International Scholars Journals

African Journal of Wood Science and Forestry ISSN 2375-0979 Vol. 13 (3), pp. 001-009, March, 2025. Available online at www.internationalscholarsjournals.org © International Scholars Journals

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Review

Preserving Nigeria's Horticultural Heritage: Genetic Resource Management and Biotech Solutions

J. U. Ogbu[1, 3, 5]*, B. A. Essien[2], J. B. Essien[4] and M. U. Anaele[4]

[1]Horticulture and Landscape Technology Programme, Federal College of Agriculture [FCA], Ishiagu 491105, Nigeria.
[2]Crop Production Technology Programme, FCA, Ishiagu, Nigeria.
[3]National Root Crops Research Institute, Plant Tissue Culture Laboratory, Umudike, P. M. B. 7006 Umuahia 440001, Nigeria.
[4]Basic Sciences Programme, FCA, Ishiagu, Nigeria.
[5]Umuahia 440003, Abia State, Nigeria.

Accepted 12 January, 2025

Plant genetic resources (PGR) are basic requirements in crop improvement programme and their importance have increased in recent years with the changing scenario of ownership and legal regimes in relation to biodiversity. Horticultural genetic resources (HGR) are subset of agro -biodiversity that is related to garden crop species or their wild genepool, having genetic material of actual or potential value. Horticultural crops comprise diverse economic species ranging from the fruits/nuts, vegetables, spices and condiments, ornamental plants, aromatic and medicinal plants. Besides the tangible materials, HGR also encompass the indigenous knowledge accumulated over ages among gardeners, and which surround the use of such biological resources. The exploration, collection, characterization, evaluation and utilization of HGR are enormous tasks in a country like Nigeria with wide diversity of these vital groups of plants. Yet relatively little effort hitherto has been made to harness these natural resources of great potential values for food and agriculture, health care, national economy, industrial development and environmental protection. This paper therefore, examined the present status of HGR in Nigeria, the scientific management aspects of the HGR including their diversity, conservation and sustainable use. It also addressed crucial concerns regarding conservation biotechnology in Nigeria vis-à-vis management of the HGR.

Key words: Biodiversity, conservation biotechnology, horticultural genetic resources (HGR), Nigeria.

INTRODUCTION

The challenge of ecological sustainable development is the single most pressing issue that confronts humans today; and diversity of biological resources provides the foundation block for that. Biodiversity, conservation and genetic resources are triple buzzwords that have come to assume significant position in most biological and environmental science fora of recent times. Biological diversity (otherwise abbreviated as biodiversity) refers to all living organisms, their genetic materials and the ecosystems of which they are a part. Diversity rich ecosystems possess greater resilience and are able to recover and adapt more readily from natural calamities and/or human- induced habitat degradations. Plant genetic resources (PGR), as a vital segment of biodiversity in general and agrobiodiversity in particular, constitute the genetic material of plants having value as a resource for present and future generation of human being (Dhillon and Saxena, 2003; LEISA, 2004). As genetic resource, the PGR may be of reproductive or vegetative propagule such as seeds, shoots, tissues, cells, pollen, DNA molecule etc, containing the functional

*Corresponding author. E-mail: ogbujugo@gmail.com. Tel: +234-8068227193.

Table 1. Diversity of world plant species.

Approximate number of plant species between	13 - 14,000,000
Number of described plant species	1,750,000
Number of higher plant species between	300,000 to 500,000
Approximate number of edible plant species	75,000
Number of plant species used for food	7,000
Commercially important plant species	150
Plant species producing 90% of calories in human diet	30
Crop species producing 60% of global food requirement (rice, wheat, maize).	3

Sources: Wilson (1992), Dhillon and Saxena (2003) and Engels and Visser (2006). b/w = between.

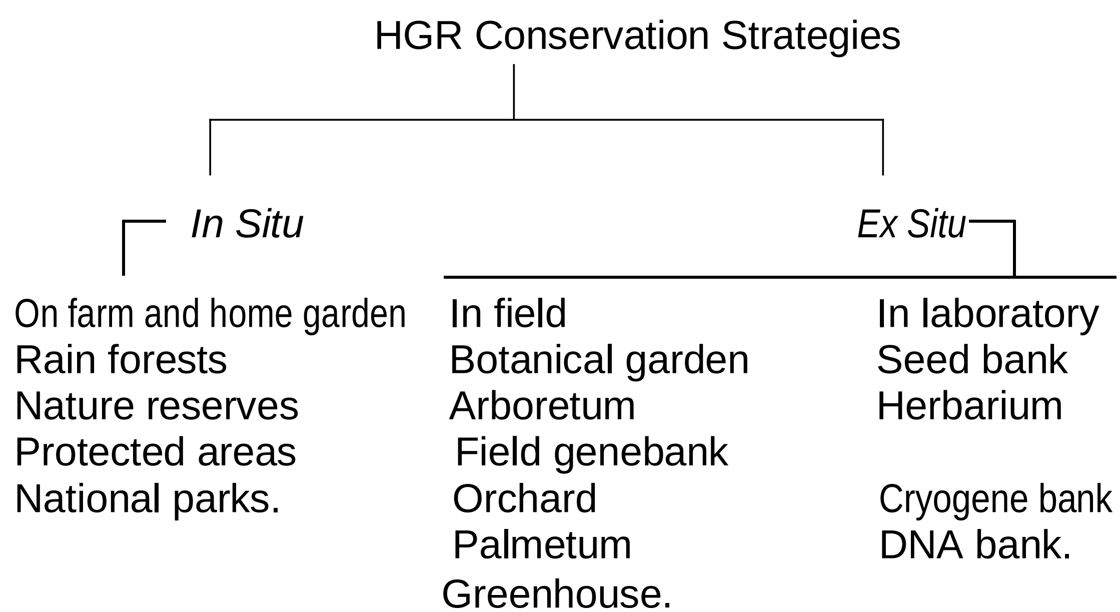

Figure 1. Conservation approaches of HGR.

unit of heredity in addition to corresponding information and knowledge about their use that can be applied in crop improvement programme and other product development. The categories of PGR range from landraces and farmers' varieties, absolute cultivars, modern cultivars, breeding lines and genetic stocks, wild relative, weedy races and potential domesticate species, exotic and indigenous species (FAO, 1996; Engels and Visser, 2006; Sharma, 2007). According to Wilson (1992) and FAO (1996), there are approximately 400,000 species of higher plants, of which 250,000 have been identified or described. Among these, 30,000 species are edible, but over the course of human civilization just about 7,000 of them have been cultivated and or used by humans for food at one time or another. Table 1 provides more facts, while Figures 1 and 2 gives diversity of world plant species. In the tropics, 25,000 species of higher plants have been variously used by mankind distributed by region as follow: 7000 species, South East Asia, 7000 species, tropical African and 11,000 species, for Latin America (PROTA Report, 2004).

Horticultural genetic resources (HGR) are a subset of agrobiodiversity that is related to horticulture plant species or their wild genepool, having genetic material of actual or potential value. Horticultural plants comprise groups of important crops commodities which include fruits, vegetables, spices and condiments, ornamental plants, aromatic and medicinal plants (Rathore et al., 2005). These groups of crops, besides improving biological productivity and nutritional standards also have enormous export potentials. In Tropical Africa houses, not less than 3972 plant species are of primary use as horticultural produce (Table 2), according to PROTA survey (Bosch et al., 2002). There are wide ranges of such groups of garden crops grown in Nigeria, some of which are indigenous while others are introduced but adapted exotic species. Important horticultural food crops in Nigeria are given in Table 3. Meanwhile, Nigeria is one

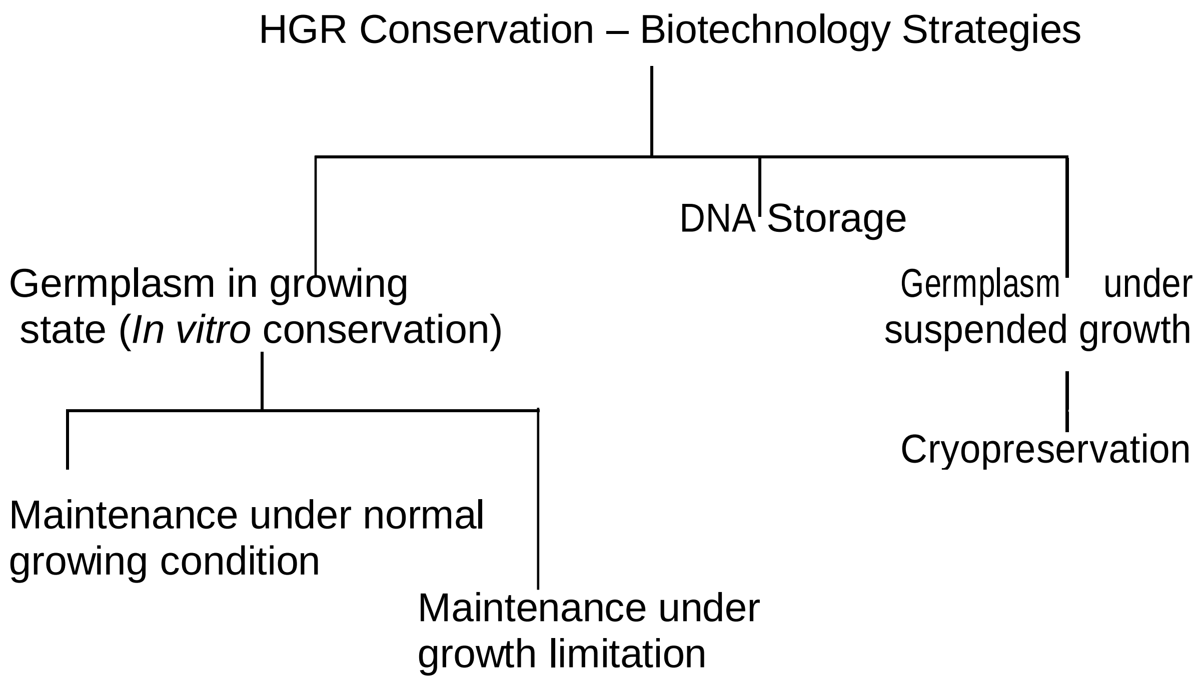

Figure 2. Biotechnological approaches in HGR conservation.

Table 2. HGR of tropical Africa by PROTA.

Commodity group	Number of species of primary use
Vegetables	397
Ornamentals	533
Fruit and Nuts	477
Medicinal Plants	1975
Spices and condiments	230
Auxiliary plants	220
Essential oils and exudates	240
Total	3972

Adapted from PROTA Basic list of species and commodity grouping (Bosch et al., 2002).

of the largest countries in West Africa, and has a land area of approximately 91.07 million hectares. Its territorial area spanned from latitude 4° 14´N to 13° 48´N and from longitude 2° 42´E to 14° 40´E. The country is a physically, climatically and biologically diverse country. It encompasses three major ecological regions, viz: A humid forest region, a sub- humid region with highland and a semi-arid region, with annual rainfall ranging from 250 mm in the Sahelian North to over 3000 mm in the Southern coastal areas. The natural vegetation varies from rainforest to savanna. Nigeria is also endowed with substantial biological resources. These include 68 million hectares of arable land, and fresh water resources covering 12 million hectares. Land use patterns in the country shows that cropland takes 34% of total land area, pasture takes 23%, forest 16%, rivers/lakes/reservoirs 13% and others 14% (Shaib et al., 1997).

Management of horticultural genetic resources (HGR) in Nigeria

The National Horticultural Research Institute (NIHORT), with its headquarters at Ibadan was established in 1975 with the mandate of developing sustainable production and utilization of horticultural crops in Nigeria. The institute's set objectives among others include collection, characterization and conservation of germplasm of fruits, vegetables and ornamentals plants; genetic improvement of tropical fruits and vegetables (Denton et al., 2000). However, there are other sister National Agricultural Research (NAR) Centres in the country that have some

Table 3. Some important horticultural food crops in Nigeria.

Species/cultivar		Biodiversity status	Cultivated/wild/semi domesticated (C,W,S)	Indigenous/introduced species (D/T respectively)
Botanical name	Common name	Abundant(+)/ rare(-)		
Fruits				
Citrus sinensis	Sweet orange	+	C	T
C. paradise	Grape	+	C	T
C. reticulate	Mandarine/tangerine	+	C	T
C. paradise x *reticulate*	Tangelo	+	C	T
C. limon	Lemon	+	C	T
C. aurantfolia	Lime	+	C	T
Musa spp. AAB	Plantain	+	C	T
Musa spp. AAA	Banana	+	C	T
M. indica	Mango	+	C	T
Ananas comosus	Pineapple	+	C	T
Carica papaya	Pawpaw	+	C	T
P. guajava	Guava	+	C	T
P. americana	Avocado pear	+	C	T
Passiflora edulis	Passion fruit	+	C	T
Annona muricata	Sour sop	+	C	T
A. squamosa	Sweet sop	+	C	T
Vitis vinifera	Grape	+	C	T
Frageria vesca	Straw berry	-	C	T
Achras sapota	Sapota	-	C	T
Morus nigra	Mulberry	-	S	T
Malus domestica	Apple	+	C	T
Phoenix dactylifera	Date	-	C	T
Anacardium occidentale	Cashew	+	C	T
Artocarpus artilis	Bread fruit	+	C	T
Irvingia garbonensis	Bush mango (sweet type)	+	C	D
Tetracarpidium conophorum	African walnut	+	S	D
Treculia africana	African breadfruit	+	S	D
Cola pachycarpa	Monkey kola (white type)	+	S	D
C. lepidota	,, (yellow type)	+	S	D
C. lateritia	,, (red type)	+	W	D
Dialium guineense	Velvet tamarind	+	W	D
Chrysophyllum albidum	African star apple	+	S	D
Spondias mumbi	Hog plum	+	W	T
Dacryodes edulis	Butter fruit	+	S	D
Canarium schweinfurthii	Incense tree fruit	+	S	D
Vegetables				
Lycopersicon esculentum	Tomato	+	C	T
Abelmoschus esculentus	Okra	+	C	T
Capiscum annum	Chili pepper	+	C	T

species of garden crops as part of their mandate crops of research, including National Root Crops Research Institute (NRCRI), Cocoa Research Institute of Nigeria (CRIN), etc.

The collection, characterization, evaluation, conservation and use of HGR are enormous tasks especially in a country like Nigeria, which has a vast heritage of these bioresources. A large number of horticultural plants are cultivated due to different agro- climatic factors, socio-economic and cultural needs. There is a wide

Table 3. Contd.

C. frutenscens	Sweet pepper	+	C	T
Amaranthus spp	Amaranths	+	C	T
Allium cepa	Onion	+	C	T
Solanum aethiopicum	Gardenegg/gilo	+	C	D
S. macrcarpon	,,	+	C	D
S. nigrum	,,	+	C	D
Cucurmis sativus	Cucumber	+	C	T
Hibiscus sabderiffa	Roselle	+	C	D
Sesamum indicum	Sesame/benniseed	+	C	D
Corchorus olitorius	'Ewedu'/'ahihiara'	+	C	D
Celosia argentea	'Shokoyokoto'	+	C	T
Lactuca sativa	Lettuce	+	C	T
Brassica oleracea var. capitata	Cabbage	+	C	T
Brassica oleracea var. botrytis	Cauliflower	+	C	T
Solanum tuberosum	Potato	+	C	T
Ipomea batatas	Sweet potato	+	C	T
Colocasia esculenta,	Cocoyams (taro/eddoe)	+	C	T
Xanthosoma sagittifolium	Cocoyams (tannia)	+	C	T
Colocynthis citrullus	Egusi melon	+	C	D
T. occidentalis	Fluted pumpkin /'ugu'	+	C	D
Cucurbita pepo	Pumpkin	+	C	T
C. moschata	"	+	C	T
Vernonia amygdalina	Bitter leaf	+	C	D
Talinum triangulare	Water leaf	+	C	D
Gnetum africanum	'Ukazi'	+	S	D
Pterocarpus soyauxii	'Uha'	+	S	D
Vitex doniana	'Mbembe'/black plum	+	W	D
Spices and condiments				
Afzelia africana	'Akparata'	+	S	D
Brachystegia eurycoma	Bay plant /'achi'	+	S	D
Detarium microcarpum	'Ofor'	+	W	D
Irvingia wombolu	Bush mango/ 'ogbono'	+	S	D
Xylopia aethiopicum	African guinea pepper	+	C	D
Gongronema latifolium	Clove	+	C	D
Ricinus communis	Castor oil	+	C	D
Parkia biglobosa	Locust bean	+	S	D
Ocimum viride	Basil leaf	+	C	T
Pentachethra macrophylla	African oil bean	+	S	D
Mucuna sloanei	Horse eye bean	+	C	D
Murraya koenigii	Curry leaf	+	C	T
Zingiber officinale	Ginger	+	C	T
Allium sativum	Garlic	+	C	T
Aframomum melegueta	Alligator pepper	+	C	D
Dennetia tripetala	Pepper fruit	+	C	D
Piper guineense	Black pepper	+	C	D

diversity in these crops with respect to mode of reproduction (seed vs. vegetative propagation), seed storage behaviour (orthodox vs. recalcitrant), growth habit (annual vs. perennial), adaptation, uses (as fruit, vegetable, ornamental, medicinal and aromatic plants), agro-technology and commercial value (like cash crops, staple food crop, minor and under-utilized). In fact, HGR management is more complex as compared to the field and plantation crops, and requires different management approaches. Keeping in view the enormity and diversity of the task involved, networking approach is essentially required. Such network should include National Horticultural Research Institute - NIHORT, Sister NAR Centres which have horticultural plants in the list of their mandate crops, like National Root Crops Research Institute - NRCRI [cocoyam, potato, sweet potato, ginger, turmeric], Nigeria Institute for Oil Palm Research - NIFOR [coconut, date, ornamental palms], National Centre for Genetic Resources and Biotechnology (NACGRAB), Forestry Research Institute of Nigeria (FRIN) [for inputs on conservation/domestication of certain important indigenous fruit trees, aromatic and medicinal plants] and other organization that share similar interest in HGR.

Plant biodiversity and genetic erosion in Nigeria

Report by Federal Environmental Protection Agency (FEPA) shows the ecological status of plant biodiversity in Nigeria to comprise of 4,903 species of angiosperms, 32 species gymnosperms, 155 pteridophytes, 80 species bryophytes, 784 species algae, 3,423 species fungi and more than 500 species virus. According to the report also, 20 species of plants had become extinct since 1950, 431 species are endangered, 45 species are classified as rare, 20 species are vulnerable, while 305 species are endemic (Adejuwon, 2000). All these are of PGR conservation concern to the country considering the unprecedented rates of occurrence in comparison with normal natural history rates. The causes of these gradual but steady lost of our plant bioresources in general and HGR in particular have been identified to include over-exploitation, massive deforestation and desertification, paucity of institutional frame work to engage in deliberate conservation of PGR of relevant to food, agriculture/forestry, inadvertent emphasis on more introduced exotic crop species/varieties to the neglect of our useful indigenous plants, etc. Given the combined effort of these deleterious factors, genetic erosion becomes inevitable where no deliberate attempt is made to forestall it (Petters, 2000).

HGR CONSERVATION STRATEGY

The conservation of HGR is extremely important to meet the present and future needs of various crop improvement programmes. Among the challenges of HGR utilization and conservation in Nigeria are the recalcitrant seed, vegetative propagation and perennial nature of a large number of horticultural plants. Modern and sustainable conservation system requires complementary strategies involving both *in situ* and *ex situ* conservation. Emphasis needs to be given to the collection and conservation of the endemic wild relatives, rare and endangered species that are rapidly disappearing from their ecological niches (Padulosi et al., 2002; Padulosi and Hoeschle-Zeledon, 2004; Dhilon et al., 2005). Plant species that are vegetatively propagated, that have long life cycles and/or produces nonorthodox seeds are traditionally maintained in field collections. Maintaining plants in the field is often costly and carries high risk of loss. Therefore, the strategies and procedures employed to establish and maintain field collections need to be practical, rational and economic, in addition to being scientifically sound. Most times, experience in cost-effective management of field collections lies with individual curators and is not readily available to guide others. Furthermore, there are increasing opportunities for using *in vitro* methods (that is biotechnological approach as contrast from the traditional or conventional approaches) for the conservation of crops normally conserved in the field (Reed et al., 2004; Singh, 2006).

In situ conservation approaches

In this approach, plant species are promoted to grow in their natural habitats where evolutionary processes continue to operate; thus making it a dynamic system. Genetic variability is generated through mutation, pollen and seed dispersal, and recombination within and among population. Selection operates on this variability leading to the development of new plant types with improved adaptability. *In situ* conservation, in addition to natural habitats in protected areas and national reserves, also need to be carried out on-farm in the areas where landraces and locally adapted farmers' varieties are cultivated. This requires active farmers' participation to conserve landraces and traditional farmers' varieties. The novel genetic resources may be conserved even in home gardens (Rathore et al., 2005; Tao, 2003) . On farm and homegarden conservation is of particular importance in country like Nigeria, to conserve indigenous HGR and to provide diverse food and other products for household needs and local markets. Large percent of the national food needs still comes from the traditional farming systems characterized mostly by mixed cropping as seen in typical homegarden setting.

With *in situ* approach however, there is always a threat of a species becoming extinct or its population declining due to demographic and environmental variations, habitat loss, over-exploitation, competition from invasive alien species, pests, genetic drift, inbreeding and human disturbances. In such situations, the alternative way to conserve diversity is to maintain it *ex situ.*

Ex situ conservation approach

The genetic material is conserved *ex situ* either in field, seed, *in vitro* and cryo genebank. In crops that produce seed, which is amenable to desiccation and can tolerate low temperature (that is most orthodox seeds), germplasm conservation through seed, is the most common approach. Seeds, equilibrated from 3 to 5% moisture content, are stored at -20°C for long term conservation. However, many horticultural plants, being vegetatively propagated or having recalcitrant seed, require field genebank facility for their conservation. The germplasm of major commercial fruits and ornamental trees in Nigeria are mainly being maintained in field genebanks by the horticultural and related research institutes. NIHORT has a broad germplasm collection of citrus fruit species and accessions drawn from different parts of the world, ranging from sweet orange, mandarins, tangelo, grape fruit, lemon, lime, tangor, sour orange and *Poncirus trifoliata*. Other fruits germplasm of plantain (*Musa* spp. AAB - 16 accessions), Banana (*Musa* spp. AAA - 6 accessions), Mango (*Magnifera indica* - 23 accessions), Pawpaw (*Carica papaya* - 14 accessions), Guava (*Psidum guajava* - 67 accessions), Avocado (*Persea americana* - 8 accessions), *Irvingia* nut (16 accessions) and *Treculia* nut (6 accessions), had been collected from within and outside Nigeria, and maintained at the institute's headquarters as well as substations in various agro-ecological zones of the country (Denton et al., 2000). NIFOR, on the other hand, has for long established and maintained a palmetum where representative palms from various areas of the world are included. Many of these palms were found to have ornamental values. So far, not less than 114 different species and accessions have been introduced (NIFOR, 1989). But on long-term, the field genebanks are expensive and cumbersome to manage and are vulnerable to natural vagaries. The alternative approaches are *in vitro* conservation and cryopreservation. These latter approaches are resource and technology-intensive driven. Cryopreservation of pollen can be an important strategy for conservation of genepool in perennial plants (Reed et al., 2004; Rathore et al., 2006).

The botanical gardens, greenhouses, orchards and arboretum also have an important role in the *ex situ* conservation of HGR. Many fruits trees, medicinal and aromatic plants, spices, ornamentals, other plants of economic value and their wild relatives are being maintained in several botanical gardens round the world. The botanical gardens fill an important gap in *ex situ* conservation of species which otherwise have not received much attention from traditional seed and field genebanks.

BIOTECHNOLOGICAL STRATEGY OF HGR CONSERVATION

In vitro conservation and cryopreservation techniques

Efficient conservation of genetic resources in case of vegetatively propagated plants and recalcitrant seed species has been hampered due to problems faced during application of their conventional method of *ex situ* conservation in field genebank. To tackle these challenges, *in vitro* techniques have been increasingly used for conservation and its related activities like collecting and exchange of germplasm of these problem species. *In vitro* meristem culture technique offers the possibility of eliminating viruses and thus, exchange of virus-free germplasm. *In vitro* slow/normal growth techniques offer up to medium-term storage option, avoiding risk of losses of germplasm on field genebank due to insects, nematodes, disease attacks and natural disasters. It is commonly use for vegetatively propagated species, nonorthodox seeded species and wild species which produce little or no seeds. While cryopreservation at ultra- low temperature, usually that of liquid nitrogen (-196°C), is the only option currently available for the long-term conservation of these PGR avoiding exogenous contamination, requiring small space and minimum maintenance. At this very low temperature, all metabolic activities of cell cease, and theoretically the cell or tissue can be stored for an indefinitely period. Both i*n vitro* conservation and cryopreservation techniques use tissue culture principles for conservation (Roca et al., 1989; Reed, 1993; Mandal, 2003).

The realization of the potential of *in vitro* conservation came about in the early 1970s, at a time when the storage of microbial cultures was a routine procedure. Since then, tissue culture techniques have been applied to more than 1,000 plant species. Subsequently, the technique has progressed from mere speculation to development and today it is routinely being used for conservation of vegetatively propagated crops and perennial species (Tyagi and Yusuf, 2003). The art and science of plant tissue culture is based on devising media for each genotype that would elicit the optimal response in terms of growth rate of the explants. However, when tissue techniques are employed for conservation, the aim is to devise a medium that would decrease the growth rate of explants to the minimum, thereby increasing the subculture intervals. Slow growth techniques have been developed for medium-term conservation of crop species (Engelmann and Drew, 1998; Sarkar and Naik, 1998). The various methods used to achieve this include the following: Use of growth retardants, use of minimal growth media, use of osmotic regulators, reduction in oxygen concentration, size and type of culture vessels, type of enclosures, maintenance under reduced temperature and for reduced light intensity and combination of more than one treatment. Explants used for *in vitro* conservation must be of right type as well as physiological stage. The apical and auxiliary meristems of very small size are the preferred explants for *in vitro* storage. In fact, organized explants have proved better than unorganized tissues, in terms genetic stability of thegermplasm (Mandal, 2003; Reed et al., 2004; Chaudhury and Vasil, 1993).

Cryopreservation refers to the non-lethal storage of biological tissues at ultra-low temperature, usually that of liquid nitrogen (LN) which is -196°C. Currently, it is the only option available for the long-term conservation of germplasm of vegetatively propagated and recalcitrant seed species. Due to storage at the temperature of the vapor phase (-150 to -180°C) or liquid phase (-196°C) of LN, cell divisions and metabolic activities are arrested and thus, plant material can be stored for unlimited periods of time. Conservation of germplasm using cryogenic approach required very limited space; the plant material stored is protected from exogenous contamination and needs very limited maintenance. It causes no change in viability, vigor and genetic make up of the conserved materials. It also eliminates the need to test stored materials frequently, thus making storage cost-effective. There have been several reviews on the use of cryopreservation for storage of plant materials (Kartha and Engelmann, 1994; Engelmann and Takagi, 2000; Towill and Bajaj, 2002; Chaudhury, 2002; Mandal, 2003; Reed et al., 2004).

The choice of material for cryogenic storage will depend on the plant species as well as the objectives of storage. For conservation of PGR, the explants can include shoot apices, auxiliary buds, dormant buds, somatic embryos, seeds, zygotic embryos, embryonic axes or pollens. Cryopreserved explants (but pollen) should eventually regenerate whole plants to be used and therefore, regeneration protocols need to be clearly defined prior to embarking on crypopreservation. Regenerated plants should also maintain genetic integrity of the starting material. The various techniques currently under investigation or in use include: the classical freezing method, encapsulation-dehydration, vitrification, encapsulation–vitrification, desiccation, pre-growth droplet freezing, and pre-growth desiccation (Mandal, 2003; Panis, 2007).

DNA bank

DNA storage is a relatively new technique that is rapidly gaining recognition. Several DNA libraries are being established which provide an easy access for scientists. DNA from the nucleus, mitochondria and chloroplasts are now routinely extracted and immobilized into nitrocellulose sheets where the DNA can be probed with numerous cloned genes. With the development of PCR (polymerase chain reaction), one can now routinely amplify specific genes or oligonucleolides from the entire mixture of genomic DNA. This approach, according to Engelmann et al. (2003), is relatively easy and of low cost. It is particularly useful for the conservation of specific genes and it allows easy access to specific material. The exchange of germplasm through DNA sequences is safe since infestations with pathogens can be simply avoided. Note however, that entire plant can not be regenerated from conserved DNA (Reed et al., 2004; Guimaraes et al., 2007).

ASPECT OF THE INDIGENOUS HGR AND WILD RELATIVES

The future HGR management strategies in Nigeria should not only focus on the already commercialized crop species as it is today. Due attention should also be paid to many relatively neglected indigenous fruits, spices and vegetables which are considered low-income crops, and have received very little coordinated research inputs. These indigenous fruits, spices and vegetables still have large genetic base. Such plants can play an important role in the diversification of food and agriculture production, in bringing stressed areas under cultivation, and producing edible fruits, nuts and vegetables with fewer chemical inputs. This effort would go a long way in promoting eco-friendly fresh and processed agro products in these days of campaign for organic agriculture. Not only that our indigenous garden plants can be made more popular like the case of *Telfairia occidentalis* and *Irvingia* nut, but working on the genetic resources of these potential crops can also develop new economic crops.

The use of wild relatives is of special concern as these are also rich in genetic diversity and carry genes particularly for resistance or tolerance to abiotic and biotic stresses. Their great genetic variability makes them important genetic resources for producing the desired traits in crops. Until recently, wild relatives of cultivated crops have rarely been used for breeding purposes because they frequently have many undesirable characteristics aside from the desired ones. However, success in breeding better adapted varieties depends partly on collection, conservation, dissemination and use of the wild relatives. The importance of wild HGR is also underlined by the reports that several wild forms of vegetables have been found to have higher contents of minerals, proteins and vitamins compared to cultivated forms (Kallo, 1992; Inforesources, 2008). Thus, the conservation of HGR, whether cultivated forms, exotic species, underutilized indigenous plants, or wild relatives, is extremely important to meet the present and future needs of various crop improvement programmes.

ACKNOWLEDGEMENTS

Many thanks to the Kirk House Trust United Kingdom and Netherlands Fellowship Programme [NFP] for their kind funding of various research trainings which abridged report is been presented in the write-up. The lead author also appreciated the supports received from both the National Root Crops Research Institute (NRCRI) Umudike and Federal College of Agriculture (FCA), Ishiagu Nigeria.

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