A REVIEW COCOYAM BREEDING IN NIGERIA: ACHIEVEMENTS, CHALLENGES AND PROSPECTS

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ABSTRACT

This paper presents the status of cocoyam breeding in Nigeria highlighting the achievements, challenges and prospects. Modest achievements have been made in evaluation of land races for yield and suitability for target products; flowering and mutation induction studies; and micropropagation. The challenges posed by lack of gene introgression due to lack of sexual propagation; the narrow genetic base of the local population; and the scourge of TLB and CRRBC were highlighted. Introduction and adaptive trialling of newly acquired exotic cultivars of *Colocasia esculenta* to identify and select genotypes that will be suitable for local production is suggested as a quick means of addressing the problem narrow genetic base and TLB and consequently increasing local production. A vibrant cocoyam rebirth initiative recently launched by NRCRI Umudike is helping to create awareness and interest in cocoyam research and production in Nigeria. However the perennial problem of poor funding must be addressed for enhanced research and production of cocoyam.

Key words: Cocoyam, Colocasia, Xanthosoma, Breeding

INTRODUCTION

Cocoyam in Nigeria refers to two edible aroid species namely *Colocasia esculenta*(L.)Schott (Taro) and *Xanthosoma mafaffa* (Tania). They are perennial, plants grown as annuals. *C. esculenta* is reputed to be the oldest cultivated plant is the world (Brown, 2000). *C esculenta* is believed to have originated in South East Asia (Purseglove, 1972) while *Xanthosoma* is believed to have originated in the American tropics (Hernando and Leon, 1994). It was introduced into West Africa around 1840 (Doku, 1980). In Nigeria, *C. esculenta* first became established as a staple in the South East followed much later by *Xanthosama* (Ezedinma, 1987) while *Xanthosoma* is the main cocoyam grown in the South West (Onwueme, 1987).

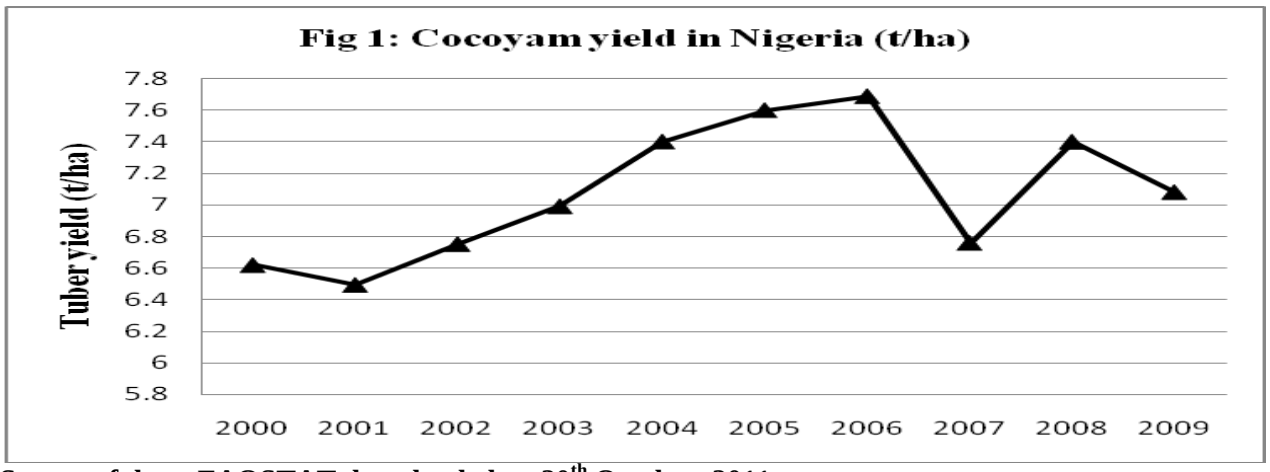
Nigeria is the largest producer of cocoyam (Taro) in the world with estimated annual production of 4.46 million metric tons as at 2009 (FAO, 2009). The cultivation of cocoyam in Nigeria is essentially by small scale resource poor farmers mostly women (Ikwelle *et al*., 2003). The production of cocoyams had stagnated and even began to in the last few years (Figs 1-3) due to several production constraints, among which are neglect, narrow genetic base, low input, scarcity of planting materials, and various pre- and post-harvest biotic challenges, including the Cocoyam Root Rot Blight Complex (CRRBC), and Taro leaf blight (TLB). Declining yields discouraged production as many farmers opted for other crops.

There are 3 cultivars of *Xanthosoma* and 10 cultivars of *Colocasia* mostly land races grown in Nigeria. This limited number of accessions and the resulting narrow genetic base may partly be responsible for the yield stagnation being experienced in recent years. Effort to develop new varieties by conventional means is hampered by poor, erratic flowering and lack of seed set by the local cultivars. Many cultivated aroids have been propagated vegetatively for so long that they have lost their ability to reproduce sexually (Coursey, 1968).

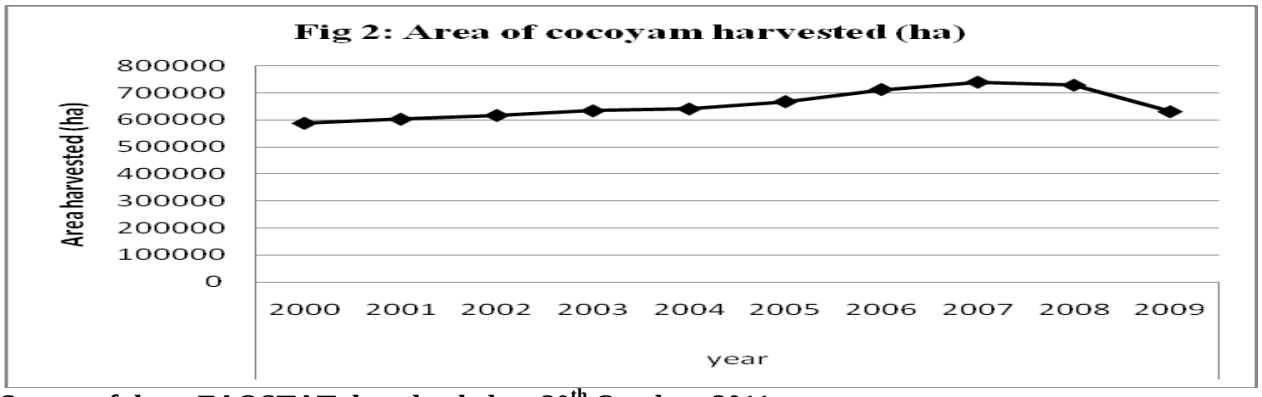
However, certain cocoyam cultivars are reported to flower and set seed naturally in Asia and Pacific regions. Many have been induced to flower and set seed. The technology for cocoyam production from true seed is in

use in the Pacific and is currently being disseminated to cocoyam producing nations through an EU-sponsored International Network for Edible Aroids (INEA) project. Nigeria is a partner in this project and is expected to benefit from this technology that has potential to revolutionize cocoyam improvement strategy.

The overall objective of cocoyam breeding at National Root Crops Research Institute (NRCRI) Umudike Nigeria is to develop high yielding disease and pest resistant genotypes with acceptable culinary and industrial qualities. This paper reviews cocoyam breeding research at NRCRI and highlights achievements, challenges and future prospects.



Source of data: FAOSTAT downloaded on 20th October, 2011



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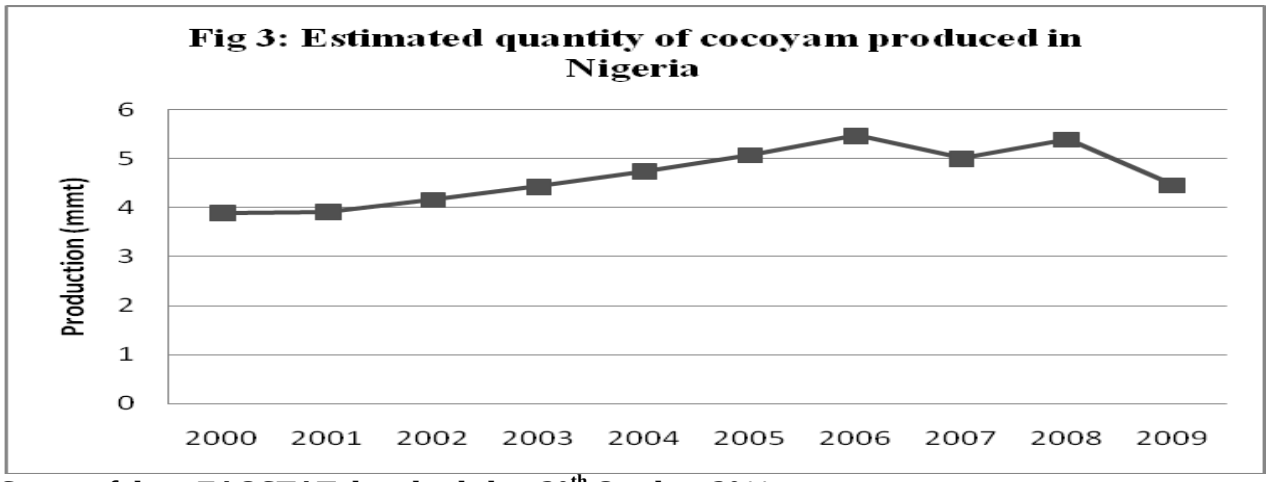

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ACHIEVEMENTS

Germplasm Collection and Classification

Comstock and Robinson, (1952), listed 3 major stages in plant breeding as: 1. Finding or developing populations from which selection can be made, 2. Selection, and 3. the use of selection in commercial production. Cocoyam improvement studies at NRCRI commenced in 1972 and by 1976 a collection of 94 accessions were assembled to provide a broad genetic base for breeding (Arene and Ene, 1987).

Table 1: Colocasia and Xanthosoma Cultivars in the Nigerian Cocoyam germplasm

Accession Number	*Local Name
Colocasia esculenta	
NCe 001	Cocondiya
NCe 002	Ede ofe green
NCe 003	Ede ofe purple
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 Okokoroko
NXs 004	Hybrid

***Local names are variable depending on the locality.**

Twenty two of these accessions belonged to 3 main groups of *Xanthosoma* locally called "Okorokoro" (yellow tuber flesh), "ede ocha" (white tuber flesh), and "ede uhie" (pink tuber flesh). The remaining 72 accessions belonged to 3 groups of *Colocasia* sp 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. 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). Currently there are 11 *Colocasia* and 4 *Xanthosoma* cultivars in the Nigerian cocoyam germplasm (Table 1). 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

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: Cocondiya (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 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 land races of *C. esculenta* and *X. mafaffa* to determine their adaptability to selected agro-ecological zones have been carried out. Results reported by Mbanaso, *et al*., (2004) indicated that *Colocasia* cultivar NCe 001 gave the highest yield across the locations. Findings of earlier evaluation of the land races for suitability for target value added products are summarised in Table 2.

Table 2: Evaluation of cocoyam landraces for suitability for target value added products

Landrace	Target product	Source
Colocasia esculenta		
NCe 001		
NCe002		
Mgbidicameroon	Cocoyam flour (soup thickener)	Ijeoma, (1983)
T3-185-70/307		
Nimbo		
Akupe		
NCe001	Cocoyam chips	
NCe001	Cocoyam frizzies	Mbanaso, (1986)
NCe001	Cocoyam fries	
Xanthosoma mafaffa		
NXs001	Cocoyam chips	
NXs001	Cocoyam frizzies	
NXs001	Cocoyam fries	
NXs002	Cocoyam chips	Mbanaso, (1986)
NXs002	Cocoyam frizzies	
NXs002	Cocoyam fries	

Flowering and fruiting studies

Flowering in most local Nigerian cocoyam cultivars is infrequent and fruiting and seed setting under natural conditions have not been reported. Studies at NRCRI Umudike, showed that flowering was improved by application of gibberellic acid, N-fertilization and sett-size (NRCRI, 1982, Mbanaso *et al.,* 2005a). Application of gibberellic acid (GA3) at concentrations of 1000-1500 ppm induced flowering and fruiting in

cultivars of *Colocasia esculenta* and *Xanthosoma sagittifolium* although profuse and prolonged flowering was optimum with 2000 ppm GA3 (Mbanaso *et al.*,2005a). Recycling of GA3 treated cocoyam material did not induce flowering and fruiting in subsequent years (Mbanaso *et al*., 2006a). Three methods of application of GA3 to induce flowering in cocoyam have been outlined (Alvarez and Hahn, 1986, Onwueme, 1999). These include treating field plants grown from corms and cormels with 1,500ppm at the 3-5 leaf stage; application of 1,000 ppm GA3 at 1-2 leaf stage for plants multiplied in a seedbed and leaving taro in the field at the end of the growing season and then treating the first leaves that emerge at the onset of the next rainy season. Treated plants produce normal flowers 2-4 months after treatment. IITA (1978) reported that cocoyams flower under conditions of high fertility and undisturbed growth. However studies at NRCRI Umudike showed that some *Colocasia* and *Xanthosoma* cultivars subjected to high fertility and undisturbed growth conditions for 2 years failed to flower naturally (Mbanaso *et al*., 2005a).

Mutation studies

The first step in mutation induction by gamma radiation for in vivo studies is to establish sensitivity, LD_{50} 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. A radiosensitivity assay showed that 4 to 6 Gy is the required dose to induce 30% growth reduction (GR_{30}) in the irradiated *in vitro* grown apices of *Xanthosoma sagittifolium* (Saborio *et al*., 2004). Blay et al, (2004) using LD_{30} as the cut off, suggested that since buds tolerated the 10 and 15 Gy doses reasonably well, these doses could, therefore, be used to irradiate large numbers of buds to induce mutations in *Xanthosoma sagittifolium.* Sukamto, (2004) showed that for *Colocasia esculenta,* LD_{30} was achieved at a dose of about 10 Gy and obtained from the resulting variants 3 promising lines with early maturity, tolerance to leaf blight and with non acrid taste.

Biotechnological approaches

Tissue culture a tool in biotechnology provides a very rapid and phytosanitary method of multiplying planting materials. Micropropagation of cocoyams have been going on for years at NRCRI Umudike to produce clean planting materials of elite cultivars. Recently, meristem explants are 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. In Papua New Guinea, successful rescue of embryo's from *C. esculenta* via tissue culture encouraged the initiation of a breeding programme involving the hybridization of exotic and local cultivars to develop new cultivars of taro (Wagih, 1994).

CHALLENGES AND PROSPECTS

Major challenges in cocoyam improvement in Nigeria are narrow genetic base, biological complexity of the crop, limited infrastructure and poor funding of cocoyam research and apathy (lack of interest in cocoyam research and production). The genetic base of cocoyam in Nigeria is limited to 10 cultivars of *Colocasia* and 4 cultivars of *Xanthosoma*. The need to broaden the genetic base of Cocoyam in Nigeria has been stressed by many authors (NRCRI, 1987; Chukwu *et al*., 2011; Onyeka, 2011). This can be achieved by introduction, collection and development of new cultivars. A significant step in this direction is the receipt of 50 exotic *Colocasia* cultivars (Tables 3 and 4) in 2 batches of 25 genotypes each in August, and October, 2011 from EU-INEA Aroid Network Project sponsored by European Union. Many of these genotypes are acclaimed to have good culinary qualities and are tolerant to Taro Leaf Blight currently ravaging cocoyams in Nigeria.

Erratic flowering and lack of fruiting and seed sett by the local *Colocasia* and *Xanthosoma* cultivars remain a major impediment to the development of an efficient breeding programme for cocoyam in Nigeria. Though the use of GA3 has greatly enabled the successful induction of flowering in many local cultivars, successful hybridization, fruiting and seed sett has not been achieved. It may well be that the local cultivars

are recalcitrant in which case the receipt of new cultivars from INEA will provide other options for local breeders. The technology for effective hybridization, production of True Taro Seeds (TTS), germination and management of True Seed derived Cocoyam seedling are currently in use in the pacific. The adoption and adaptation of this technology to our local conditions currently being encouraged by the EU sponsored Taro Project, will enhance the development of new improved cultivars of Cocoyam in Nigeria.

The biotechnology programme at NRCRI Umudike is being strengthened through the procurement of new equipments and manpower development to play a critical role in Cocoyam improvement especially multiplication of clean planting materials of newly acquired and local cultivars.

Funding of cocoyam research has never been accorded a priority in Nigeria. This must change if we are to effectively tackle the epidemic of Taro leaf blight and the endemic Cocoyam Root Rot Blight Complex which are currently the two major biotic constraints to cocoyam production in Nigeria. Unfortunately Cocoyam is again missing from the priority list of crops to be supported under the Agricultural Transformation Agenda of the present Nigerian Government. The launching of a cocoyam rebirth initiative by NRCRI Umudike in 2007 (Chukwu *et al*., 2011) has opened up new prospects in cocoyam research. This has reinvigorated interest of scientists and removed apathy.

Table 3: Exotic varieties of cocoyam introduced into Nigeria in 2011(Batch 1)

CEPACT CO	VARIETY	ORIGIN	Col Type	TLB Susceptibil	Taste
BL/HW/08	PE x PH15-6	Hawaii	Breeders' line	Tolerant	Not edible
BL/HW/26	BC99-11	Hawaii	Breeders' line	Tolerant	Very good
BL/HW/37	Pa'akala	Hawaii	Breeders' line	Tolerant	Very good
CE/IND/08	IND 178	Indonesia	TANSAO core	Susceptible	Good
CE/IND/19	Hejo	Indonesia	TANSAO core	Tolerant	Very good
CE/MAL/12	Klang	Malaysia	TANSAO core	Resistant	Very good
CE/MAL/14	Kluang	Malaysia	TANSAO core	Resistant	Poor
BL/PNG/03	C2-E3	Papua N Guinea	Breeders' line	Resistant	Good
BL/PNG/10	C3-12	Papua N Guinea	Breeders' line	Tolerant	Very good
BL/SM/43	Samoa43	Samoa	Breeders' line	Tolerant	Very good
BL/SM/80	Alafua	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/111	Pauli	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/120	Manono	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/128	Nu'utele 2	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/132	Fanuatapu	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/134	Sapapalii	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/138	Moataa 2	Samoa	Breeders' line	Tolerant	Very good
BL/SM/147	Asau	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/149	Lepa	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/151	Letogo	Samoa	Breeders' line	Tolerant	Very good
BL/SM/152	Saleapaga	Samoa	Breeders' line	Tolerant	Very good
CE/THA/08	Looh Lom	Thailand	TANSAO core	Susceptible	Very good
CE/THA/09	Ta Daeng	Thailand	TANSAO core	Susceptible	Acceptable
CE/THA/24	Boklua	Thailand	TANSAO core	Susceptible	Good
CA/JP/03	Miyako	Japan	Elite	No Information	No Information

Source: EU-INEA Aroid Network Project

Table 4: Exotic varieties of cocoyam introduced into Nigeria Batch 2

CEPACT COI	VARIETY	ORIGIN	Col Type	TLB Susceptibili	Taste
BL/PGN/11	C3-22	Papua New Guinea	Breeders' line	Resistant	Acceptable
BL/PGN/13	C3-46	Papua New Guinea	Breeders' line	Resistant	Acceptable
BL/SM/13	Samoa 13	Samoa	Breeders' line	Tolerant	Good
BL/SM/83	Samona	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/116	Manu	Samoa	Breeders' line	Tolerant	Very good
BL/SM/136	Matautu	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/143	Vaimauga	Samoa	Breeders' line	Tolerant	Very Good
BL/SM/148	Malaela 2	Samoa	Breeders' line	Tolerant	Very good
BL/SM/157	Malae-o-le-la	Samoa	Breeders' line	Tolerant	Very good
BL/SM/158	Lalomanu	Samoa	Breeders' line	Tolerant	Very good
CE/IND/06	IND 155	Indonesia	TANSAO core	Susceptible	Good
CE/IND/10	IND225	Indonesia	TANSAO core	Susceptible	Good
CE/IND/12	IND237	Indonesia	TANSAO core	Susceptible	Good
CE/IND/14	Lamputara	Indonesia	TANSAO core	Susceptible	Good
CE/IND/16	Lebak	Indonesia	TANSAO core	Susceptible	Good
CE/IND/24	IND512	Indonesia	TANSAO core	Susceptible	Poor
CE/IND/31	Manokwari	Indonesia	TANSAO core	Immune	Very good
CE/IND/32	IND231	Indonesia	TANSAO core	Immune	Very good
CE/THA/05	Hom	Thailand	TANSAO core	Susceptible	Good
CE/THA/07	Srisamrong	Thailand	TANSAO core	Susceptible	Good
CE/THA/10	Klonglan	Thailand	TANSAO core	Susceptible	Acceptable
CE/THA/12	Khamin	Thailand	TANSAO core	Susceptible	Good
CA/JP/01	Tsuronoko	Japan	Elite	No information	Acceptable
CA/JP/06	Akame	Japan	Elite	No information	Acceptable
CA/JP/08	Takenoko-imo	Japan	Elite	No information	No information

Source: EU-INEA Aroid Network Project

REFERENCES

Alvarez, M.N. and Hann, S.K. (1986) Seed production in sweet potato, yam and cocoyam at IITA. In: Cock, J.H. (Ed.). *The proceedings of the global workshop on root and tuber crops propagation*. 13-16 Sept. 1983. Cali, Colombia. CIAT, Cali Colombia.

Arene, O. B. And Ene, L. S. O. (1987) Advances in cocoyam research at National Root Crops Research Institute Umudike (1972 – 1986). In cocoyams in Nigeria: Production, storage, processing and utilization. Proceedings of the 1st National Workshop on cocoyam August 16-21, 1987, NRCRI Umudike Nigeria. Pp 58-71

Blay, E.T., S.K. Offei, E.Y. Danquah (2004) Genetic diversity in cocoyam as revealed by random amplified polymorphic DNA (RAPD) markers. In Genetic Improvement of Under-utilized and Neglected Crops in Low Income Food Deficit Countries (LIFDCS) Through Irradiation and Related Techniques. IAEA, Vienna, 2004 IAEA-TECDOC-1426. pp131-142.

Brown Deni (2000) Ariods: Plants of the Arum Family. 2nd Edition. Timber Press, 468pp

Chukwu, G. O., Uwasomba, C., Okoye, B. C. and Onwubiko, O. (2011) Cocoyam re-birth:Aa crop model in rebranding Nigerian agriculture. In: Amadi, C. O., Ekwe, K. C., Chukwu, G. O., Olojede, A. O. and Egesi, C. N. edited Root and Tuber Crops Research for Food Security and Empowerment. National Root Crops Research Institute Umudike. Pp 287-300

Comstock, R. E. and Robinson, H. E. (1952) Genetic Parameters: Their estimation and significance. Proc. Sixth inter grassland congress pp. 284-291

Coursey, D. G. (1968) The edible Aroids, World Crops Grampiam Press Ltd. London

Doku, E. V. (1980) Strategies for progress in cocoyam research In tropical root crops research strategies for the 1980s. Proc. 1st Symp. ISTRC-AB, 8-12th Sept. Ibadan Nigeria

Ekanem, A. M. and Osuji, J. O. (2006) Mitotic index studies on edible cocoyams (*Xanthosoma* and *Colocasia* spp.) African Journal of Biotechnology Vol. 5 (10) 846-849

Eleje I. (1987) Cocoyam: A major national carbohydrate staple for the future in Nigeria. In cocoyams in Nigeria: Production, storage, processing and utilization. Proceedings of the 1st National Workshop on cocoyam August 16-21, 1987, NRCRI Umudike Nigeria. Pp 11-16

Ene, L. S. O. (1977) Cytogenetic studies in root and tuber crops. In Proc 1st National Seminar on Root and Tuber Crops. Umudike, march 21-25, 1977 pp. 58-70

Ezedinma, F. O. C. (1987) Prospects of cocoyam in the food system and economy of Nigeria. In cocoyams in Nigeria: Production, storage, processing and utilization. Proceedings of the 1st National Workshop on cocoyam August 16-21, 1987, NRCRI Umudike Nigeria. Pp28-34

FAO (2009) Food and Agricultural Organization (FAO) production statistics 2009

Hernándo, J.E. and León, J. (1994) Neglected Crops: 1492 from a different perspective. Plant Production and Protection Series No. 26. FAO, Rome, Italy (1994) 253–258.

IITA (1973) International Institute of Tropical Agriculture. Annual Report for the Root and Tuber Improvement program. Ibadan Nigeria

IITA (1978) International Institute of Tropical Agriculture. Annual Report for the Root and Tuber Improvement program. Ibadan Nigeria

Ijeoma, B. C. (1983) Utilization of cocoyam. Annual Report Cocoyam programme. National Root Crops Research Institute Umudike. P 152.

Ikwelle M. C, Ezulike T. O, Eke-okoro O.N (2003). Contribution of Root and Tuber Crops to the Nigerian Economy. Proc. 8th Triennial Symposium of the International Society for Tropical Root Crops-Africa Branch (ISTRC-AB) held at the International Institute of Tropical Agriculture, Ibadan, Nov. 12-16, 2001. pp. 13-18.

Mbanaso, A. (1992) Evaluation of cocoyam. Annual Report, National Root Crops Research Institute Umudike.

Mbanaso, A. (1986) Utilization of cocoyam. Annual Report Cocoyam programme, National Root Crops Research Institute Umudike.

Mbanaso, E. N. A. and Nwachukwu, E. C. (2008) Radiation sensitivity in different cultivars of cocoyam. Annual Report 2008 National Root Crops research Institute Umudike. Pp156-158

Mbanaso, E. N. A., Chukwu, L. I., Ogbonye, P. And Nwoko, S. U. (2005a) Induction of flowering and fruiting in cocoyam using various concentrations of gibberelic acid(GA3). Annual Report 2005, National Root Crops research Institute Umudike. Pp 152

Mbanaso, E. N. A., Echendu, N. T C., Olojede, A. O., Chukwu, G. O., Obasi, M. N. and Okoye, B. C. (2005b) In-country germplasm collection of cocoyam in Southern Nigeria. (Progress report) Annual Report 2005, National Root Crops research Institute Umudike. Pp157-159.

Mbanaso, E. N. A., Chukwu, L. I., Ogbonye, P. And Nwoko, S. U. (2006a) Recycling GA3 treated cocoyam planting materials for flower and fruit production. Annual Report 2006, National Root Crops research Institute Umudike. Pp 145-147

Mbanaso, E. N. A., Opara, M. U. A., Ikpeama, A. and Chukwu, L. A. (2006b) Assessment of cassava starch – gelled medium for in vitro multiplication of cocoyam. Annual Report 2006, National Root Crops research Institute Umudike. Pp 149-151

Mbanaso, E. N. A., Obasi, M. N. and Okoye, B. C. (2004) Evaluation of 4 cultivars of cocoyam in different ecological zones of Nigeria. Annual Report 2004, National Root Crops research Institute Umudike. Pp 116-118

NRCRI (1982) National Root Crops research Institute Umudike. Annual Report 1982.

Okonkwo, C. (1975) Grouping of cocoyam germplasm. Annual Report, National Root Crops Research Institute Umudike.

Onwueme I. (1999) Taro Cultivation in Asia and the Pacific. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific Bangkok, Thailand, 1999

Onwueme, I. C. (1987) Strategies for increasing cocoyams (*Colocasia* and *Xanthosoma*) in the Nigerian food basket. In cocoyams in Nigeria: Production, storage, processing and utilization. Proceedings of the 1st National Workshop on cocoyam August 16-21, 1987, NRCRI Umudike Nigeria. Pp35 – 42.

Purseglove, J.W. (1972) *Tropical crops. Monocotyledons*. Longman London.

Saborio, F., G. Umana, W. Solano, P. Amador, G. Munos, A.T. Valerin, S. Torres, R. Valverde (2004) Induction of genetic variation in *Xanthosoma* spp**.** In Genetic Improvement of Under-utilized and Neglected Crops in Low Income Food Deficit Countries (LIFDCS) Through Irradiation and Related Techniques. IAEA, Vienna, 2004 IAEA-TECDOC-1426. pp143-154.

Sukamto, L.A. (2004) Development of early maturing and leaf blight resistant Taro (C*olocasia esculenta* (l.) Schott) with improved taste In Genetic Improvement of Under-utilized and Neglected Crops in Low Income Food Deficit Countries (LIFDCS) Through Irradiation and Related Techniques. IAEA, Vienna, 2004 IAEA-TECDOC-1426. pp175-184.

Onyeka T. J. (2011) Understanding Taro Leaf Blight: A new challenge to cocoyam (*Colocasia esculenta*) production in Nigeria. In: Amadi, C. O., Ekwe, K. C., Chukwu, G. O., Olojede, A. O. and Egesi, C. N. edited Root and Tuber Crops Research for Food Security and Empowerment. National Root Crops Research Institute Umudike. Pp 301-312

Wagih, M. E. (1994) Seed Rescue Culture: A technique for regeneration of Taro (*Colocasia esculenta*) African Crop Science Journal 2(1) 9-15