



Pearl Millet (*Pennisetum glaucum* [L. R. Rr.] Varietal Loss and its Potential Impact on Smallholder Farmers in Northern Nigeria: A Review

Sa'adu Mafara Abubakar^{1*}, Salisu Mohammed², Francis Bayo Lewu², Muhammad Nuraddeen Danjuma¹, Adewole Tomiwa Adetunji², Joseph I Kioko³

¹Department of Geography,
Bayero University, Kano, NIGERIA

²Department of Agriculture,
Cape Peninsula University of Technology, SOUTH AFRICA

³Faculty of Applied Sciences,
Cape Peninsula University of Technology, SOUTH AFRICA

*Corresponding Author

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Abstract: Pearl millet is an alternative source of livelihood for poor farmers who use it to supplement food and income. Pearl millet has high medicinal value and its consumption reduces the risk of type 2 diabetes, constipation, and anemia. Pearl millets are an excellent source of protein and fiber, and a great source of starch, making it a high-energy food. It is an exceptional food source for babies from six months of age because it has high nutrients and is easily digestible. Pearl millet is the most widely cultivated millet varieties in the world. The cereal crop is grown in arid, infertile, marginal lands in Africa and Asia, and cope with unpredictable climatic conditions. Nigeria is the second-largest producer of pearl millet in the world with a tremendous amount of pearl millet diversity. However, there is growing recognition that the diversity of pearl millet in northern Nigeria is vastly diminishing thereby affecting the livelihood of smallholder farmers. This paper reviews the erosion of pearl millet, multiple drivers of loss of local varieties of pearl millet and presents some of the strategies that can be implemented to save the erosion of its diversity in northern Nigeria.

Keywords: Diversity, genetic erosion, pearl millet, smallholder farmers, varieties

1. Introduction

Pearl millet (*Pennisetum glaucum* [L.] R. Rr.) is an annual crop extensively cultivated in the arid and semi-arid regions of the world (Jika *et al.*, 2017). It is the sixth most important world cereal crop after barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), sorghum (*Sorghum bicolor*), rice (*Oryza sativa*) and maize (*Zea mays* L.) (Desalegn *et al.*, 2017). Food and Agricultural Organization showed between 2003 and 2013, the global millet harvest area between 29 and 38 million hectares, and world millet production that ranked it as six among the world's most important cereal grains was 29.8 million tons in 2013. And 15 million tons (50.3%) were produced in Africa, followed by Asia with 13.7 million (45.9%) and other countries shared 1.1 million (3.7%) (Miller, 2020). Pearl millet consumption reduces the risk of type

*Corresponding author: saadumafara2014@gmail.com

2 diabetes, its potential nutritional and medicinal value helps in reducing other human ailments such as cancer, cardiovascular and neurodegenerative diseases. Pearl millet is an exceptional food for babies from six months of age, it has a lot of nutrients and also easily digestible (Arora, 2017). Pearl millet increases insulin sensitivity, lowers the level of triglycerides, and is very efficiently used to regulate blood sugar levels (Arora, 2017). The crop also has high levels of energy, some vitamins, dietary fiber, and many essential minerals (Jukanti *et al.*, 2016). Pearl millets are the way forward for Africa and countries such as India where food and nutritional security are major challenges (Singh *et al.*, 2017).

Pearl millet is the most widely cultivated millet varieties in the world (Bhuva, 2018). The cereal crop is grown in arid, infertile, marginal lands in Africa and Asia and cope with unpredictable climatic conditions (Vara, Prasad, & Staggenborg, 2010). Pearl millet was domesticated in the Sahel region of West Africa, where its wild ancestors were found and spread to South Asia by 2300 BC (Burgarella, *et al.*, 2018). The topmost five (5) world millet producers with annual mean production between the years 1999 to 2010 were India with the highest production, followed by Nigeria, Niger, China, and Mali respectively. A total of 21,637,331 tons equivalent to 72.4% of world millet production is realized by five major countries, and other countries in the world produced 8,232,727 equivalent to 27.6% as in (Table.1) below (FAOSAT-Food and Agriculture Organization Statistics, 2015; Mukhtar, *et al.*, 2017; World Atlas, 2017).

Table 1 - Leading Pearl Millet Producing Countries in the World

Rank	Country	Production	
		(Tons)	(%)
1	India	10,910,000	36.5
2	Nigeria	5,000,000	16.7
3	Niger	2955000	10
4	China	1620000	5
5	Mali	1152331	3.86
6	Other countries	8232727	27.6
	Total	29870058	100

Source: World Atlas (2017)

Nigeria was ranked as the second-largest pearl millet principal producing country in the world after India, its average annual pearl millet production between 2005 and 2010 was estimated at 6.28 million tons equivalent to about 13.4% of the total world production. It was estimated that millet production in Nigeria was 1,468,668 tons in 2016 (Food and Agriculture Organization Corporate Statistical Database, 2016).

Pearl millet exhibits a tremendous amount of diversity at both phenotypic and genotypic levels (Abdulahakeem, *et al.*, 2019). The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) collected 23,092 accessions of pearl millet germplasm originating from 52 countries, and it is the largest collection of pearl millet germplasm in the world (Upadhyaya, *et al.*, 2017) A total of 123 accessions were collected from three Pearl millet production regions of Ghana and concluded that there is wide phenotypic variation among landraces (Asungre, 2014). Northern Nigeria is also home to diverse varieties of pearl millet (Ogechi, 2014). For example, Angarawai, *et al.* (2016) collected 125 accessions of Nigerian *Maiwa* type of pearl millet. David *et al.*, (2017) also reported 24 genetic diversity of Nigerian and Indian pearl millet accessions. However, other studies show the continuing concern over the extent of erosion of genetic diversity of the crop (Diamond 2002, Izge & Song 2013). Thus, a better understanding of, and support for, farmers' management of diversity is still needed, despite significant advances in this area.



Fig. 1 - Pearl Millet bunch growing on farms in northern Nigeria. Source: Muhammad, (2005)

1.1 Structure

Smallholder farmers' systems play a key role as crop genetic resources diversity hot spots, since the beginning of domestication; they maintain crop varietal innovations, evolution, and conservation. Consequently, the role of farmers in developing and maintaining genetic resources has been widely acknowledged (FAOSTAT, 2015). Human activities and environmental changes have greatly reduced the genetic diversity of pearl millet cultivars and affected the livelihood of many smallholder farmers (Abdulkhakeem, *et al.*, 2019). This corroborates with the "unprecedented" decline in global biodiversity that has alarming implications for human health, prosperity, and long-term survival. (UN Report, 2019). Studies conducted have shown that loss of biodiversity often has negative consequences on nature and results in several livelihood disturbances (Fischer, *et al.*, 2005; Angarawai, *et al.*, 2016).

Crop diversity loss is the outcome of multiple direct and indirect drivers that operate simultaneously and interactively at various scales. For example, several works have reported that pearl millet, despite its importance; can be considered a "lost" crop because its varieties are slipping backward. Therefore, genetic erosion has resulted in the rapid shrinking of the area under millet production over the last decades (Danjuma & Mohammed, 2014; Jika *et al.* 2017; Kumar *et al.*, 2018). This paper reviews the erosion, multiple drivers of loss of local varieties, and the control of varietal loss of pearl millet in northern Nigeria.

2. Distribution of Pearl Millet in Nigeria

Nigeria is one of the hotspots for plant genetic resources and cultural diversity (Nnamani *et al.*, 2017). Its various geographical zones provide a wide variety of plant genetic resources including millets. Among all varieties, pearl millet exhibits a tremendous amount of genetic diversity in northern Nigeria hence is the most widely distributed across the region. Various studies including Mohammed (2005) have reported about 12 landraces in Northeastern Nigeria, which are preserved by farmers using genetic manipulation to deal with environmental uncertainty such as variability in rainfall, soil moisture, and fertility in the area. Jika *et al.* (2017) found 27 landraces of pearl millet collected in Lake Chad Basin Northeastern Nigeria. Northwestern Nigeria is diverse in terms of millet species but this has not been effectively reported. However, an informal interview conducted with key informants across northwestern Nigeria in 2019 suggests that the area comprised twenty-seven main varieties and eighteen sub-varieties of pearl millet. Pearl millet production is concentrated within northern Genuine, Sudan, and Sahel savanna agro-ecological zones of northern states of Nigeria. These areas are suitable for pearl millet cultivation for their favorable climatic conditions (Danjuma & Muhammad 2014). Fig.2 below showed Millet production states in Nigeria and production levels.

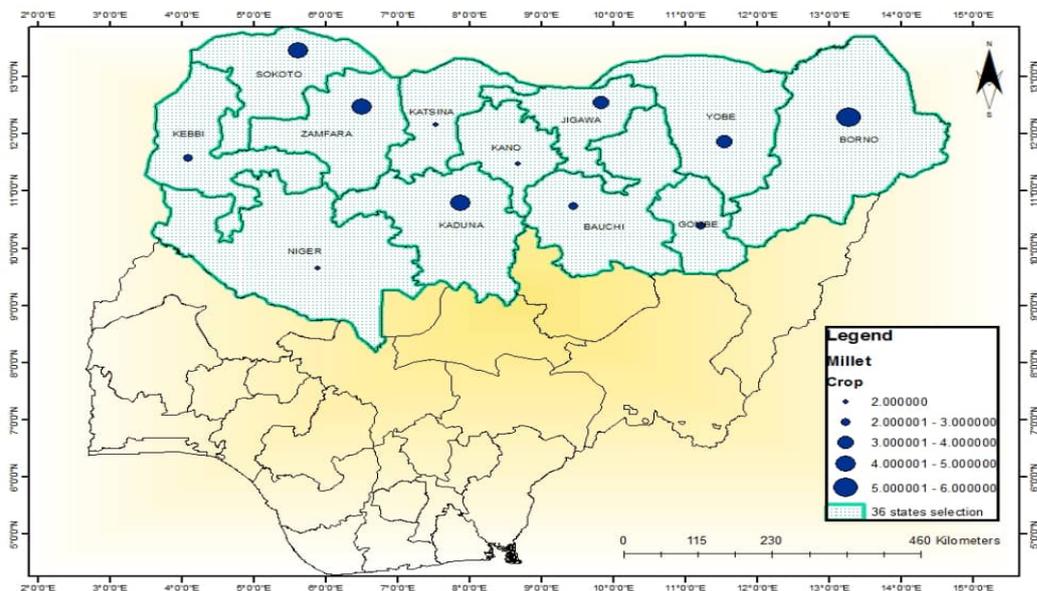


Fig. 2 - Adapted from Google image

3. Genetic Erosion of Pearl Millet

Genetic erosion was defined as the loss of individual genes and the loss of particular combinations of genes (i.e. of gene complexes) such as those maintained in locally adapted landraces (FAO, 2010). An analysis of published reports and/or studies on diversity trends globally has shown that, overall, some crops in farmers' fields have indeed decreased in diversity. Evidence suggests that genetic erosion in farmer varieties exists because of the total shift from traditional

production systems (Bhandari *et al.*, 2017). For example, pearl millet in Niger has faced unprecedented genetic shifts in farmers' fields (Bezançon *et al.*, 2009). In northern Nigeria, recent evidence in the literature has shown that limited varieties of pearl millet dominate over large areas. Busso *et al.* (2000) indicated that this is an indicator of potential loss and erosion of millets. Despite the availability and productive management of its diversity in several parts of Nigeria, increasingly the manifold challenges of small-scale farmers in arid and semi-arid lands throughout sub-Saharan Africa have made pearl millet unfortunately vulnerable to erosion (Vara, *et al.*, 2010).

A report from India revealed, a large number of millet species in Tamil Nadu, are no longer cultivated in their native habitats due to their genetic erosion (Dulloo, 2008). In Yemen *Eragrostis tef* and finger millet varieties, which were among the most important traditional varieties very rich in nutrients were only grown in a very specific area (FAO, 2010). Another study, however, has reported a genetic shift in farmer's varieties of pearl millet in the Niger Republic (FAOSTAT, 2007).

4. Drivers of Loss of Local Varieties of Pearl Millet in Northern Nigeria

Nigeria is facing many challenges including that of the seed sector. Several studies like (Izge, 2013; Ogechi 2014; Abdulhakeem, 2019) have reported that the effects of unprecedented loss of pearl millet varieties include declining farm output, increasing poverty, food insecurity, malnutrition, and diseases and susceptibility to diseases and pests. Loss of diversity is often driven by multiple factors acting together. The range of causes leading to loss and the level of loss vary, even for the same crop (Thormann, 2015). Despite different opinions regarding the drivers of loss or erosion of pearl millet local varieties as highlighted in the literature, our findings underline a need to emphasize the following because they are more limited to these areas:

4.1 Replacement of Local Varieties with Modern Cultivars

Genetic variability, which is the basic material for the selection of any crop, is fast eroding in pearl millet because of modern cultivars replacing the traditional varieties (Vidyadhar, *et al.*, 2007; Abdulhakeem *et al.*, 2019). Although pearl millet has the potential to withstand drought and grow under the soil with low fertility and low rainfall in Northern Nigeria, genetic viability in this crop is fast eroding because modern cultivars are replacing traditional varieties (Bhoite, *et al.*, 2008; Mohammed, 2018). A similar finding of (Drucker, *et al.*, 2005) reported the level of genetic erosion in crops from 143 countries. Nearly all countries reported the loss of wild and cultivated landraces. 81 countries traced the cause of genetic erosion was the replacement of local landrace by improved varieties. Following the Green Revolution modern varieties spread to large areas of Africa, Asia, and the rest of the world, which were majorly responsible for the erosion of the plant genetic resources, including pearl millet in Nigeria (Manga, 2015).

4.2 Pests and Insects Attack

Sharma, *et al.* (1997; Azere, *et al.*, 2020) reported that several species of grasshopper including the desert locust, *S. gregaria*, caused damage to grasses such as sorghum and pearl millet by feeding on leaves, flowers, and grain. *Leptoglossus phyllopus*, the destruction was more prevalent later in the season when grain filling was at its peak. *Leptoglossus phyllopus* is known to be a grain feeder of pearl millet in Nigeria., Obeng, *et al.*, (2015) also identified *Apis mellifera*, *Coleomegilla maculate*, *Danaus plexippus*, *Epicauta pestifera*, *Euschistus servus*, *Harmonia axyridis*, *Helicoverpa zea*, *Halictus spp.*, *Leptoglossus phyllopus*, *Melanoplus differentialis*, and *Schistocerca americana* insect species as very dangerous to pearl millet production at all levels.

The major insect pests causing seed erosion of pearl millet include; Cutworm: *Agrotis ipsilon Hufnagel* (Lepidoptera: Noctuidae), White grub *Holotrichia consanguinea Blanch* (Coleoptera: Scarabaeidae), Shoot fly: *Atherigona soccata Rondani* (Diptera: Muscidae) and Stem borer: *Chilo partellus Swinhoe* (Lepidoptera: Pyralidae) (Satyagopal, *et al.*, 2014). This finding is similar to the finding that identified the riskiest insects affecting pearl millet cultivation and causes genetic erosion includes; Grasshopper: *Hieroglyphus* spp. (Orthoptera: Acrididae), Grey weevil: *Myloccerus sp* (Coleoptera: Curculionidae), Earhead bug: *Calocoris angustatus Lethiery* (Hemiptera: Miridae), Hairy caterpillar: *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae) and Blister beetle: *Mylabris pustulata* Gyllenhal (Coleoptera: Meloidae) (Obeng *et al.*, 2015).

From an analysis of literature, it appears that genetic erosion may be greatest in the case of cereals, followed by vegetables, fruits, and nuts, and food legumes (FAO, 2010). Therefore, several studies example Westengen, *et al.* (2019) have highlighted that loss and erosion of varietal seeds are taking place at an alarming rate by broader categories of drivers particularly in the dry regions where degradation and destruction of the environment have resulted in the permanent loss of resources. In the absence of sustainable resource management, large-scale breakdown of the seed system in northern Nigeria is a "creeping vulnerability" to pearl millet in the medium to long term.

4.3 Climate Variability

There is growing evidence that climate change is perhaps responsible to depress crop yields and increase production risks in many regions of the world (Bagamba *et al.*, 2012). It plays a key role in influencing the choice of smallholder

farmers of what plant to cultivate and how to cultivate it, and greatly affects plant genetic diversity in Nigeria (Azere *et al.*, 2020). Climate change is now widely considered a driver of diversity loss at farmers' level (Sultan, *et al.*, 2013). Africa is facing serious climate variability including, frequent droughts that have resulted in the degradation of natural resources. Climate variability has caused a very critical dwindling of natural resources, which affected the local level seed system globally (UN Report, 2019). Mohammed (2005) concluded that there was a rapid decrease in the cultivation of traditional pearl varieties in Northeastern Nigeria, due to a decrease in rainfall because of climate change. In Dagaceri, a massive disappearance of late mature pearl millet variety was observed for its higher drought maladaptive characteristics. Several findings agreed that the cultivation of late matured pearl millet variety was affected by a decrease in rainfall as a result of its seize when the crops were not fully matured (Muhammad, 2018; Bhuva, & Khanpara, 2018). These observations corroborate with those made by FAOSTAT, (2007) that genetic shifts in farmer's varieties of pearl millet due to decrease in rainfall were increased rapidly in the Niger republic.

Literature has shown that genetic erosion of pearl millet continues to take its toll owing to drought and unreliable rainfall in northern Nigeria (less than 300mm) and in many years, barely adequate to support the cultivation of millet which is the primary grain crop of the area (Federal Government of Nigeria, 2012). Thus, climate variability is a leading driver of the loss of pearl millet cultivars in northern Nigeria (Izge & Song, 2013). The global food crisis that causes seed erosion, and affects the livelihood of small-holders farmers in Nigeria, has been attributed to several factors including climate change (Okechukwu & Tony, 2014).

4.4 Changes in Food Preferences

Pearl millet was the only reliable cereal crop to relieve the core threat of starvation in the harsh climatic areas of the world (Porter, 2014). It serves as a major source of food for more than 40 million smallholder farmers living in the marginal agricultural lands of Northern Nigeria (Chandra-sekara, & Shahidi, 2011). Yet, at present, pearl millet suffers from disregard and misunderstanding because the crop grows in some of the poorest countries and was considered as the food for the poorest people in the world. Therefore, people have unjustly stigmatized it as a poor crop. It was replaced by other crops such as rice, wheat, and maize in Nigeria and other parts of the West Africa sub-region. Changes in food preferences of a growing urban population, the market orientation of growers, and decreasing demand for local products may also enhance the loss of pearl millet diversity (FAO, 2010; Karandikar, 2018). Due to commercial farming and change in food preference in southern Africa, maize has almost displaced millet cultivation (Gloria, 2013).

4.5 Conflicts

4.5.1 Insurgency in Northern Nigeria

The Boko Haram insurgency has led to massive displacements and high levels of insecurity in Northern Nigeria. Many communities have fled in large numbers because of violence, placing considerable pressure on the fragile agricultural sector. An FAO Seeds System Security Assessment indicated that the insurgency has negatively affected both the formal and informal seed systems in the northeastern states (FAO, 2017). There have been reports that over 4.4 percent of the households in Borno, Yobe, and Adamawa states could not cultivate due to the lack of essential farm inputs including seeds and fertilizers. This is attributed to the insurgency attacks, which affected agricultural activities in the states (FAO, 2016). Incessant bombing and violent attacks of smallholder farmers by the Boko Haram sect pose a grievous risk to northern farmers, it has forced them to migrate to the neighboring countries of Niger, Chad, and Cameroun. The crisis has forced them to abandon their land and loss the genetic erosion of their several traditional crops including pearl millet that was suitable to the harsh climatic condition in the area (Okechukwu, & Tony, 2014).

4.5.2 Bandits and Herdsmen or Farmers Attacks

In recent years, violent attacks between herdsmen and farmers reached significant proportions in many states around the country, the conflict emanated as a result of the use of limited natural resources in the area (Onyibe, 2019). The competition turned into serious hostilities and social friction in many parts of Nigeria (Ajibo, *et al.*, 2018) And have established a high potential to worsen the insecurity crisis particularly among the small-holder farmers in rural communities. The effect of this conflict ranges from the destruction of lives, properties, a decline in agricultural products, and farmers in the frontline were kept away from their farmlands due to bandit attacks (Suleiman & Iguda, 2019). During these conflicts, innocent community members are attacked, pastoralists invade farms and damage crops that are peculiar with the environmental conditions in the area, subsequently, such crop varieties will be a loss (Ahmadu, & Ayuba, 2018). In line with this Fasona, *et al.* (2016) reported that in most cases Fulani herdsmen hardly request any permission and thus are regarded as invaders, this has been a major trigger of violence with the consequence to the livelihood of small-holder farmers.

An attack on the small-holder farmers forced them to abandon their homes, farm products, stored seed, and search for alternative safety places (Nte, 2016). A report from Kaduna state revealed that militia herdsmen in some villages of Sanga Local Government area killed 123 farmers (Shiklam, 2014). Similarly, Zamfara State experiences an orgy of violent attacks by Fulani herdsmen and more than 200 were killed (Net, 2016). Several crops with diverse genetic

resources were lost including pearl millet. The destruction has a direct impact on the small- holder's livelihood as their source of food and economic activities are tied to those environmental resources.

4.6 Plant Breeding

Modern breeding has resulted in crop varieties that meet the requirements of high-input systems and strict market standards. However, the introduction of modern varieties or hybrids to traditional farmers appears to have influenced the neglect of genetic diversity, although the loss of pearl millet varieties situation is equally complex. Studies have reported that plant breeding is a strong force in the reduction of genetic diversity (Gepts, 2006). This view was earlier reported by Bennet, 1973 that the introduction of modern cultivars has seriously affected several crops including pearl millet at different levels in the regions of northern Nigeria. Hybridization in the form of modern agriculture has caused the loss of variation in crops and genetic erosion of crops in almost all parts of the world (Mark *et al.*, 2009).

4.7 Inappropriate Legislation and Policy

African farmers are custodians of enormous genetic diversity of millets, which has adapted to adverse agro-ecological conditions of the continent (Manson, Maman & Pale, 2015). Despite the careful selection of plant materials through various methods and preferences, crop landraces throughout the world are rapidly being lost, due to increasingly more limited use by growers in many areas of the world, which is traceable to the beginnings of the "Green Revolution" (Walters, 2018). The Green Revolution had a globalizing effect on agriculture and plant breeding, bringing broadly adapted new crop varieties to regions of high crop genetic diversity where locally adapted landraces grew. This has culminated in the erosion of the 'genetic estate' on which future crop development depended (Sara, 2016). Literature is replete with information that the politics of seed has been a barrier to crop diversification in Africa (Scoones & Thompson, 2011). Today, the lack of appropriate legislation and policy on seeds has arguably been a major driver of the loss of pearl millet varieties in Nigeria.

5. Saving the Pearl Millet Varieties of Northern Nigeria

Several suggestions were hitherto given in the literature to constructively revive seed related activities in Nigeria. The following will inform the re-design of an appropriate pearl millet seed system for targeted communities and Nigeria at large.

5.1 Outlining the Roles and Responsibilities of Key Actors in the Seed System in Nigeria

The National Agricultural Seed Council (NASC) is Nigeria's seed distribution channel. Implementation of the National Seed Policy is directly coordinated by the NASC as the principal institution under the Federal Minister of Agriculture and Rural Development (FAO, 2016). It is saddled with the responsibility of ensuring the availability, access, quality, and varietal suitability of seeds in the country. The National Seed Policy has since undergone review; however, it is far from a crisis. Its regulatory policy aimed at the protection and conservation of seeds needed to be improved for the implementation of seed programs and projects to move the industry forward. The underlying fragile seed situation triggered by other factors example an upsurge in conflicts in the north has disturbed local markets.

5.2 Community Seed Banks and Seed Fairs

The preservation of seeds in repositories known as seed banks emerged, as a conservation strategy, in the 1960s and 70s, as an approach to protect agricultural genetic diversity against 'genetic erosion' of landraces (Sara, 2016). At the community level, seed banks have been important means of preserving the biodiversity of the threatened seeds. Smallholder farmers have historically used traditional techniques of protection of threatening biodiversity through restricting the collection of germplasm and development of seed banks and farmer seed exchange networks (Mkindi, 2015). A review of literature has shown that gene banks have taken on responsibility for collections of materials with special genetic characteristics in rural societies in northern Nigeria. Mohammed (2005) reported that the farmer seed system (community-based) is responsible for the 'robust' production of pearl millet in northeastern Nigeria. This further confirms that to be able to cope well under stress, smallholder farmers demonstrate a high level of interdependence in the seed system (Ortiz *et al.*, 2008). Seed banks, therefore, enhance crop diversity because varieties can also be sourced ex-situ and by collecting samples in situ or acquiring them from another person or organization.

5.3 Outlining the Roles and Responsibilities of Key Actors in the Seed System in Nigeria

Breeding is simply defined as the selective mating of individuals of a population to isolate or combine desired morphological, physiological, or genetic traits such as appearance (Mohammadi & Prasanna, 2003; Chen, *et al.*, 2019). Before the advent of science-based agriculture, plant breeding was strictly a local activity. Farmers selected genotypes

according to their own needs and preferences and for adaptation to a particular place. The transition from primitive to advanced cultivars had the effect of narrowing the genetic base as new varieties were uniformly bred, aiming for high yields and broad geographical coverage (Frankel & Bennett, 1970; Markgraf, 2018). Participatory breeding is a strategy for avoiding global genetic erosion through practices of collection and preservation of seeds that create records of genetic diversity. In this way, 'primitive' plant varieties that were endangered by changes in agricultural practices could be preserved by freezing their seeds (Sara, 2016).

6. Saving the Pearl Millet Varieties of Northern Nigeria

Pearl millet has proved very valuable in northern Nigeria. Its high nutritive values increase insulin sensitivity, lower the level of triglycerides, and very efficiently used to maintain blood sugar levels. It also has a high level of energy, some vitamins, dietary fiber, and many essential minerals, leading to greater benefits to smallholder pearl millet farmers in Nigeria. However, environmental, social, and cultural changes amongst various challenges facing the farmer-saved seed system in Nigeria, have led to erosion of the genetic diversity of pearl millet. Accordingly, smallholder farmers were affected to plant the local varieties of pearl millet, which adapted most to the agro-ecologies of the region. This study, therefore, recommends that there is a need for the creation of activities such as seed fairs, participatory varietal seed selection, and storage and treatment process. This can be achieved by the full participation of government by taking appropriate actions such as organizing enlightenment workshops, which have a direct bearing on the actual farmers at the grass-root level. Secondly, there is the need to institutionalize this informal system of indigenous practice of seed management to complement and enhance a better control of seed erosion. This can be achieved by harmonizing on-farm activities through agricultural organizations and NGOs.

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