Pearl Millet Breeding and Production in Nigeria: Problems and Prospects

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ABSTRACT

This work reviews the problems in pearl millet production and breeding and its prospects. Pearl millet is a staple for millions of people in arid and semi-arid ecologies around the world especially in northern Nigeria. The crop has a potential of becoming an important component of intensive agriculture because it responds well to management inputs. However, improvements in certain traits of pearl millet need to be undertaken if high yields are to be attained. Considering also its hardiness and genetic enhancement prospects, the crop has the potential of becoming important components of intensive agriculture especial in Nigeria. Breeding work on the various aspects of this crop and sustained cultivation need to be encouraged.

Keywords: *Pearl millet, Breeding, production, staple*

INTRODUCTION

Pearl millet (*Pennisetum glaucum L. R. Br.)* known as *bajra* in Hindu or *'yadi'* in Marghi language of north eastern Nigeria is the most important and probably having the greatest potential among the millet varieties. It is a robust, quick growing cereal grass with large stems and leaves which are tall and vigorous, with exceptional grain and fodder yielding potentials. It is one of the most important dual purpose crop, and a staple food for millions of people in arid and semi-arid ecologies around the world according to Chopra (2001). Pearl millet is the sixth most important cereal annually cultivated as rain fed crop in arid and semi-arid areas of Africa and the Indian sub-continent (Khairawal, Rai, Andrew and Harrnarayana, 1999; FAO, 2007). It is grown in over 40 countries predominantly in Africa and Asia as a staple food grain and source of feed and fodder, fuel and construction material (FAO, 2007). The crop is well adapted to some extent to growing areas characterized by drought, low fertility and high temperatures. It could relatively perform better on soils with high salinity or low pH values. Because of its tolerance to difficult growing conditions, it can be grown where other cereals such as maize or wheat would not survive. Pearl millet responds well to management inputs, therefore it has high potential of becoming an important component of intensive agriculture especially in arid and semi-arid regions (Izge, 2006). India according to ICRISAT report of 2011, is the largest producer of pearl millet in Asia, both in terms of area and production with an average productivity of 930kg/ha. However, yields of pearl millet have over the years decreased. Pearl millet breeding in West and Central Africa and indeed in Nigeria has concentrated on the development of open-pollinated varieties. Hybrids in Nigeria and elsewhere are likely to have at least 25-30 % grain yield advantages over OPVs and hence a new herculean and costly initiative have been put in place by individuals and Lake Chad Research Institutes in Maiduguri, Nigeria that has a national pearl millet research mandate to develop hybrids adapted to drier regions. Twenty-five OPVs, developed and released by ICRISAT have been adopted by farmers in nine countries in the West and Central African regions including Nigeria. The most popular varieties like SOSAT-C88 and GB 8735 for example have been released in Nigeria for many years back. Limited seed production and distribution has in addition to research progress been a major bottleneck and has slowed the spread of improved cultivars in the region. Within the last two decades, Nigeria has become increasingly important in the production of pearl millet even with the numerous problems involved in its cultivation. Nigeria has moved from the third to the present second largest producer in the world (Aminu, Ajayi, Ikwelle and Anaso, 1998).

Pearl millet improvement programme in Nigeria is concerned with higher yield for human food and this will likely play a major role in easing the world food shortage as population skyrockets. Izge (2006) reports that the purpose for expanding pearl millet production in Nigeria has actually been deliberate to meet the growing demand for food which incidentally depends on the success of research in pearl millet cultivation and hybrid improvement programmes. Pearl millet production is hampered by numerous problems and as such there is a need to find ways of improving its productivity. Izge, Abubakar Echekwu (2005) have reported high potentials for making progress in the selection of traits in pearl millet towards higher grain yields because of higher genotypic variability existing among the land races. The work reviews the uses, constraints and the prospects of pearl millet production and breeding research in Nigeria.

Uses of Pearl Millet: Nigeria uses millions of tones of pearl millet as staple food in many homes, especially among the poor predominantly in Northern Nigeria (FAO, 2007). It is also used in making a popular fried cake known as *"masa"*. Its flour is also used in preparing *"tuwo"* a thick binding paste, also referred to as *"toh"* in northern Africa. It contains 18% protein, rich in vitamin B especially niacin, B6 and folic acid. It is fitted for flat bread especially because it lacks gluten. It is an important food across the Sahel. It is particularly the main staple in a large region of northern Nigeria, Niger, Mali and Burkina Faso. It is often ground into flour, rolled into large balls, parboiled, liquefied into a watery paste using fermented milk and then consumed as a beverage. This beverage called *"fura"* in Hausa or *"tukura"* in Marghi language is a popular drink in northern Nigeria and southern Niger. Pearl millet is an excellent forage crop because of its low hydrocyanic content. The green fodder is rich in protein, calcium, phosphorus and other minerals with oxalic acids in safe limits. It is more digestible when fed green to animals rather than chaffed straw (Chopra, 2001). The glumes and pericarp *"dusa"* are also used in preparing feeds for livestock including poultry. The stalks are used in making mulches and as fuel woods. People with celiac diseases can replace certain gluten containing cereal in their diets with pearl millet.Pearl millet has significant potential as feed and food grain in addition to its current use as forage. The agri-tourism and recreational wildlife industries are finding superior results from using pearl millet in rations for bobwhite quail production (Savage 1995), and for supplemental feeding. It also seems to be an excellent feed for other birds, including dove, turkey, song-birds, ducks, and swine. The large immigrant population from Africa and the Indian subcontinent where pearl millet is a staple food ensures a steady demand in the US in the foreseeable future. Being gluten-free, marketing opportunities for this grain also exists in the health-food outlets.

Pearl millet is well-adapted to regions where many numbers of broilers are produced around the world (Radcliffe et al., 2001). It is equal to or better than typical maize-soybean poultry diets for broiler production and can be fed at up to 10% of the ration without grinding (Davis, Dale and Ferreira, 2003; Hidalgo, Davis, Dale and Dozier, 2004), thus reducing feed processing costs. Pearl millet grain is at par or even better than maize in poultry diets (French 1948; Singh and Barsaul 1976; Sharma, Sadagopan and Reddy, 1979). Broilers fed on pearl millet rations were heavier and had better feed conversion rate than those fed on maize (Lloyd 1964), and mixed maize and sorghum (Sullivan, Douglas, Bond and Andrews, 1990). Kumar, Reddy V., Reddy P. and Reddy R. (1991) studied feed efficiency of laying hens and found increased egg size and better feed conversion when pearl millet was substituted for maize at 60 % by weight. Pearl millet grain contains 27 % to 32 % protein, higher concentration of essential amino acids, twice the extract (fat) and higher gross energy than maize (Ejeta, Hansen and Mertz, 1987; Davis, Dale and Ferreira, 2003). The energy density of pearl millet grain is relatively high, arising from its higher oil content relative to maize, wheat, or sorghum (Hill and Hanna 1990). Collins *et al.* (1997) note commercial layers given feed containing pearl millet grain had lower Omega-6 to Omega-3 fatty acid ratio, endowing the eggs with a fatty acid profile more favorable to human health. The amino acid profile of pearl millet grain is better than that of normal sorghum or normal maize and is comparable to those of the small grains wheat, barley, and rice (Ejeta, Hansen and Mertz, 1987) with a less disparate leucine/isoleucine ratio (Hoseney, Andrews and Clark, 1987; Rooney and McDonough, 1987). The lysine content of the protein reported in pearl millet grain ranges from 1.9 to 3.9g per 100g protein (Ejeta, Hansen and Mertz, 1987). Pearl millet grain appears to be generally free of any major anti-nutritional factors, such as the condensed tannins in sorghum grain having a pigmented testa, which reduces protein availability.

Ethanol use as an additive in formulated gasoline will increase. Wu, Wang, Bean and Wilson (2006) observe that the rate of fermentation of pearl millet was 30 % greater than rate of fermentation of corn, and distillers dried grains with soluble (DDGS) crop products were higher in protein and fat. Less ethanol is produced from pearl millet fermentation, but because of its higher protein content, the yield and value of DDGS is greater, resulting in higher economic return from pearl millet than from corn. Experiments indicate that pearl millet can supplement maize and sorghum feed stocks for fuel ethanol production (Hidalgo, Davis, Dale and Dozier, 2004). Ethanol production is a potential future market for the grain, since few fermentation facilities currently exist.

Challenges in Pearl Millet Breeding

Poor productivity for grain yield of unimproved cultivars of pearl millet is related to its low harvest index; numerous biotic stresses including diseases, insect pest and striga and abiotic stress factors such as heat drought and low soil fertility. Clearly all these factors cannot be addressed with the same priority at any given time by breeding. The relative impacts of production constraints on yield loss are the primary criterion in research prioritization (Rai, Murty, Andrews and Bramel-cox, 1999). However, when it comes to genetic enhancements the probability of success can be affected by a complex interplay of several factors such as availability of genetic resources, inheritance and stability of the traits desired to be improved, simplicity and effectiveness of the screening techniques, that is, reliability and cost effectiveness, access to test environments and availability of technical manpower and material resources that also become determinant and sometimes of overriding importance. Breeding for high and stable grain yield with an improved harvest index continues to be the top priority in all millet programmes worldwide; this is because according to Chopra (2001):

i. Impressive grain yield through cultivar improvement especially in hybrids have been made in the past and there are no indications that yield ceiling have been reached.

ii. The available germplasm provides vast genetic variability for yield components and adaptation traits of which only a fraction even from the cultivated types have been utilized.

iii. Understanding of the inheritance of most of the characters has been sufficient for utilization.

iv. Evaluation procedures like effective use of visual assessment are relatively simple to use.

v. Breeding for most of those traits requires no special environment.

In drier and in areas with marginal rainfall for example, drought is the most devastating constraints that can occur at any growth stage in pearl millet. Rai, Murty, Andrews and Bramel-cox, (1999) report that post flowering, that is to say, terminal or end of season drought stress is of greater significance and is much better understood than pre-flowering stress in pearl millet. For instance the crop growth that occurs during the post flowering period have been demonstrated to be the most sensitive to water deficits (Mahalakshmi and Bidnger, 1985). The terminal drought has been shown to reduce grain yield by 40 - 49 % with large variation among genotypes (Fussel, Bidinger and Bider 1991). Panicle threshing percentage under stress condition is a good indicator of terminal drought tolerance in pearl millet. In conjunction with grain yield potential and earliness, it accounts for greater than 80 % of the genotypic variation in grain yield under terminal drought stress (Bidinger and Mahalakshmi, 1993). However, published information confirming the existence of adequate variability for drought tolerance parameters and adequate heritability of the traits associated with drought tolerance are not in abundance. Also, the effectiveness of the screening techniques available for selecting the drought tolerance have not been demonstrated convincingly in terms of material selected for superior drought performance in a drought nursery at one location will perform under drought stress in another location.

Pearl millet downy mildew caused by *Sclerospora graminicola* has also been a serious problem to plant breeders even though; it presents a clear contrast to drought. Its impact to pearl millet production on a global context even though secondary to that of drought, however, its epidemics on a single-cross hybrid has occurred in Africa. Breeding for resistance of downy mildew therefore, has been accorded highest priority as reported by Hash *et al.* (1997) and it is the integral part of the majority of the breeding programmes in Africa because:

i. A large number of resistance sources (including elite breeding lines) have been identified in diverse genetic backgrounds and effective screening techniques have been developed (Singh *et al.*, 1997); and
ii. Inheritance of resistance is better understood with most of the evidence in favour of resistance being dominant and displaying continuous variation in segregating populations.

Over the years many centers in the National Agricultural Research Systems have initiated or stepped up their downy mildew resistance breeding activities (Chopra, 2001).

Genetic Resources and Future Prospects for Pearl Millet Breeding

Germplasm collection was initiated in India by the Indian council of Agricultural Research and Rockefeller foundation some years back. A world collection of germplasm of different millet was assembled and evaluated by the Indian Agricultural Research Institute New Delhi. Most lines from Africa were found to be susceptible to rust, smut and downy mildew. Alleles for early flowering (55 days) were found in East African collection and in some lines from Ghana. Late flowering types (80 days) or more were observed in the West African material particularly from Mali and Senegal (Murty, Arunachalam and Saxena, 1967; House, 1980, 1985).

Pearl millet germplasm evaluation has identified sources of increased grain yield potential, cytoplasmic male sterility systems (Hanna, 1990, 1993), disease resistance to rust *(Puccinia sp.)* and *Pyricularia* leaf blast (Hanna and Burton, 1987; Wilson and Hanna, 1992) and apomixes in several species and wild relatives (Hanna, 1995). Sources of resistance to important diseases such as downy mildew (*Schlerospora graminicola)*, Smut *(Moeziomyces penicillariae)* and ergot *(Claviceps fusiformis)* have also been identified according to (Thakur and King, 1988; Singh, King and Werda, 1993). Through improved screening systems in pearl millet tolerance and resistance to witch weed (Striga *hermonthica)*, head miner (*Heliochelus albipunctella)*, stem borer *(Coniesta ingnefusalis)* have been identified.

Research shows that a greater impact may be made on pearl millet productivity in Africa through hybrid cultivars as occurred earlier in India and Nigeria. House *et al.* (1997) summarized yield trial result of several studies in Africa and show that generally, hybrid grain had yield advantages of 25 - 60% over OPVs. A similar summary by Rai *et al.* (1997) showed that top cross and inter-population hybrid had a 30 - 50% grain yield advantage over improved OPVs. Some of the popular pearl millet OPVs included M2D2 and M9D3 in Mali, Souna III in Senegal, Sere 3A n Tanzania, Sere 6A in Botswana and Okashana I in Namibia and SOSAT-C88 and EX-BORNO in Nigeria. Most of these varieties yielded only 10 - 20% more than the unimproved locals and were not backed by adequate seed production which leads to their low coverage.

Pearl millet will continue to be an important grain for farmers in dry regions of the semi-arid tropics of Asia and Africa since suitable areas and government policies for the expansion of favored cereals such as rice, wheat, barley and maize have dwindled. Therefore, pearl millet which has exceptional qualities for growth and adaptation to marginal environments has the potential of becoming a more important crop for feeding the growing population in those regions in the 21st century. Several published reports on the inheritance of downy mildew resistance summarized by Hash *et al.* (1997) demonstrate downy mildew resistance to be controlled by one or two dominant genes, while Izge, Kadams and Gungula (2007) reported it to be controlled polygenically and by additive and non additive gene effect. Breeding for resistance to disease of economic importance especially downy mildew will contribute to productivity and stability of pearl millet grains, stover and forage yields.

Pearl millet has a higher level of protein and better amino acid profile than sorghum. The digestibility of sorghum protein is relatively poor because cross-linked prolamine levels are relatively high in sorghum than in pearl millet (Rai, Murty, Andrews and Bramel-cox, 1999). No high-lysine mutants have been identified yet in pearl millet study and has shown that is should be possible to select for increased protein without sacrificing grain yield (Kumar, Gupta and Andrews, 1993). Also considerable pearl millet area especially in Nigeria has highly acidic soils (pH<5.0).

Genetic variability for high tolerance to acid soil toxicity has been observed in pearl millet (than sorghum) (Clark, Flores, Gourley and Duncan, 1990; Flores, Clark and Gourley, 1991). Breeding pearl millet cultivars with this tolerance trait will not only boost the yield of this crop in Africa but pearl millet will be considered a potential crop for this region. Pearl millet is already finding a place in other places around the world as a component of acid soil tolerant mulch in a no till soybean production system (Uemura, Urben and Netto 1997). The area sown to pearl millet is growing rapidly around the world.

CONCLUSION

Unlike rice, wheat, barley and maize which are used both for food and industrial purposes pearl millet have so far remained a traditional food crop for subsistent farmers in Nigeria and many other dry regions of Africa and Asia. The crop is also a source of excellent feed for livestock. Considering also its hardiness and genetic enhancement prospects, the crop has the potential of becoming important components of intensive agriculture especial in Nigeria. Breeding work on the various aspects of this crop and sustained cultivation need to be encouraged.

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