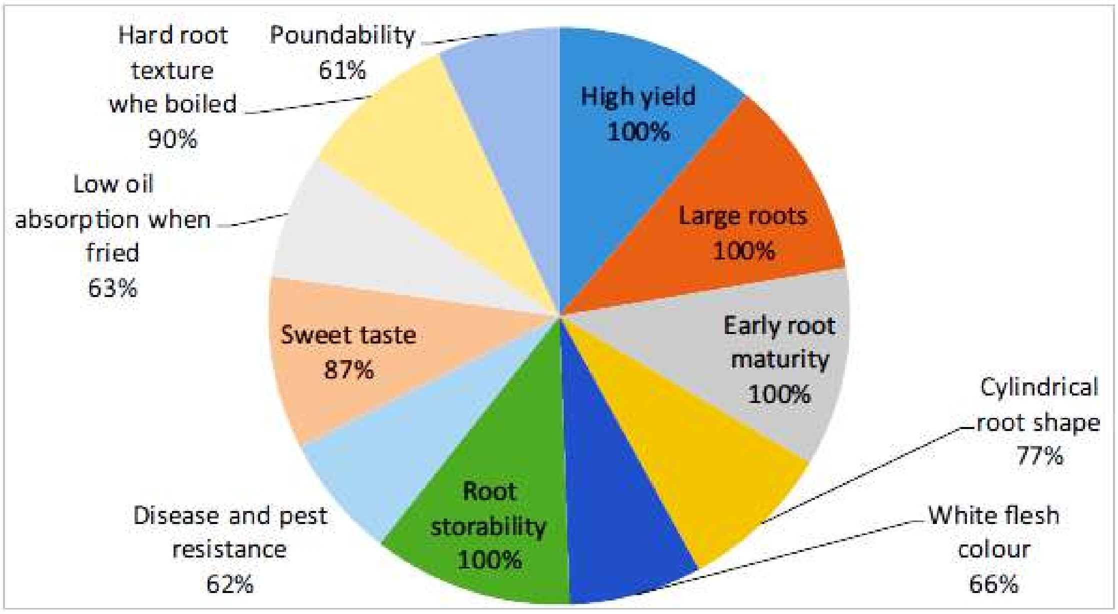

Fig. 68a: Important sweetpotato cultivar characteristics identified, and the proportion (%) of Benue state sweetpotato farmers that identified with the trait

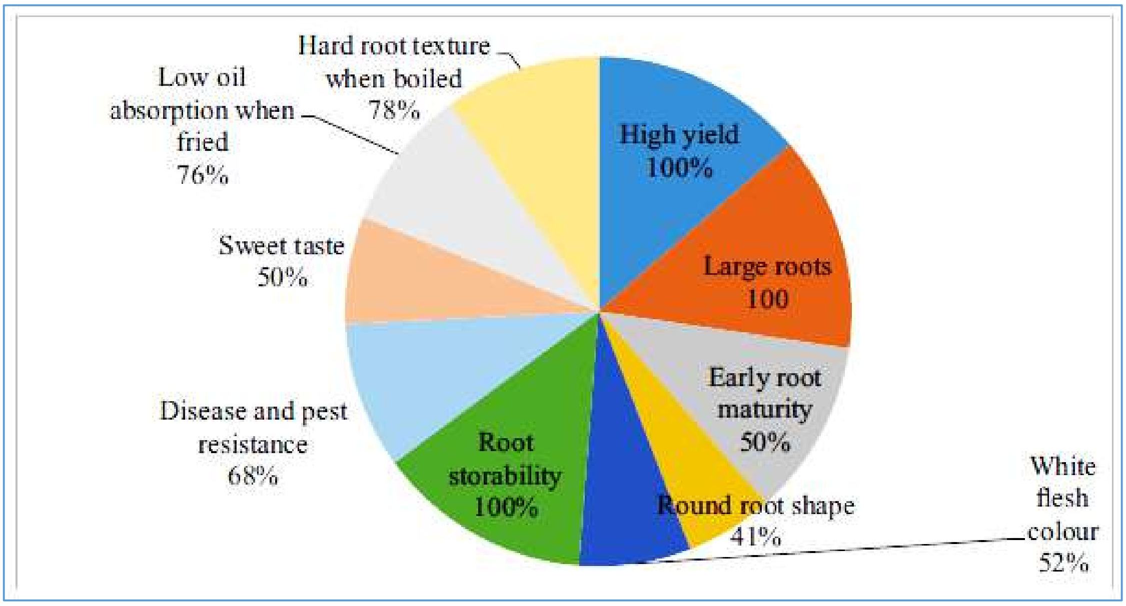

Fig. 68b: Important sweetpotato cultivar characteristics identified, and the proportion (%) of Abia state sweetpotato farmers that identified with the trait
Source: Afuape et al. (2021)

iv. Institutionalization of sweetpotato seed business plan in Nigeria

For the first time in the history of Nigeria; we have been able to develop a business plan for a sweetpotato seed system that can be adopted by other crop seeds of similar morphologies for the seed business.

v. **Sweetpotato Seed Unit has finally established a Sustainability measure** of ensuring that Early Generation Seed EGS of Sweetpotato are available and accessible through the use of a Revolving Fund (RF). – 1n 2019, NRCRI solved one of the challenging problems in the sweetpotato system – the unavailability of quality planting material at the onset of rain for planting, thus, In corroboration with CIP under the SAHSA 2 project, the Institute institutionalized RF business approach, with this, sweetpotato seeds are available, affordable and accessible all year round with or without any intervention. This has already been introduced to seed producers (DVMs) and other seed companies.

vi. Establishment of cost and price for Sweetpotato seed

The programme has established a price for EGS (pre-basic and basic seeds) which is generally adopted now in Nigeria. This also involves institutionalizing the Sweetpotato pricing strategies as a business model where early order, bulk and advance payment take advantage of special discounts.

vii. NRCRI; first runner up in the sweetpotato marketing strategy competition in Kenya

Part of the agenda in the 10th consultation of the Seed Systems and Crop Management Community of Practice (CoP), organized by Sweetpotato Action for Security and Health in Africa (SASHA) project in November 2018 was to assess the effectiveness of partner National Research Institutions' (NARIs) marketing strategies -for early generation sweetpotato seed. A marketing strategy competition was launched in 2017 with the aim of encouraging the institutions to strategically plan for effective marketing of their sweetpotato vines, selling them at a price and quantity that would sustain subsequent production of quality early-generation seed. Out of 13 partner NARIs involved, seven NARIs institutions participated, **National Root Crops Research Institute (NRCRI) came second position** awarded on Wednesday 14th November 2019 in Nairobi, Kenya. The marketing strategies adopted include; stakeholder meetings, jingles on the radio to reach a wider audience, field days and exhibitions, demo plots at strategic places, advocacy visits and policy influencing, use of t-shirts and customized caps to create awareness on the availability of quality vines and campaigns on social media.

Fig. 69: NRCRI; first runner-up in the sweetpotato marketing strategy competition in Kenya

viii. **Harmonization of Sweetpotato Seed Producers in the Country**

In corroboration with CIP (SASHA 1&2, TAAT, etc.), the Institute was able to develop the capacity of sweetpotato vine multipliers (DVMs) and decentralized them in all States of the country. This group of farmers were empowered with production facilities such as net tunnels, pre-basic seeds etc. The harmonization was achieved through key activities which included; stakeholder meetings, building a seed producer platform, and maintaining the seed producer loyalty.

10.6 Nutrition and Health

Nutrition and health considerations are important aspects of a pragmatic functional Food System aimed at diversifying food forms and nutrition sources for consumers. The Sweetpotato Programme of the Institute has as one of its cardinal aims the development of nutritious food forms, especially with the provitamin A-rich OFSP varieties, capable of enhancing consumers' health. As such, the Institute has developed some tangible innovations that tend to create more choices for improved nutrition and health of consumers. Critical to the realization of this goal is the development of the three OFSP varieties with enhanced beta-carotene content. Some of the innovations include:

i. **OFSP juice –** The development of a protocol for the production of provitamin A-rich OFSP orange drink from OFSP varieties was undertaken by the Food Scientists of the Sweetpotato Programme. The protocol for the production of OFSP juice was developed and used to produce acceptable OFSP juice which was one of the products that enjoyed patronage in the Institute's OFSP Snacks Bar. The OFSP Juice is one of the key OFSP-based technologies extended to communities, women and youth organizations, farmer groups, etc. during training on sweetpotato value addition. The protocol for producing OFSP juice is available at the NRCRI, Umudike for any intending investor.

ii. **Protocol for the production of OFSP bread and other confectionaries –** Protocols for the production of baked and confectionary products such as OFSP bread, chin-chin, buns, cakes, etc. using appropriate wheat-OFSP flour composite have been developed by the Institute's Food Scientists. The products, which have been demonstrated and found to be commercially viable through their commercial test-runs at the Institute's OFSP Snacks Bar, have been extended to many groups and communities during the Institute's different training sessions on value additions for end-users by the Women-in-Agriculture unit of the Institute.

Fig. 70a: Staff panelists sampling OFSP juice against commercial juice during OFSP juice

Fig. 70b: OFSP juice sold in plastic bottles

Fig. 71a: Wheat bread and orange-fleshed sweetpotato-based bread

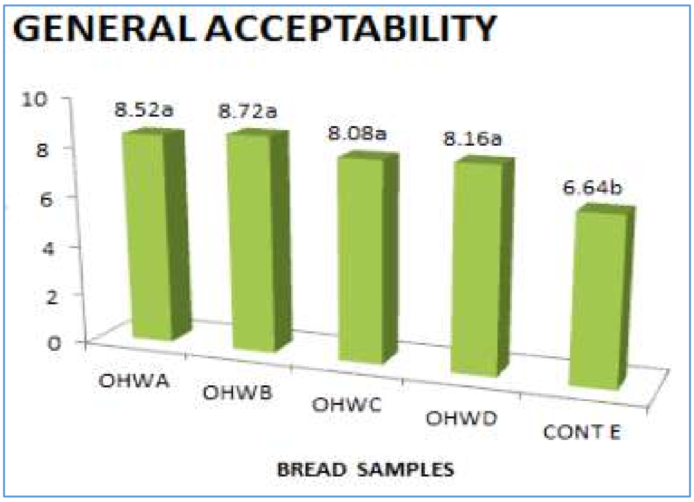

Fig. 71b: Evaluation of wheat (control) and pro-vitamin A "Golden Bread" samples made from wheat-high quality cassava flour-sweetpotato puree composite. Source: Omodamiro *et al. (2018)*

Fig. 72: Orange French Fries

Fig. 73: Other sweetpotato utilization channels in Nigeria

10.7 Collaboration and Participation

A functional food system emphasizes the involvement of multiple stakeholders that are critical to the delivery of a crop from the farm to the table. In effect, it involves a holistic crop value chain which includes critical stakeholders in the crop value chain. So for the Institute to be able to deliver a sustainable and functional sweetpotato value chain to the country, there is need for a critical network of collaborators and actors that bring divergent skills, influence and capabilities to bear on delivering a sweetpotato functional sweetpotato food system. As such, the Institute, through its Sweetpotato Programme and Sweetpotato Breeding Program, established deep collaboration and working relationships with such organizations as the International Potato Centre (CIP), different sweetpotato farmer groups (such as POGPMAN – Potato Growers, Processors and Marketers Association of Nigeria; POFAN – Potato Farmers Association of Nigeria; SPAN – Sweetpotato Producers Association of Nigeria), processors, the Federal

Ministry of Agriculture and Food Security (FMAFS, States Agricultural Development Programmes (ADPs), private sweetpotato farms, and other stakeholders.

The Institute's partnership with CIP-SSA (CIP, sub-Sahara Africa Office in Nairobi, Kenya) has been on coordinated research efforts targeted at delivering genetic gain in farmers' fields through the enhancement of the development and distribution of highly nutritious orange-fleshed sweetpotato (OFSP) varieties to farmers. Through the partnership between the NRCRI and CIP, elite sweetpotato germplasms (in vines and botanical seeds) were shared, leading to the release of the flagship OFSP variety, Mother's Delight. Many other elite genotypes received from CIP had been incorporated into the sweetpotato crop improvement program to enrich the genetic diversity. This has led to the release of another OFSP variety, Solo-Gold. Namanga, an introduced variety from CIP-SSA is presently undergoing its last pre-release trial phase prior to its nomination and eventual release as yet another testament of the rich collaboration between CIP and the Institute.

Realizing that a good variety in poor seed background will never give its full potential, the Institute and CIP spearheaded the development of the sweetpotato formal seed system to kick-start a sustainable seed system in Nigeria. This effort has led to the development of a public-private partnership seed system model that involves the production of early generation seed (EGS – virus-clean sweetpotato vines) by the Institute, and the purchase of EGS by DVMs to produce Quality Declared Seed (QDS - a high quality planting material). With this structure, the narrative of the use of seeds from the informal seed system has changed. Sweetpotato vine production has become a huge enterprise that is changing lives of farmers and improving rural economy in sweetpotato important communities.

The NRCRI-FMAFS (Federal partnership on sweetpotato has largely been on the distribution of quality vines to farmers, and the training of sweetpotato farmer-groups and women and youth groups in each geopolitical zone on sweetpotato production, processing and marketing. Also, the FMAFS has carried out sweetpotato seed intervention programmes through which quality seeds were purchased from known sources and distributed to farmers in flood-ravaged states and internally-displaced persons camps to serve as a quick means of improving food and nutrition security of the affected people. Through the RAINBOW Project, FMAFS has been involved in direct funding of research and development in sweetpotato. This partnership between the Institute, the FMAFS and CIP under the RAINBOW Project birthed the development of the Decentralized Vine Multiplier (DVM) scheme and served as the first attempt at promoting the consumption and processing of OFSP in Nigeria.

The Institute's works with private farms, farmer groups and processors have largely focused on training and backstopping them with the requisite skills to help them deliver on their goals. Training on sweetpotato best agronomic practices, value addition and sourcing of high quality planting materials have been the key areas in the Institute that have made great impacts.

Conclusion

Since the 1970s when the NRCRI, Umudike started active research on sweetpotato, it has made huge research progress that has transformed the sweetpotato value chain. The crop has moved from its previous status of poor man's food to the current enviable position where health-conscious individuals have seen it as a go-to nutrient-fortified food. Putting the many research achievements together, the Institute, with its network of collaborators within and outside the country, have worked together to create a functional, sustainable sweetpotato food system that delivers nutritious, vitamin A-fortified sweetpotato roots and products to the tables of the populace in both rural and urban communities, and in the form that they can identify with. Evidence of this is the increase in production that has reached about 4 million tonnes of roots produced by the country, which is the 3rd largest in the world, the 2nd largest in Africa, and the largest in West Africa**.** Our research achievements have culminated in the transformation of sweetpotato from a peasant farmer's crop to a cash crop with a formal seed system that delivers improved seed of the nest varieties to farmers' fields.

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CHAPTER 11

MINOR ROOT CROPS RESEARCH PROGRAMME: ACHIEVEMENTS

11.1 Introduction

Minor Root Crops Research Programme (MRCRP) is one of the seven commodity crop research programmes in the Institute. It became fully operational over a decade ago, with the responsibilities of developing technologies for the improvement of Livingstone potato (Plectranthus esculenta N.E. Br), Hausa or Frafra potato (*Solenostemon rotundifolius*), Polynesian arrowroot (*Tacca leontopetaloides* Kuntze) known locally as "Amora" Turmeric (*Curcuma longa* L), American Yam Bean (*Pachyrhizus ahipa*) and other minor root crops of economic importance in Nigeria. The Institute has carried out exploratory trips to collect indigenous knowledge about the production and utilization of some minor root and tuber crops in all 36 States of Nigeria. Data collected were used to delineate minor root and tuber crop-growing areas in the country.

11.2 Goals of the Programme

The mission of the Programme, a subset of the overall mission of the Institute, is to develop and promote the underutilized root and tuber crop species towards becoming commodity crops for food security, poverty alleviation, improved health care delivery, and economic growth in Nigeria. To accomplish this goal, the research activities in the Programme have been focused more on building up the information database through indigenous knowledge, germplasm exploration, and collection, crop improvement through conventional and biotechnology techniques, and development of environmentally friendly and socio-culturally acceptable production.

11.3 Achievements

1. **Exploration and collection of local germplasms of minor root and tuber crops in Nigeria and other countries**: The program collected fifteen sugar beet accessions from the USA and fourteen accessions from Germany, totalling 29 accessions of Sugar Beet collections. We also acquired 45 accessions of turmeric, 19 accessions of Hausa potato, 13 accessions of Livingstone potato, and 19 accessions of Polynesian arrowroot.
2. **Information database**: The minor root crops program went into the building of an information database on endangered root and tuber crops through indigenous knowledge from the local farmers on production, processing, marketing, and utilization to assist in developing technological interventions. Assessment of the

various endangered root crops for their biochemical and food values for developing value-added products.

3. **Mapping of the production areas of minor root crops in Nigeria:** Identification of 10 potential turmeric varieties, which are undergoing accelerated multi-location trials preparatory to releasing them to farmers. The program has also carried out exploratory trips to collect indigenous knowledge about the production and utilization of some minor root and tuber crops in all 36 States of Nigeria. Data collected were used to delineate minor root and tuber crop-growing areas in the country (Fig. 74).

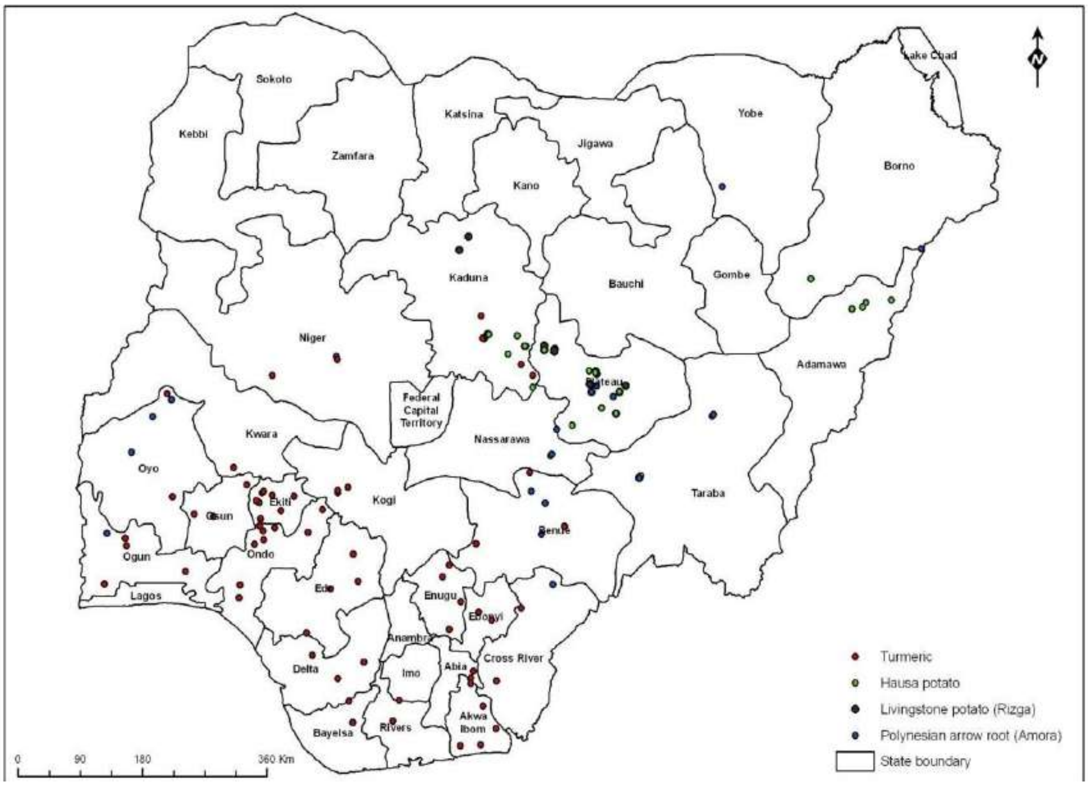

Fig.74: Map of Nigeria Showing Geographic Distribution of Minor Root and Tuber Crops

4. **Processing of Turmeric into powder form:** The Minor Root Crops program processed the rhizome of turmeric, which is the portion of the plant used medicinally, into powder. It is usually boiled, cleaned, dried, and milled into a yellow powder. Turmeric powder is used as a spice. The ingredient that gives curry powder its characteristic yellow colour is turmeric. Turmeric powder is used extensively in foods for its flavour and colour, Curcumin, oleoresin, and volatile oil are the main ingredients in turmeric powder used for medical purposes.

Fig. 75: Turmeric powder

5. Domestication of Polynesian arrowroot through seed technique and production of quality Polynesian arrowroot (*Tacca Leontopetaloides*) starch from freshly harvested amora tubers: potentials for the export market and income generation were carried out. Starch is one of the major biomaterials used in food (54%) and non-food (46%) industries. The non-food industries include pharmaceuticals, plastics, cosmetics, textiles and adhesives. A Polynesian Arrowroot tuber (locally known as Amora in North Central Nigeria) is considered to be bitter if untreated. Though the tuber has a high starch yield, it is unpalatable with a bitter taste. It also produces inflammation and shows occasional toxicity. The starch has been extracted outside Nigeria and sold commercially in quantities to Europe, where it was used in bread making. It also has various local medicinal uses. People in the Middle Belt Region of Nigeria use starch in preparing their local delicacies.

Plate 11: Photographs of some operational steps in amora starch extraction. A = Fresh amora tuber, B= peeled, washed amora tubers steeped in water, C Grating and sampling of amora mash (pulp), D = Multiple washing of pulp to free amora starch, E=decanting washed wet amora starch cake, F= flash drying of wet amora starch cake and G = packaged quality amora starch

6. **Popularization and sensitization of farmers on the use of turmeric in the southern part of Nigeria:** The program aimed to popularize turmeric production and processing in Southern Nigeria, particularly in Ebonyi State. Community-based organizations, including cooperative societies, farmers' associations, age groups, and faith-based organizations, participated in the training. The training was attended by a large number of people, who were enthusiastic about the process and accepted rhizomes for multiplication.

Fig. 76: Farmers being sensitized on turmeric

Fig. 77: Farmers group during the exercise

7. Phytochemical, Proximate, and Elemental Analysis of Hausa Potato leaves: The study evaluated the benefits of Hausa potato leaves, revealing their phytochemicals, including flavonoids, tannins, alkaloids, phenols, and saponins, which may have anti-diarrhoea properties. The extract was administered to albino rats with symptomatic diarrhoea, resulting in stooling and faeces restoration. The organ bath technique also showed the extract's anticholinergic properties, suggesting its potential for managing diarrhoea and excessive gastrointestinal spasms.

Fig. 78: Hausa potato (Solenostemon rotundifolius leaves

Fig. 79: Anti-diarrhea evaluation on experimental albino rats

Fig. 80: Organ Bath

8. Evaluation of newly introduced American yam bean accessions in Nigeria: American yam bean (Pachyrhizus spp) (AYB) has been successfully introduced in some African countries with exciting results. Fourteen AYB accessions were received from CIP Lima and Peru. The program assessed the performance of twelve American yam bean accessions under Nigeria environmental conditions to identify and select adapted genotypes with high yield and acceptable culinary qualities. Twelve accessions 209039, 209016, 209013, 209037, 209019, 209015, 209038, 209018, 209041, 209045, 209042, and 209044 were accessed. Yields obtained showed that these selected accessions have the potential to serve as alternative sources of calories to help feed the increasing population.

CHAPTER 12

GINGER RESEARCH PROGRAMME: ACHIEVEMENTS

12.1 Introduction

The Ginger Research Programme is one of the seven commodity crop programmes under the Crop Research Operations Department (CROD). Ginger Research Programme of the Institute is charged with the responsibility to carry out research on ginger (*Zingiber officinale Rosc).* The Programme has a unique feature of handling a crop that is basically not consumed directly as food but rather finds its use as a major spice in the culinary, food beverage, medicinal and confectionary industries. The programme was formerly under the Other Root Crops Programme and became a full programme in the year 1984. Since it became a full programme till date, it has been headed by 12 Coordinators. Each Coordinator has imparted so much to the progress of the programme as can be observed in the Annual report from the 1970s to date. The programme ensured that there was at least one tangible research breakthrough report in the Institute's annual report book as well as several ongoing trials. Some of these innovations have been extended to end users. Some of them include good agronomic practices (production systems, herbicides application, climate resilience methods), processing systems (value additions, design and fabrication of Ginger splitting and drying machines, rapid multiplication methods, registration of two ginger landraces, post-harvest storage system, advances in hybridization and ginger mutation breeding. The list is endless. Based on the mandate, research activities are structured into various units, breeding, agronomy, microbiology/ plant protection and socioeconomics. Research activities are undertaken with respect to these units based on farmers' perceived and identified problems in their areas. The farmers who constitute over 70% of the production landscape in Nigeria are the key actors in the ginger value chain.

Ginger Programme has the mandate to:

- Develop high-yielding and disease-resistant ginger varieties that can compete favourably in terms of quality in the international market.
- Remove drudgery in ginger production through the mechanization of the production process.
- Develop affordable means of storing and processing ginger without compromising its quality.
- Develop efficient marketing channels for ginger in Nigeria.

Sequel to these mandates, the Institute commenced effective research on ginger in 1982, although ginger cultivation in Nigeria started around 1929 in Jema'a federated districts of Kaduna State. Ginger Research programme of the Institute is currently charged specifically with the responsibility to carry out research on this crop (Ginger).

The primary objectives of the programme are to:

- Develop through research, suitable ginger cultivars, appropriate production, processing, post-harvest as well as marketing technologies to improve yield and farmers' income.
- Popularize ginger cultivation in other parts of the country outside the traditional home, Southern part of Kaduna State.

The Crop "Ginger" (*Zingiber offcinale Rosc.*)

The ginger plant is a monocotyledonous perennial plant grown mainly as a cash crop for its spicy and aromatic rhizomes (Amadi *et al*., 2022). The pungency and fragrance of ginger are due to the presence of oleoresin and other essential oils. Ginger was introduced in Nigeria about a century ago and since then its production, processing and marketing have increased. The crop is a tuber crop widely traded domestically and globally in various forms such as fresh rhizome, split dried, powdered, essential oil and ginger oleoresin. It has diversified usage, as a spice in food, medicine, and industry. A well-managed ginger farm is presented in Figure 81.

Fig. 81: Well-Managed Ginger Farm

Major uses of Ginger

Ginger leaves and rhizomes are used for a variety of purposes including

- ❖ Culinary: Ginger is an essential ingredient in many Nigerian dishes.
- ❖ Medicinal: Ginger is well-known for its medicinal properties, such as alleviating digestive issues, reducing inflammation, antioxidants, etc
- ❖ Beverage Industry: Ginger is widely used in various beverages, including tea, ginger ale, etc.
- ❖ Confectionery and Snacks: It is also used in the production of confectionery items like gingerbread, candies, and snacks.
- ❖ Cosmetics: Industrially processed oleoresin is an essential raw material for the production of perfume

Production

Globally, ginger production is dominated by five major countries including Nigeria, India, China, Indonesia and Bangladesh, with Nigeria occupying more land area (about 56.23%) of the whole land area under cultivation. Nigeria is currently the 2nd highest producer of ginger in the world. The production landscape of ginger is dominated by over 70% of small-scale farmers. It was confined almost exclusively to the Southern Zaria, especially in Kwoi, Kafanchan and Kagoro in Kaduna State and in the neighbouring part of Plateau State. However, research has shown that ginger can grow well in Agricultural zones other than the Southern Zaria district (Arene, Orkwor and Okwuolwulu, 1987). With cultivation occurring in a wider area of the country, the total ginger hectarage was increased, but the yield was found to be too low (5-12 tonnes/ha (Anon, 1984). Yet under improved cultivation conditions, yields could be as high as 38 tonnes /ha. Thus the actual yield of ginger in Nigeria was far below the potential yield of the crop. Two cultivars of ginger UMUGIN 1 locally known as *Tafin giwa* or yellow ginger, and UMUGIN 2 locally known as *Yatsun biri* or black ginger are cultivated.

The Cultivar UMUGIN 1 (Figure 82) is characterized by erect plant with upright leaves; large rhizomes with robust fingers resembling the foot of an elephant (hence the local name *Tafin giwa* meaning elephant foot); light yellow rhizome skin and flesh; high potential yield (39 tons/ha) and nutritional content CP 8.04; Fats 0.65%, CHO 68.42%, CF 6.86%, Oleoresin 6.55%.

Fig. 82: UMUGIN 1 cultivar showing robust rhizomes

The cultivar UMUGIN 2 (Figure 83) has an erect growth habit with slightly drooping leaves, slender rhizome fingers (It resembles those of a monkey hence the local name *Yatsun biri* meaning monkey fingers), a pale yellowish-grey rhizome flesh, a potential root yield of 30 t/ha, moderate resistance to yellow leaf spots, and high nutritional content CP 7.94; Fats 0.71%, CF 7.00, Ash 3.71, CHO 68.78%, and high oleoresin 7.02%.

Figure 83: UMUGIN 2 showing slender rhizome

Research Work towards Increasing Ginger Production and Yield in Nigeria

The production of ginger in Nigeria started in 1927, but research on this important crop was not given conscious effects until the 1960s. The early research in ginger started with increasing ginger hectarage by exploring and introducing varieties that may be adapted in all parts of the county or all agroecological zones of the country.

Agronomic Practices

Over the past 5 decades, from 1970 several experiments were conducted in NRCRI to standardize the agronomic practices for enhanced ginger production and yield in Nigeria.

Site Selection

Based on the findings, ginger tolerates a wide range of soils: clay loams, sandy loams, sandy clay loams, and lateritic soil with high organic matter. It performed better in well-drained fertile, friable loamy slightly acid (5.5-6.5 PH) soil. Ginger is very sensitive to soil temperature, preferably better in warm rather than hot and erratic sunshine (23-35^{o}C). It is recommended to find out the nutritional status of the soil through soil testing before planting. In case the ideal soil is not having enough nutrients, organic matter application is recommended at the time of soil preparation.

Land Preparation

Ploughing, harrowing and ridging are done before seedbed preparation to encourage the proliferation of ginger roots for maximum absorption of soil nutrients and moisture. Beds are preferred to ridges in planting ginger; 2 metres by 10 metres seed beds at a depth of 15 cm with an interspace of 50 cm in between beds. Exactly 360 of such beds are recommended in 1 hectare of land. Organic fertilizers (poultry manure, farmyard manure etc.) are incorporated into the soil during seedbed preparation and allowed to stay for 14 days (2 Weeks) before planting. Poultry manure is most preferred as organic manure due to the fact that it contains the highest amount of nitrogen, phosphorus and potassium of all animal manures. It is recommended to be added to the soil at a rate of 20 tonnes per hectare or 40 kg/bed if sourced from the deep litter system and 4 tonnes per hectare or 8 kg/bed from the battery cage system.

Planting Materials (Sett Size)

Natural seed ginger (hybridization) is yet to be developed, however hinders breeding systems and compels the research for the best seed setts to improve ginger rhizome yield. Different sett sizes are used for different purposes and have a functional relationship with variety, yield, multiplication ratio, and inflorescence-bearing ability (Anon, 1984). Meanwhile, two ginger landraces which are commonly grown in Nigeria include; Umugin 1 (Yellow Ginger) and Umugin 2 (Black ginger). The exotic varieties in the Institute include Maran, Himachal, Pradesh, St. Vincent, Rio de Janeiro and Wynad local. The yields and characteristics of these varieties are not superior to Umugin 1 and 2. Ginger yields increase with the increase in sett size as small setts <10 grams yield ginger seeds (Okwowulu and Odurukwe, (1985-1988) while larger setts size of 20 grams and above trigger inflorescence development. The decrease in sett weight results in an increase in the multiplication ratio. However, the use of very large sets is not economical due to the large seed rate. Farmers require between 3600-4400 kg ginger rhizomes (seeds) /ha (360 beds) as planting materials or alternatively 90-110 bags/ha (for a 40 kg bag of ginger seed) (Ohaeri and Ukpabi, 2021). However, a bed of 2m x 10m will require 10-12 kg of ginger seeds for planting at a spacing of 20 cm x 20 cm. About 90-110 bags of 40 kg or 60-75 bags of 60 kg bags (Table 13). It will require a 60kg bag of ginger seeds to cover about 5 of 2 m x 10 m beds

Table 13: Quantity of ginger seeds needed based on plot size

Plot size	Number of Bed	Quantity of Ginger seeds	Spacing
2 m x 10 m	1	10-12 kg	20 cm x 20 cm
100 m^2	5	60 kg bag	20 cm x 20 cm
1 hectare	360	90-110 bags of 40 kg bag	20 cm x 20 cm
1 hectare	360	60-75 bags 0f 60 kg bags	20 cm x 20 cm

Planting / Spacing

March to April is the optimum time for planting especially in the rainforest zone (Southern Nigeria), April to May (Northern Nigeria) while October to November is ideal for irrigation. Ginger requires slow to moderate rainfall/irrigation during crop sprout but heavy and evenly distributed water during crop growth and then dry weather one month before harvesting. Ginger is planted using clean rhizomes which are cut into sets of 2.5-3.5 cm weighing about 10-20 g. Planting rhizomes should be treated with 45g Mancozeb and 10g Bevistin (Carbendazim). Each set is recommended to have at least 3 buds.

The seed sets are placed in holes about 8 cm deep at a planting spacing of 20 cm x 20 cm. Shallow planting can lead to the desiccation of the seeds. The Ginger plant responds best to closer spacing (Menta (1987). It is also amenable to mechanized operation using the modified potato planter. It is sown on furrows in upland and on ridges or raised beds in lowlands (Figure 84). Ginger loves plenty of sunlight, but not direct sun. It is a shade-loving plant preferably tall trees or crops.

Fig. 84: Holes on a raised bed with ginger seed sets

Mulching

The importance of mulching in ginger production cannot be over-emphasized. It helps in moisture conservation, enhancement of organic matter, improvement of physical soil properties, prevention of soil erosion, and weed control. Mulching is done within two days after planting. Extensive work has been done on the best mulching practices at the least cost. It is recommended to use matured green grass with tough straw because of its slow rate of decomposition. There is a significant increase in the overall performance of ginger at 5 and 10 cm thick levels of mulch which out-yielded the zero mulch by 29.5 and 21.3%. A good 4-5cm thick mulch at planting is enough to cut down on the cost of mulching lightly 2-3 times. Some common mulching materials include straws, dried leaves, etc. The picture of a well-mulched bed is shown in Figure 85. Research has proven that mulched ridges gave higher rhizome yield at the closest intra-row spacing (10 cm), but flat seedbed preparation is recommended as it is easier to mulch and retains mulch better the ridges, (Orkwor *et al*.,1986). However, there is a need to look for cheaper and more available mulching materials (Arene *et al.*, 1983).

Figure 85: Well-mulched bed

Weed Control and Earthing

Weed is a strong competitor of ginger. Uncontrolled weed growth caused a yield loss of 44-81% (Melifonwu and Orkwor, 1985). The critical period of weed competition is between 12 and 16 weeks after planting. The first weeding should be done 30 days after planting, while the second weeding should be done 45-60 days. Manual weed control is laborious, time-consuming, and expensive. Orkwor, (1985) evaluated the efficacy of herbicides and found that ginger yield increased with a decrease in herbicide rate. It is recommended to use Diuron at 3.6kg a.i./ha followed by pre-emergence herbicide at the rate of 4.5kg. Equally Premextra Gold 660 SC (S-Metolachlor + Atrazine) at 2.5 kg a.i/ha is applied pre-emergence a day after planting and before mulching using a knapsack sprayer fitted with a nozzle calibrated to deliver at a rate of 250 litres spray volume/ ha. Paraquat at 0.8 kg a.i/ha is recommended to be applied post-mergence. Earthing up ridges/beds is done to build up reduced beds as a result of rain or irrigation pressure on the soil. Two periods of earthing up recommended are during the second weeding and on the 120-135th day.

Soil fertility Management (Fertilizer/Organic manure requirement)

Ginger is a heavy feeder crop. It requires good integrated soil fertility management practices. For ginger production, organic manure is of paramount importance. The combination of 25-30 tons/ha of well-decomposed farm-yard manure or compost or poultry manure and NPK 15:15:15 are required. Although, there is a significant difference in the growth and yield of ginger with 200kg N/ha in combination with 80kg P2O5/ha (Musa, 1986). For soils low in N, P and K, 300 kg/ha of N. P.K 15:15:15 are recommended to be applied 4 weeks after planting for optimal ginger production. Alternatively, straight fertilizers should be used as follows; 60 kg/ha N, 20 kg/ha P and 50 kg/ha K, using (NH4)2 SO4, SSP and KCl, respectively (Ohaeri and Ukpabi, 2021).

Pests and disease control

Ginger like every other crop is attacked by some pests and diseases, resulting in varying degrees of damage to the crop and yield loss or reduction. Planting ginger in fertile soil may reduce the incidence of pests and diseases in ginger. Nnodu and Emehute (1988) (unpublished data) observed leaf spot disease caused by Phyllosticta zingiber is the most important disease of ginger in Nigeria. Also, they observed that Bacterial wilt (Figure 86),

Fusarium yellows, and rhizome rot are very common in Nigeria's ginger production. Generally, pests and diseases are controlled using chemicals (pesticides and fungicides) specific to different types and species. Use of clean planting seeds, planting early, avoiding water-logged fields, selecting fertile soil and applying balanced fertilizer, crop rotation, and proper harvest time are recommended.

Fig. 86: Bacterial Soft Rot caused by Erwinia carotovora

Cropping system

Ginger can be grown as a sole crop under open or shade apart from as a component in inter, mixed, and other cropping systems. Ginger is intercropped with vegetables (cabbage, tomato, chillies, french bean, and lady's finger), pulses (pigeon pea, black gram, and horse gram), cereals (maize, finger millet), oilseeds (castor, soybean, sunflower, etc) and other crops (sesbania, tobacco, and pineapple). Ginger can also be grown as a mixed crop with castor.

Harvesting and Storage

The maturity of ginger coincides with the age of the crop at which there is maximum dry matter and fibre content. Harvesting is determined by the consumer's needs and purposes. Harvesting for culinary purposes takes 4-5 months (Oti *et al*., 1988), as fresh ginger for exports 7-10 months (Anon, 1982), for storage is when soil is moist to reduce bruising to a minimum. Harvesting may be done manually by carefully lifting the soil with a digging fork, hoe or other suitable implement to expose the rhizome. It is recommended to harvest before the onset of early rains in March to avoid the sprouting or rotting of rhizomes in the soil. In a well-managed ginger field, a yield of 30 to 40 tonnes/ha can be obtained in Southern Nigeria.

For fresh ginger rhizome storage, the most suitable organic materials that maintain the physiological and nutritional quality of ginger rhizome recommended are grass, wood shaving, and palm bunch (Ezebuiro *et al*., 2022). Well-stored ginger rhizomes are shown in Figure 87. Larger quantities are best stored in heaps under tree sheds and covered with dry grass or inside well-ventilated huts.

Figure 87: Well Stored Ginger rhizomes

Ginger rhizome Processing

The ginger rhizome can be processed into various forms such as split dried, powdered, essential oil, and ginger oleoresin as key raw materials for industries and exports. The method of processing is a determinant of acceptance and pricing in international trade. The drudgery particularly to ginger splitting is what led research to develop a ginger splitting machine in 1988, courtesy of Engr. Dr Nwokedi and team.

This machine was mass-produced and distributed to key ginger-producing communities, particularly to communities in Southern Kaduna. The model developed then is presented in Figure 88. The machine was of great assistance to the yearning of ginger producers particularly to smallholder farmers, ginger producers' cooperatives, and commercial producers.

Fig. 88: Well-designed ginger rhizome splitting machine

Ginger breeding

The major constraint of Nigerian ginger production was the narrow gene pool upon which production was based. Incidentally, there is an urgent need to increase the yield of ginger and develop new varieties that are resistant to yellow leaf spot to be released to the farmers. Presently, there are two varieties grown in Nigeria out of the many known cultivars either as a result of genetic erosion or accidental losses.

Conventional Hybridization

Conventional hybridization leading to the generation of variability upon which selection is imposed to identify promising genotypes requires that parental lines must flower and set viable fruit. Consequently, ginger cultivars were evaluated for flowering and fruiting under different agro-ecologies. Studies carried out showed that increasing the weight of planting material led to a significant increase in the number of flowers in the rainforest and cool mid-altitude of Jos (Okwowulu, 1988, Amadi *et al*., 2015). Treatment with plant hormones promoted number of flowers and duration of flowering. However, in all these treatments, ginger cultivars failed to fruit and set viable seeds either from natural or hand pollination. Lack of fruiting and seed set may be due to inherent incompatibility.

Development of Ginger Mutant Lines

Mutation is an effective way to induce variability in crop plants. With little progress made with conventional hybridization, Scientists at NRCRI Umudike tried to use gamma rays to induce mutation in Ginger. Nwachukwu *et al.* (1994) and Iwo *et al.* (2009) determined the mutability and radio-sensitivity of two ginger landraces bombarded with gamma rays from a 60 Co gamma source. They determined LD50 at 8.75 Gy in both cultivars and estimated the dose limitation range for ginger to be 5.0 - 9.0 Gy. Through gamma radiation, ginger mutant lines have been developed by scientists at NRCRI Umudike (Iwo and Nwauzor, 2009; Amadi *et al*., 2012; Amadi *et al*., 2020). Selections from this population have led to the identification of a number of promising lines with high, stable, quality yield, resistance to diseases across locations, and improved oleoresin content. These are undergoing pre-release evaluations. The rhizome yield of some mutant lines at Umudike is presented in Table 14.

Table 14: Rhizome yield of ginger mutant lines from Umudike location

S/N	Clonal ID	Rhizome Yield (t/ha)
1	UG1-5-49	22.8
2	UG1-2-35	20.2
3	UG1-5-52	20.1
4	UG2-11-03	19.6
5	UG1-11-07	19.3
6	UG1-5-35	18.1
7	UG1-7-24	17.5
8	UG1-5-22	16.3
9	UG1-13-02	16.2
10	UG1-5-18	15.7
11	UG2-9-01	15.4
12	UG1-5-04	15.1

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Registration of Ginger Landraces in Nigeria

The team of ginger programme scientists led by Dr. Charles Amadi after due characterization, on-station, multi-location evaluation, and proximate analysis of ginger landraces, achieved a milestone through the official registration of two ginger landraces. These include UG1 which is the yellow ginger now officially registered as UMUGIN 1 (Figure 89) and UG2 (Figure 90) which is the black ginger now officially registered as UMUGIN 2 (Amadi *et al.,* 2021). Some general and specific descriptors of UMUGIN 1 and UMUGIN 2 are presented in Table 15. The nutritional quality and the oleoresin content of the ginger landraces are presented in Table 16.

Fig. 89: UMUGIN 1 cultivar showing the leaves, and robust rhizomes with yellow flesh colour

Fig. 90: UMUGIN 2 showing slightly drooping leaves, slender rhizomes, and a pale yellowish-grey rhizome flesh

Table 15: Some general and specific descriptors of UMUGIN 1 and UMUGIN 2

Descriptors	UMUGIN 1	UMUGIN 2
Plant growth habit:	Upright	Upright
Plant height:	60 – 100 cm	65 – 110 cm
Number of tillers:	4 – 10	4 – 10
Attitude of top leaf:	Erect	Erect with drooping tip
Number of leaves:	21 – 28	21 – 28
Leaf green colour intensity	Dark	Dark
Flowering	Flowers present	Flowers present
Rhizome skin colour	Light yellow	Pale grey
Rhizome flesh colour	light yellow	pale yellowish-grey
Rhizome skin surface	Smooth	Smooth
Anthocyanin colouration of apical bud	Strong	Strong
Number of primary rhizome fingers	3 – 8	4 – 8
Size of primary rhizome fingers	2.5 – 3.0 cm	2.0 -2.5cm
Adaptation	Rainforest, and Guinea Savannah	Rainforest, and Guinea Savannah
Days to maturity	260 - 275 days	265-275
Potential root yield	39 t/ha	30 t/ha
Pest/Disease reaction	Moderately resistant to yellow leaf spot	Moderately resistant to yellow leaf spot

Table 16: Percentage Composition and Oleoresin content of ginger (UG 1 and UG 2)

Composition (%)	UMUGIN 1	UMUGIN 2
Moisture Content	12.07	11.87
Crude Protein	8.04	7.94
Fat	0.65	0.71
Crude Fibre	6.86	7.00
Ash	3.94	3.71
CHO	68.42	68.78
Energy value (Kcal/100g)	311.87	313.26
Oleoresin content	6.55	7.02

With this official registration, farmers, seed companies, the National Seed Council, and ginger merchants including local and international can easily carry out business with ease. Perhaps this is also a great prospect for further ginger breeding in Nigeria.

Conclusion

The ginger research programme has done well in keeping with its mandate. Major achievements of the programme include; the development of good agronomic practices, the design, and fabrication of a ginger splitting machine, and the registration of two ginger landraces. Others include the development of more than 50 ginger mutant lines with all the necessary attributes for further breeding, and evaluation. In the near future, the programme is hopeful of releasing to farmers more varieties of ginger.

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CHAPTER 13

FARMING SYSTEMS RESEARCH PROGRAMME: ACHIEVEMENTS

13.1 Introduction

As of the early 1980s, a backlog of new technologies in Yam, Cassava, Sweetpotato, Potato, Cocoyam, Maize, Rice, Beans, etc., developed by commodity programmes of NRCRI and other research institutes in Nigeria existed but were not extensively utilized by farmers. These new technologies need to be tailored to the needs and capabilities of small-scale farmers in Nigeria in order to achieve accelerated food production.

The Board of Governors of National Root Crops Research Institute (NRCRI) Umudike in 1982 mandated the Agricultural Extension and Research Liaison Services (AERLS) of NRCRI to conduct a Benchmark survey of root and tuber crops based farming systems of Nigeria. Four Southeastern states; old Anambra, Cross River, Imo and Rivers States were selected to serve as pilot states for the survey. This benchmark revealed that farm production was limited by lack of capital and other production inputs, pests and disease attack and seasonal labour shortages resulting in high costs of labour, land preparation, late planting and inefficient weeding.

The objectives of establishing/creating the Farming Systems Research Programme were to;

i. Specifically, orient part of NRCRI research efforts towards benefiting resource-poor farmers by working with the farmers under their conditions.
ii. Identify major agricultural production constraints in the Southeast zone.
iii. Incorporate improved technologies from commodity Crops and Animal programmes of NRCRI and other research institutes in Nigeria into the traditional farming systems.
iv. Identify more efficient, economic and sustainable methods of managing farming systems by South East States.

How the Programme Operated

At the early stage of the formation of the programme, scientists worked in teams and collaborated among themselves and with extension agencies – Federal and States (e.g. Federal Department of Agriculture (FDA), Federal Agricultural Coordinating Unit (FACU), National Seed Service (NSS), National Agricultural and Food Production Programmes (NAFPP) and State Agricultural Development Programmes (ADP's). The teams also collaborated with other Research scientists from either the commodity Programmes of these Institutes or faculties of Agric of neighbouring Universities and the out-stations of sister Research Institutions within this agroecology to carry out the following activities:

i. Upstream (on-station) research to develop component technologies on farming systems.
ii. Downstream (on-farm) research to test prototype technologies on the farmers' fields and conditions in collaboration with the farmers.
iii. Diagnostics survey to identify agricultural production problems and opportunities
iv. Continuously update the technical know-how of extension personnel and scientists' knowledge about farmers' problems in response to technologies transferred.

The overall goal of this programme is to integrate the efforts of Research and Extension in the identification of major agricultural production constraints and to develop sustainable technically feasible, economically viable and socio-culturally acceptable alternative production technologies that meet the needs and capabilities of the resource-poor farmers without destroying the natural resource base of the Southeastern agro-ecological zone of Nigeria. The programme is concerned with the development of components technologies centred on the management of available resources such as soil, vegetation, fallow, crops, animals (including fishes), labour and material inputs like fertilizer and agrochemicals among others.

The upstream research is aimed at the development of alternative prototype technologies for further testing on-farm. For instance, in a crop combination of cassava/yam/maize-based multiple cropping management studies, the objectives are to:

a. Continue with the development of appropriate alternative management practices for optimum and sustainable cassava, and yam systems for the Southeast farming system research and extension zone of Nigeria.
b. Evaluate various improved crop varieties developed by the different commodity programmes of this institute and other national and international research agencies within and outside Nigeria for their compatibilities and increased productivity when grown or when intercropped.
c. Determine optimum planting densities arrangement and sequences for increased productivity of any crops found to be compatible in mixtures.

Justification

Yam/cassava/maize have been identified as the most common crop mixtures in the Southeast agricultural zone of Nigeria. Research and management had all along been based on the individual crops grown in monocultures. For the resource-poor farmers who invariably always grow these three crops in mixtures, there is a need to determine alternative optimum management practices for multiple cropping involving these crops, so as to maximize both the biological productivity of individual crops and the overall productivity of the systems.

Targets

i. To raise the biological productivity of the individual yam, cassava, and maize crops to the level of their respective crop yields.
ii. To increase the overall productivity of yam, cassava and maize by 50% per unit of land compared with the farmer's practices.

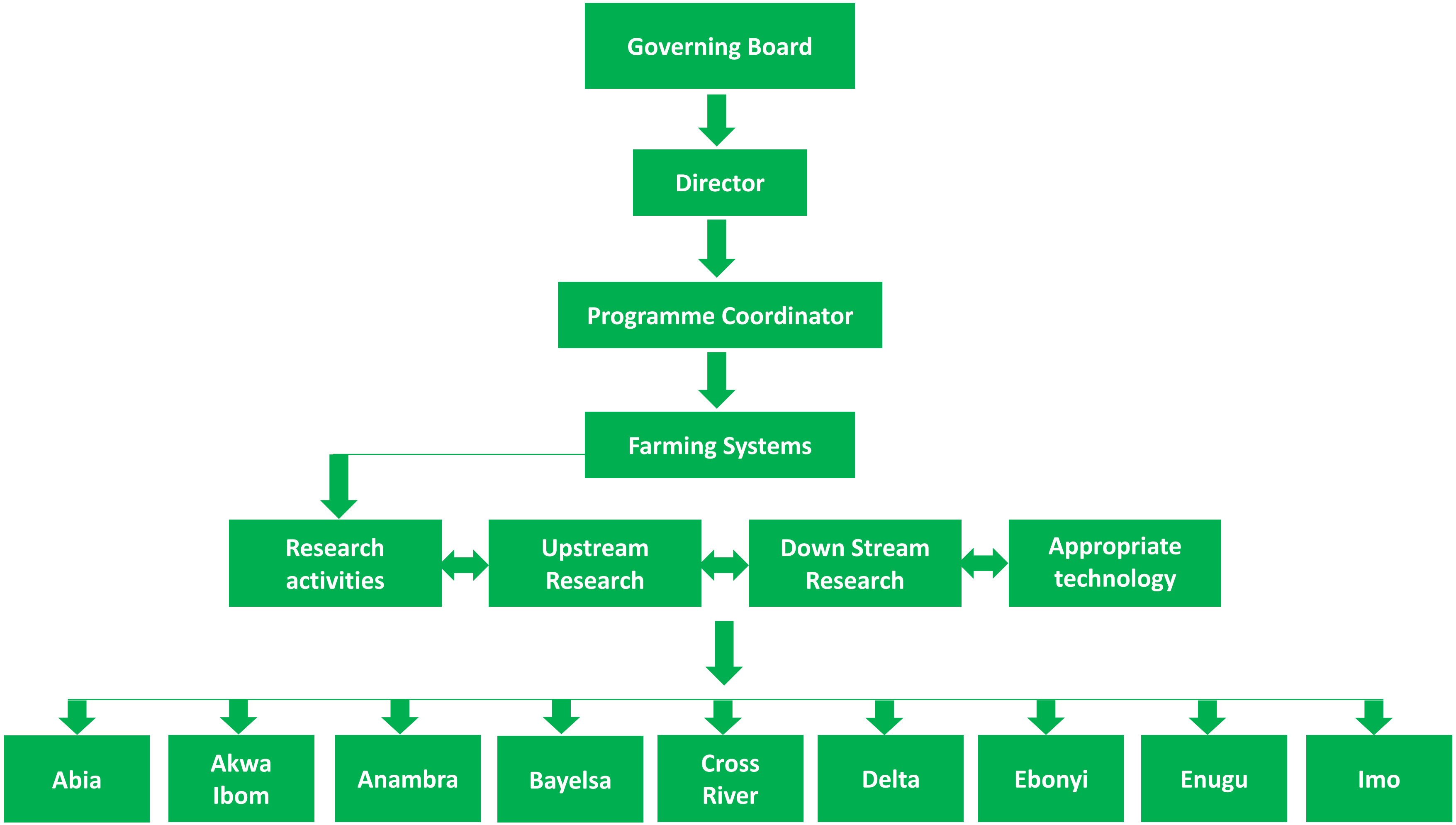

Fig. 91: Organogram showing the movement of technology from research to farmers in southeastern zone of Nigeria early 1980

13.2 Restructuring of Farming System Research and Extension Programme in NRCRI, Umudike

The Cropping system in the early 1980s gave birth to the Farming Systems Research and Extension Programme in NRCRI, Umudike. The cropping system was headed by the late Dr. S. O. Odurukwe. The first and major assignment to the Programme (FSRP) in 1982 was to conduct a Benchmark Diagnostic Survey of the farming systems of the Southeastern agricultural zone of Nigeria and the people majorly involved in this activity were Researchers and Superintendents of NRCRI. The survey gave an insight into the traditional farming system of Anambra, Cross River, Imo and River states and also it revealed information on the following areas; dominant crops, dominant crop mixtures, planting patterns, dominant livestock, methods of keeping livestock, role of livestock in the cropping system, labour distribution, pests and diseases problems and farmer's attitude and experience in the use of improved technologies. By July 9, 2003, the Farming System Research and Extension Programme was divided into two programmes;

Farming System Research Programme and **Extension Services Programme**, each with a Coordinator. The Farming Systems Research Programme was headed by Late Dr. A. Udealor, while the Extension Programme was headed by Dr. G. N. Asumugha. The aim of the division was to achieve greater efficiency. Extension Services Programme activities were to publish Research Bulletin, Extension leaflets and guides. There is a Liaison and Training Section, Subject Matter Specialist and News Media Sections.

Training

The Farming System Research and Extension Programme is involved in different forms of training at the zonal level and focuses on ADPs and farmer groups within and outside the zone. Training of groups within and outside the zone centred on Good Agronomic Practices (GAP) and Value Addition with respect to root and tuber crops of economic importance. These activities help the institute extend its technologies to farmers within the shortest possible time. Meetings/Training were held at the ADP level or NRCRI, Umudike. Research Extension Farmer-Input-Linkage System (REFILS), a collaborative linkage of Research, Farmers and Input supply agencies in a cost-effective manner, is aimed at rapidly increasing agricultural production and productivity of resource-poor and rural farmers

The stages in REFILS include:

- Target and Research Selection Area, Diagnosis, Planning/Execution – Upstream (On-Station Research) and Downstream (On-Farm Research). The Downstream could either be researcher-managed trials (On-Farm Research or On-Farm Adaptive Research). After the trials, Dissemination and Adoption which include Small Plot Adoption Techniques (SPATS), Field Days, etc., are follow-ups.

Monthly Technology Review Meeting (MTRM) is held at the ADP Headquarters, with NRCRI, Umudike Team Leaders coordinating in conjunction with Resource Persons which could be drawn from Institutions within the state or outside. Here, technologies are transferred to Subject Matters Specialists (SMS) from the ADPs of the different zones of the state.

Fortnightly Training (FNT) is held at the zonal level, involving the Zonal Manager, SMSs and Zonal Extension Officer (ZEOs) (Agents (E/As). The zonal SMSs and ZEO transfer the technologies received at the MTRM to the EAs, who in turn transfer the same to farmers during Block meetings.

The Joint Scientific Field Evaluation visit is carried out for the purpose of evaluating the performance of the ADPs in the implementation of Research and Extension activities of the ADPs proposed for that year. The areas of coverage are usually on the identification of strengths and weaknesses in various activities and field problems of farmers. The team for the field evaluation is made up of scientists from the coordinating research institute – NRCRI, Umudike, the nine State ADPs, FACU, and Enugu. The Joint Scientific Field Evaluation is held annually to ascertain field situations with respect to the establishment and management of OFR, OFAR, SPAT, Venues for FNT and MTRM, Women In Agriculture (WIA) components, etc.

The Steering Committee Meeting (SCM) is held quarterly at the coordinating research institute (NRCRI). The venue of the meeting is also rotated among the ADPs in the South East Zone. The members of SCM include the zonal coordinator of REFILS, who is the Chairman, Heads of Technical Services and extension Services, WIA of the ADPs, Input Supply Agencies, representatives of the Universities in the South East and Team Leaders of the ADPs from NRCRI. One of the team leaders acts as the Secretary. Research and Extension activities are discussed at the meeting and reviews are made.

The Technical Coordinating Committee Meeting (TCCM) is held twice a year. The venue of the meeting is rotated among NRCRI and the ADPs in South East. The members of the TCCM include the Executive Director of NRCRI, Programme Managers of the ADPs, representatives of the Universities in South East Zone, Input Agencies and the Zonal Coordinator of REFILS. The Executive Director is the Chairman, while the Zonal Coordinator of REFILS is the Secretary, TCCM is the apex policy-making body of REFILS.
Other meetings of importance are held as the need arises.

13.3 Team Leaders and Coordination of States

Team leaders were appointed by the Executive Director/Chief Executive of the Institute to oversee REFILS activities in ADPs of each mandate State. The mandate of the Team Leaders in their respective states was;

- Liaise between the institute and ADPs
- Ensure proper execution of REFILS activities which include;
    - On-Farm Adaptive Research (OFAR)
    - Monthly Technology Review Meetings (MTRM)
    - Field Visits
    - Diagnostic Surveys
- Act as the Chairman (representing the Executive Director) of the state REFILS Team and at the MTRMs.
- Facilitate selection of appropriate scientists as resource persons for MTRM topics, when necessary.
- Build and maintain *esprit de corps* of the state REFILS Team.
- Assist in the execution (establishment and analysis) of OFAR trials in the state of coordination.
- Participate in Zonal Steering Committee Meetings (SCMs).
- Collate (on a regular basis) farmers' production constraints and reactions to extended messages/technologies as feedback to research through the Zonal REFILS Coordinator.

13.4 Technologies Developed and Transferred

Technologies were developed based on the farmer's felt needs. These were transferred to the farmers to address gaps in the farming system. The National Farming System Research and Extension emphasized in addition to the crop-based cropping system, the inclusion of Livestock, Fishery and Women in Agriculture components. The major focus in the zone is an integrated farming system in which livestock and fisheries were included with crop-based farming activities. This system is believed to have the greatest potential for sustainable Third World Agriculture. The National Farming System Research Network involved an Ecological Diagnostic Survey of the existing farming system, improving on the same through research and extending research findings to farmers for increased productivity, higher profit margin and enhanced living standards of the rural populace. Increased agricultural productivity can only come through agricultural development which essentially means a continuous process of change of transformation of agriculture to increasingly satisfy demand. No nation can survive if it cannot provide the basic food needs of its citizens. The provision of such needs requires considerable investment in technology generation.

Some Technologies Extended to the ADPs in the Southeast Zone as of 1987

- Yam/Maize/Egusi/Vegetable/Cassava
- Early Maize/Egusi
- Plantain/Cocoyam/Telfaria
- Groundnut/Cassava
- Sweetpotato Sole
- Plantain Sole
- Cassava Sole
- Swamp Rice
- Upland Rice
- Cocoyam Sole
- Late Maize
- Cowpea/Soya Bean
- Yam Sole
- Cassava/Maize/Egusi/Telfaira
- Yam/Maize/Telfaria
- Cowpea Production
- Dry Season Vegetable production
- Maize Sole cropping
- Yam Miniset techniques of seed yam production
- Line Row planting
- Cocoyam/Maize intercrop
- Livestock keeping/rearing
- Fish Farming
- Yam/Maize/Egusi fb Cowpea+ Cassava
- Cassava/Late Maize/Cowpea cropping
- Yam/Maize/Cassava/Egusi intercrop
- Yam Miniset/Late Cowpea
- WIA activities on value addition, etc.
- Alternate row planting
- Seedbed preparation
- Correct plant spacing (Plant geometry)
- Optimum plant population
- Improved varieties
- Fertilizer application

- Rabbits as cheap source of animal protein
- Sheep and goat production
- Homestead fish production (Construction of concrete and eastern fish ponds)
- Agro-forestry – apiculture and snail farming
- Alley cropping

Some Reasons for non-acceptance of some of the technologies could be location-specific, as shown in the table below:

Technology	Reason for Non-Acceptance
Cassava at 1mx1m spacing	Too wide and low population Spacing too small for the size of the mounds, especially in the flooded areas
Late Maize/Cassava/Cowpea	Cassava components not adopted become cultivatable land is scarce. Cassava ties up the land for the next cropping year
Late Maize/Cowpea	High risk of crop loss due to pests of late maize and cowpea Competition with rice for land and labour
Improved Cassava varieties	Preference for short-duration varieties that could be harvested June – July to give way for other crops e.g. rice in shallow swamps Demand for varieties that mature earlier
Line or Row Planting	Too time consuming
Mound making inline	Higher labour cost
Cassava/Maize/Egusi	Preference is for groundnut in place of Egusi
Yam Miniset	Yams too small for the market

The greatest constraint to the operation of REFILS is the lack of adequate backup research technologies to generate the needed recommendations for onward transfer to farmers.

CHAPTER 14

POTATO RESEARCH PROGRAMME: ACHIEVEMENTS

14.1 Introduction

Potato Programme is one of the sub-stations of the National Root Crop Research Institute Umudike, Abia State. The sub-station as the name implies is in charge of Potato (Potato Irish) research and some other minor root crops. The Potato Research Programme based at Kuru, Jos South of Plateau state was established in the year 1975 and took off in 1976. The aim was to mark the beginning of the rapid expansion of potato production and research in Nigeria. The station was established under the leadership of Dr. B. E. Onochie (Director, NRCRI) whose focus was to address the problems of climatic adaptation of the crop (Potato). Low tuber yields and inadequacy in the supply of the potato crop to Nigerians. Before the establishment of the station at Kuru, Potato varietal trials were already going on at Ta-Hos in Riom Local Government, Saminaka and Zaria in Kaduna State, which was sponsored by the Institute of Agricultural Research, Samaru, Zaria with a Canadian officer, Mr Suchomel in 1967.

On the establishment of the Potato Program Research Station, Mr Suchomel was later employed by the National Root Crop Research Institute, Umudike to primarily develop the station to standard, the reason being that the station did not have offices and residential structures at that time. Later, temporary offices and residential accommodation were provided by our neighbouring Institute, the National Veterinary Research Institute, Vom, Plateau State. Two bungalow buildings were donated by the Ministry of Agriculture to accommodate some of the senior staff. Then, the land was acquired at the Kuru by the headquarters (NRCRI, Umudike), which was developed to provide both offices and residential accommodation in 1977. The major aim was accommodating the pioneer researcher and other staff at that time.
The station is charged with some mandates but not limited to:

- To research on genetic improvement of potato
- Training of farmers and other stakeholders on research activities
- Expanding the production of potato production in Nigeria, etc.,

The station is headed by a coordinator and assisted by a senior researcher, followed by the accountant who helps with the accounts section, while the head of administration heads the administrative section.
The following are the research and other units of the Potato Programme Research Station at Kuru. They include Breeding, Agronomy, Entomology, Pathology laboratory

and Farm mechanization. Other non-research units are Accounts, Administrative, Security, Argomet and Library.

Fig. 92: Potato Research Programme, Kuru, Jos

The Potato Programme of NRCRI is one of the most successful Potato Research Programmes in Africa. Since its inception in 1975, the programme has made significant achievements in research, leading to increased potato production, improved food security, and increased income for farmers in Nigeria and other parts of the world. The NRCRI Potato Programme has achieved these successes through a combination and collaboration of research, development, and extension activities. The programme has developed improved potato varieties, agronomic practices, and storage and processing technologies. The programme has also trained farmers and extension agents on potato production and management. Some of the milestone research achievements of the potato programme of NRCRI can be summarized as follows:

1. **Development of improved potato varieties that are resistant to diseases and pests that are high yields, and are suitable for different agroecological zones in Nigeria, including Plateau, Kano, Kaduna, Obudu and Mambila.**
   NRCRI has, through the Potato Programme registered and released over 8 improved potato varieties since its inception. These varieties have been developed through a rigorous breeding program by CIP and evaluated in Nigeria by NRCRI, taking into account the needs of farmers and the challenges of potato production in Nigeria. The varieties released by the NRCRI through the Potato Programme have been shown to be resistant to a variety of diseases and pests, including late blight, the most serious disease of potatoes, and tuber moths. They also have high yields, making them a valuable option for the farmers growing potatoes anywhere in Nigeria.

2. **The Programme has developed new planting methods, fertilizer application rates, and irrigation scheduling that have helped to increase potato yields.**
The NRCRI Potato Programme has conducted research on the best planting methods, fertilizer application rates, and irrigation scheduling for potatoes in Nigeria. The research led to the development of recommendations that have helped farmers to increase their potato yields. For example, the NRCRI Potato Programme has recommended that potatoes be planted in ridges to improve drainage and aeration. The Programme has also recommended that farmers apply fertilizers at the recommended rates to ensure that their potatoes have the nutrients they need to grow.

3. **Development of training manuals for farmers and extension agents on potato production and management**
The Potato Programme has developed training manuals for farmers and extension agents on potato production and management. These manuals have helped to improve the knowledge and skills of farmers, making them more likely to adopt improved potato production practices. The Potato Programme has also trained extension agents, who are responsible for disseminating the programme's research findings to farmers.

4. **Promotion of the development of a potato value chain, including the development of storage and processing facilities, as well as the promotion of potato exports.**
The Potato Programme has promoted the development of a potato value chain in Nigeria. This includes the development of storage and processing facilities in Nigeria. The Potato Programme has helped to establish a number of storage and processing facilities in Nigeria, making it easier for farmers to store and process their potatoes. The establishment of the facilities was mainly sponsored by the Federal Ministry of Agriculture and Rural Development (FMARD). The Programme has also researched into the export promotion of potatoes and potato products, such as chips and french fries although much success has not been recorded in the area.

5. **Recent registration and release of four varieties of potato for commercial use in Nigeria 2023.**
Potatoes are the third most important and consumed crop globally, outperforming most other major food crops in terms of energy and protein production per unit area and unit of time. They are also rich in several micronutrients, including vitamin C, iron, vitamins B1, B3, and b6, and minerals. The average potato yield (3.7ha^{t-1}) in Nigeria is significantly lower than the crop's potential and to address this, the Potato Programme of NRCRI Umudike, in collaboration with CIP, released 4 improved potato varieties in 2023 in addition to the already existing ones.

Fig. 93: Kyau variety

The variety Kyau (Fig. 93), matures at 120 days after planting with a potential tuber yield of 44.3t/ha, Resistant to late blight. The nutrient contents include a dry matter of 29.5%, starch content of 25.3%, fibre of 0.8%, protein of 6.0%, and Vitamin C 78.1 mg/100g.

Fig. 94: Babban variety

The variety Babban, (Fig. 94) matures at 120 days after planting with a potential tuber yield of 45.3t/ha, Resistant to late blight and PVX. Its outstanding characteristics include High dry matter, high yielding and large tubers. The nutrient contents include a dry matter of 27.9%, starch content 26.1%, fibre 0.9%, protein 5.7%, and Vitamin C 52.2 mg/100g.

Fig. 95: Juriya

Variety Juriya (Fig. 95), matures at 120 days after planting with a potential tuber yield of 45.3t/ha, Resistant to late blight, PVY and PVX. Its outstanding characteristics include High dry matter, high yielding and large tubers. The nutrient contents include a dry matter of 30.4%, starch content 35.9%, fibre 0.9%, protein 4.0%, and Vitamin C 52.4 mg/100g.

Fig. 96: Unica variety

Variety Unica (Fig. 96), is an early maturing variety that matures 90 days after planting with a potential tuber yield of 44.3t/ha, resistant to late blight, PVY and PVX. Its outstanding characteristics include High dry matter, high yield, and versatility across many ecologies and heat tolerance. The nutrient contents include a dry matter of 20.9%, starch content of 21.5%, fibre of 0.8%, protein of 4.4%, and Vitamin C 52.3 mg/100g.

The research achievements of the Potato Programme have had a significant impact on the potato industry in Nigeria. The Programme has helped to increase potato production, improve the quality of potato products, and reduce the cost of potato production. The programme has also helped to create jobs and boost the economy of Nigeria through the expansion of potato production.

The Potato Programme of NRCRI is a model for other countries that are looking to develop their potato industries. The programme has demonstrated that it is possible to achieve significant success in potato research through a combination and collaboration of research, development, and extension activities.

CHAPTER 15

EXTENSION SERVICES RESEARCH PROGRAMME: ACHIEVEMENTS

15.1 Introduction

The Agricultural Extension Research and Liaison Services (AERLS), which later became the Extension Services Programme, was initially established to collaborate with the National Agricultural Extension Research and Liaison Services (NAERLS) in disseminating agricultural technologies in partnership with the Agricultural Development Programs (ADPs) under the Research Extension Farmers Input Linkage System (REFILS). AERLS (Agricultural Extension Research and Liaison Services) played a significant role in shaping socio-economic patterns. Over time, it was integrated with extension services to form the Agricultural System and Extension Research Department (ASERD). As funding became available, the institution was responsible for assigning duties to various programs, and many staff members were deployed to the field as field staff. REFILS aimed to transfer technologies developed and validated at the National Root Crops Research Institute (NRCRI) through monthly training review meetings (MTRMs) and fortnightly trainings (FNTs) attended by the Director Technical Services, Director Extension, and Subject Matter Specialists (SMSs) from the ADPs. Dr. H.E. Okereke was in charge during this period. At that time, there was no organized farming system, and the focus was primarily on subject matter specialist programs (SMSP), liaison and training activities. Liaison and training involved validating research results, while printing and news coverage were handled by the subject-matter expert program. The Agricultural Extension Research and Liaison Services functioned as the main division, eventually transitioning into a department. Dr. Emezue Eneh served as the Director, alongside notable scientists such as Drs. Enyinnia, Nnayereugo Eze and Godwin Asumugha. With the advent of World Bank support in 1996 through the National Agricultural Research Project (NARP), the REFILS program gained prominence. Late Dr. Ray Unanma coordinated REFILS in the South-East Agricultural Zone of Nigeria, funded through NARP and involving Farming.

15.2 Systems Research and Extension activities

However, when the World Bank exited in 1997, the Agricultural Development Programs (ADPs) could not sustain the momentum, leading to a decline in the impact of technology transfer to resource-poor farmers in different zones, blocks, and circles. During this period, the Extension Services Programme at the National Root Crops Research Institute (NRCRI) stepped up the responsibility to transfer technologies related to the institute's mandate crops, and other extension activities were carried out under the leadership of Dr. T.O. Ezulike, the Director of Farming Systems Research and Extension in 2004 with Dr. A. Udealor assisting him while Dr G.N Asumugha anchored as the Coordinator of Extension Services programme. The Extension Services Programme employed various strategies to sustain extension activities within the institute, including the establishment of demonstration farms, ad hoc training, and utilizing print and electronic media for information dissemination. Dr. Mrs. L.E.F. Amamgbo oversaw liaison and training activities, while the Media and Publicity unit, led by Mr. Eugene Ekedo at that time, and handled news coverage. Additionally, field days and exhibitions were organized to showcase technologies, and impact assessments were conducted to evaluate the effectiveness of the research activities. In 2012, the Extension Services Programme became a part of the West African Agricultural Productivity Programme (WAAPP) coordinated by Dr. G.N. Asumugha while Dr, Mrs. H.N. Anyaegbunam served as the Monitoring and Evaluation officer of the Programme. This program, supported by the World Bank and coordinated by the Agricultural Research Council of Nigeria (ARCN), focused on disseminating agricultural information to farmers through training, in adopted villages and students through Agricultural Research and Outreach Centers (AROCs).

The program covered Abia, Imo, Anambra, and Benue States. Recently, the Agricultural Research Council of Nigeria (ARCN) reorganized the departments and programs within the NRCRI. The former Farming System Research and Extension (FSR&E) Division was renamed the Research Outreach Department (ROD), but the activities and functions of the Extension Services Programme remained the same. The Extension Services Programme is currently anchored on activities such as radio and television farm broadcasts, print media dissemination, establishment of demonstration plots, adoption and impact assessment of technologies, and ad hoc training to enhance agricultural production and post-harvest practices.

Specifically, the programme is anchored on the following activities:

a. Production of radio/television farm broadcasts with major electronic media in the South East Nigeria as well as the National Media House for the dissemination of institutes activities and technologies.
b. Promotion and dissemination of the institute’s new research findings through print media such as newspaper, magazines as well as the institute’s owned news bulletin and guides.
c. Establishment and use of demonstration plots with improved production practices to showcase prototype on farm evidence of various technologies developed by the institute for teaching myriads of students, farmers and other visitors that visit the institute.
d. Adoption and impact assessment of NRCRI dissemination technologies.
e. Dissemination and popularization of improved root and tuber crops’ production and post-harvest technologies (value additions) through ad-hoc training of adopted villages/schools outreaches, out-grower scheme and other stakeholders.

15.2 Strategies for Achieving Extension Mandate

To accomplish its mandate, the program employs the following strategies:

1. **Training**

   Training activities are organized for farmers, processors ADP staff, women and youths on good agronomic practices and value addition to all our mandate crops. This involves:

a) Establishment of demonstration farm and Guided Tours

Fig. 98: Turmeric section of the demonstration farm

Fig. 97: Interview with BCA TV crew at the demonstration farm

Fig. 99: Students on Excursion visit to the Demonstration farm

Fig. 100: Monitoring Exercise at the Demo Farm

b) Exhibitions, Agricultural shows and Value Addition Training

The Women-In-Agriculture (WIA) unit of the Extension program has played a pivotal role in significantly enhancing the technical skills of ADP staff, farmers, women, processors, and youths across Nigeria. This is achieved through training programs focused on good agronomic practices, and value addition to root and tuber crops. In addition to the training initiatives, the unit participates in key agricultural events such as Agricultural Shows, Field Days, and Trade Fairs. By showcasing NRCRI technologies during these events, the unit further engages stakeholders and highlights the advancements made in the agricultural sector. Some of the training conducted and achievements made by the WIA Unit include;

Training on Good Agronomic Practices/post-harvest technologies (Value addition) to end-users on the mandate crops.

1. Training of Agricultural Development Programme Abia State (ADP) staff, 2004.
2. Training conducted for rural women in Abatete, Anambra State, 2005.
3. Training organized for Idea Builder (NGO) at Arochukwu, 2005.

4. Training of 1498 farmers group in Abia State, 2005.
5. Training of 2303 farmers in the South-east and South-south states- Abia, Enugu, Delta and Akwa Ibom state, 2006.
6. Training of 300 AGIP farmers (male and female) from Rivers, Bayelsa, Imo and Delta States, 2008.
7. Training of unemployed youths, 50 each from Ebonyi and Imo States, 2008.
8. Training of Kolping Staff (NGO), 2009
9. Training of 200 women and youths in NRCRI, Umudike Host Communities, 2009.
10. Training of 1100 farmers, women and youths in four states (Enugu, Rivers, Imo and Abia) of Southeast and South-south, 2012.
11. Training of 120 women and youths in the six NRCRI, Umudike Host Communities (Amawom, Amaoba-ime, Umuariaga, Umudike-Ukwu, Umuoparaozara and Itu Olokoro, 2019). This training attracted the First Lady of Abia State
12. Training of 50 youths at WIA Unit, NRCRI 2019 among others.
    Extension Programme through the Woinn in Agriculture unit (WIA) participates in Instructional television and radio training. The radio and television trainings include:
    a. Instructional TV and Radio WIA value-addition training, 2009 (BCA and NTA, Umuahia)
    b. WIA training on value addition (BCA and pacesetter), 2009.
    c. *Ndewonu ndi oru ubi*, a radio training aired by Vision Africa–104.1 FM in 2010. Trainings were conducted on *otu esi emeputa ntu- achicha ji beke na starch bekee, etu esi eji ntu ji-bekee na starch bekee wee meputa achicha, and etu esi emeputa stipsna doughnut ji bekee*
    d. How to make High Quality Cassava Flour (Pacesetter, 2010)
    e. Ginger drink production, 2010 (Vision Africa, 104.1 FM)

c) Agricultural Shows, Field Days and Trade Fairs

Agricultural Shows, Field Days and Trade Fairs are opportunities for the Extension programme to display NRCRI value- addition technologies in Nigeria. The programme has led the institute to victory in two occasions. NRCRI exhibitions have attracted dignitaries including Ministers, Traditional Rulers, and a host of others.

a. Royal Agric. Show, Stoneleigh, England (WIA produced the items exhibited by the then Executive Director, Late Dr Kenneth Nwosu at Stoneleigh, 2005.
b. Abia Cropping season NRCRI won the first prize in the exhibition, 2005.
c. Raw material exhibition, Umuahia, 2005.
d. Imo cropping season, 2005
e. Agro-enhancement Exhibition, Abuja, 2005.
f. World Food Day and Agric Show. Abuja 2022. NRCRI Team emerged second
g. The 45th regular meeting of the National Council on Agriculture, 2022

Fig. 101: Training of women in NRCRI Host communities

Fig. 102: Executive Director Dr. J.C. Okonkwo addressing Participants during the training of host Communities

Fig. 103: Dr. Helen Anyaegbunam taking the participants on Sweetpotato

Fig. 104: Dr Mrs. C. Aniedu teaching the participants on value-addition in one of the practical sessions

2. Production of information materials and training aids

The extension program undertakes the collation and compilation of the institute's research findings and publishes them in a simplified language in the form manuals, extension guides, extension bulletins and newsletters.

Fig. 105: Array of extension guides produced by Extension program

3. General publicity

Fig. 106: NRCRI Staff during the 2022 External Annual Research Review Workshop

The Extension program is responsible for promoting the institute and its activities to the public. This encompasses a range of efforts, including the creation of agricultural programs for radio and television, public addresses coverage, disseminating general information, documenting various activities, and managing the NRCRI's social media network and website.

Fig. 107: NRCRI Socialmedia Platforms

4. Adopted villages and outreach schools

The efforts to reach farmers with available technologies in root and tuber crops and to arouse the interest of secondary school students in agriculture as a worthwhile discipline led to the creation of the adopted villages and outreach schools unit of the program. This is achieved through establishment of demo farms, supply of materials to the schools and establishment of agricultural research outreach centres (AROCs).

15.3 Other Achievements of Extension Services Programme

After 100 years, Extension services program has made a lot of progress in achieving her mandates. Some of these achievements include

- Development and revision of over 50 extension guides and leaflets on several subject matters in root and tuber crops.
- Annual Establishment of demonstration farm on improved root/tuber crops varieties
- Demonstration of improved production technologies such as yam miniset technique, yam staking methods, good agronomic practices on cassava, sweet potato, cocoyam, ginger and turmeric to host communities and other stake holders.
- Training of well over 100,000 visitors including students on various aspects of root and tuber crops production.
- Provision of relevant agricultural market information on root and tuber commodities to farmers and other end users – price, inputs, market etc.
- Numerous research findings on diverse socio-economic issues associated with impacts, livelihoods and gender studies, economic and marketing of root and tuber commodities as well as farmers' awareness adoption and diffusion of root/tuber crop technologies.
- Production of NRCRI, Newsletters, twice every year for the past decades, these include; NRCRI Bulletin, more than 20 volumes have been published.
- Promotion of NRCRI activities through Radio and television channels in Nigeria like NTA, Channel TV, Vision Africa, Pacesetter, NRCRI programme in BCA, "The Farming World" and "Agriculture Today". Aired by BCA radio every Saturday at 7.40 pm and Television every second and last Monday of the month at 10.30 am. Over 50 million farmers have been reached through mass media.
- Promotion of NRCRI activities through the internet. Over fifty million people have been reached the Unit, with agricultural information through internet and social media networks such as face book, linked-in, Twitter, you-tube and website.
- The Programme helps in the Documentary of NRCRI activities and achievements in the past decades under News media unit
- Coverage of NRCRI Community activities such as seminars, workshops, conferences and other events as the occasion arises.
- Training of over 10,000 women and youths on value addition to root and tuber crops.
- Between 2009 and 2015, NRCRI/ WAAP funded adopted village and outreach school project adopted 9 villages across Abia (4), Imo (2), Anambra (2) and Benue (1) and 13 schools as AROCs in Abia (5), Imo (3), Anambra (3), Benue (1) and FCT (1). The schools in the AROCs were equipped with agricultural bulletins, guides, CDs, televisions, Videos, computers, generators, textbooks, bookshelves and other information materials.
- In 2021, the institute adopted two communities and schools respectively. These schools were equipped with agricultural bulletins, guides, generator, plastic chairs and tables while demonstration farms were established in the adopted communities.

Fig. 108: Training of Women and youths in NRCRI, Umudike Host Communities

Fig. 109: Presentation of Plaque won by the Institute to the Executive Director Prof. Chiedozie Egesi (World Food Day and Agric Show. Abuja 2022. NRCRI Team emerged second)

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