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Opportunities for enhancing production, utilization and marketing of Finger Millet in Africa

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Abstract

The world is faced with the challenge to produce more food to feed a projected 9 billion people worldwide; including 2.5 billion in Africa. Just a few "mega-crops" currently feed the world, with rice, wheat and maize providing 60 percent of the total population's energy intake. Finger millet belongs to a group of secondary crops that provide another 25 percent of the world's food energy. Finger millet is adaptable to diverse agro-ecological conditions, has beneficial nutritional properties and outstanding agronomic attributes as a subsistence food crop; therefore, it holds promise for the future of food and nutrition security in Africa and around the world. Despite these desirable attributes, only about 3 million tones are produced globally each year. Common production constraints include low soil fertility, *Striga* weed infestation, and pest and disease pressure, particularly finger millet blast disease, which can cause up to 50% yield loss. Low rates of finger millet production are compounded by a lack of stable market outlets and inadequate product development strategies. Recent research efforts in Africa and South Asia, however, have the potential of alleviating these production constraints. Opportunities now exist for enhanced technology development, which may increase production, product development, value addition, marketing and consumption of finger millet. Capitalizing on these opportunities could ensure that finger millet, as a "novel" crop, increases food and nutrition security in Africa and around the world.

Key words: Finger millet, technology development, food and nutrition security

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Introduction

Projections indicate that the world's population may increase from about 7.9 to 10.5 billion people by 2050 (United Nations, 2009). In order to achieve sustainable food and nutrition security for the growing population, global agricultural production needs to increase by 60% to 110% on the same timeline (Tilman *et al*., 2011). Increased food production, however, will be constrained by several factors including the numerous effects of climate change. It is predicted that attaining high yields on existing cropland, especially in under-yielding nations, will be of great importance if global crop demand is to be met with minimal environmental impacts (IPCC, 2007; Schmidhuber and Tubiello, 2007). Over the past few years, food production in Africa has increased at a very minimal rate, yet the continent will need to produce at least 50% more food by 2050 to feed a projected 2.5 billion people (Godfray *et al*., 2010). This presents a challenge to African scientists, policy makers, entrepreneurs and farmers, to intensify their efforts to achieve food and nutrition security. In order to sustainably feed Africa with nutritious foods, we must diversify beyond conventional food crops (rice, wheat, maize, etc.) also known as 'mega-crops' and increase attention to 'orphan', 'neglected' or 'underutilized' crops such as sorghum, millet, root and tuber crops, and legumes.

Millet production in Africa and South Asia

Millets are a diverse group of cereal crops that produce small seeds with good nutritional properties compared with more conventional staple grains (Table 1). Millets are a major food source for resource-poor farmers in the semi-arid tropics, due to their ability to grow in poor soils with limited inputs (Kothari *et al*., 2005). There are many different millet species grown on nearly 20 million hectares in Africa (FAOSTAT, 2015). Four of the most commonly grown millets are: Pearl millet [*Pennisetum glaucum* (L.) R. Br.], Foxtail millet [*Setaria italica* (L.) P. Beauv.], Proso millet (*Panicum miliaceum* (L.) and Finger millet [*Eleusine coracana* (L.) Gaertn.]. The rest are referred to as minor millets and include Barnyard millet (*Echinochloa* spp.), Kodo millet (*Paspalum scrobiculatum*), Little millet (*Panicum sumatrense*), Guinea millet (*Brachiaria deflexa*) and Browntop millet (*Urochloa ramose*) (Amadou *et al*., 2013). Millet production is distributed differentially among a large number of African countries; the largest producers being in West Africa led by Nigeria (41%), Niger (16%), Burkina Faso (7%), Mali (6.4%) and Senegal (4.8%) (Obilana *et al*., 2002).

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Table 1: Nutrient composition of finger millet and other cereals (per 100 g edible portion; 12% moisture)

Component	Rice (brown)	Wheat	Maize	Sorghum	Pearl millet	Finger millet
Energy (kcal)	362	248	358	329	363	336
Carbohydrate (g)	76	71	73	70.7	67	72.6
Protein[a] (g)	7.9	11.6	9.2	10.4	11.8	7.7
Fat (g)	2.7	2	4.6	3.1	4.8	1.5
Ash (g)	1.3	1.6	1.2	1.6	2.2	2.6
Crude fibre (g)	1	2	2.8	2	2.3	3.6
Ca (mg)	33	3	26	25	42	350
Fe (mg)	1.8	3.5	2.7	5.4	11	3.9
Thiamin (mg)	0.41	0.41	0.38	0.38	0.38	0.42
Riboflavin (mg)	0.04	0.1	0.2	0.15	0.21	0.19
Niacin (mg)	4.3	5.1	3.6	4.3	2.8	1.1

[a]All values except protein are expressed in dry weight basis (Saleh *et al*., 2013).

Millet productivity in the last five decades showed consistent increases in China, 132%, India, 182%, Nigeria 80% and Uganda, 40%. However, in African countries including Kenya, Namibia, Rwanda, Burundi, and Zaire, productivity declined substantially by up to 71% in the last decade (Dwivedi *et al*., 2012). This decline, both in production and consumption could be attributed to the negative attitude and stigmatization of millets including finger millet which are often referred to as a 'lost', 'minor', 'poor man's crop' or 'birdseed' (United States National Research Council, 1996). Therefore, there is need to change the negative perspective of finger millet especially in Africa where it has great potential as a food and nutrition security crop.

Finger millet production and utilization potential in Africa

Finger millet is one of the most important millets worldwide. It was domesticated and is mostly produced in the eastern African sub-humid uplands (Hilu *et al*., 1979; United States National Research Council 1996). It belongs to the grass family *Poaceae* in the sub-family *Chloridoidae*. It is an allotetraploid (2n=4x=36), genome constitution AABB. Cultivated finger millet resulted from the selection and domestication of a large-grained mutant of the wild *E. coracana* subsp. *africana* (Hilu *et al*., 1979, Babu *et al*., 2007; Dida *et al*., 2008). The common name "finger millet" is derived from the shape of the inflorescence which consists of a number of spikelets which resemble the shape of human fingers. The spikelets produce seeds which are globose and smooth and may be coloured brown, reddish brown, black, purple, orange or white (Duke, 1983). The high variability of the inflorescence may be a consequence of farmers' selection preferences for crop characteristics (de Wet, 1995). Subsequently, the races and sub races of finger millet can be differentiated from one another by inflorescence morphology (Prasada Rao *et al*., 1993).

Finger millet is ranked fourth in importance among millets in the world after sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*); and can be cultivated under varied agro-climatic conditions (Upadhyaya *et al*.,

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2007; Dida *et al*., 2007). In Africa, it is extensively cultivated in Uganda, Kenya, Tanzania, Ethiopia, Rwanda, Burundi, Zambia and Malawi (Mnyenyembe and Gupta, 1998; Obilana *et al*., 2002). In South Asia, finger millet is widely cultivated in India and Nepal (Upadhyaya *et al*., 2007). It is estimated that finger millet accounts for 11% of production of all millets worldwide (Bennetzen *et al*., 2003). Under irrigated conditions, yields of up to 5–6 metric tons ha^{-1} have been obtained (United States National Research Council, 1996).

Finger millet has wider adaptability (Upadhyaya *et al*., 2007), higher nutritional quality (Gopalan *et al*., 2002), and higher multiplication rate as compared with other species of millet. Finger millet can also be stored for a long time without insect damage (Adekunle, 2012), hence it is important during periods of famine. These qualities make finger millet an ideal crop for use as a staple food and for famine reserve. However, even though traditional finger millet varieties are adapted to current environmental conditions, it is predicted that they will be less suitable to the changing climate. Research results indicate that finger millet is sensitive to high temperature stress during reproductive stages, and there is genotypic variability among finger millet genotypes for number of seeds per panicle and grain yield under high temperature stress, therefore the challenge will be to accelerate its adaptation to climate change (Vermeulen *et al*., 2012, Opole *et al*., 2018). Additionally, the projected food demand for 2025 will require the yield of millets to rise from 2.5 to 4.5 t ha^{-1} (Borlaug, 2002). This increase will largely come from improved varieties modified for resistance to abiotic and biotic stresses (Kothari *et al*., 2005).

Finger millet is grown mainly by subsistence farmers and serves as a food security crop because of its high nutritional value and excellent storage qualities. Due to these desirable characteristics, it is now receiving increased attention from food scientists, technologists, and nutritionists, especially as an ingredient with the potential to prevent chronic disease (Kannan, 2010; Saleh *et al*., 2013). These health benefits are attributed to its polyphenol content (Chethan and Malleshi, 2007) with antioxidant properties that protect against degenerative diseases (Rhodes and Price, 1997; Hooper and Cassidy, 2006). Every 100g of grain contains 72.6 g of carbohydrates, 7.7 g protein, 1.5 g fat, and 3.6 g crude fiber. High levels of calcium (350 mg), iron (3.9 mg); and amino acids thiamine 0.42 mg, riboflavin 0.19 mg, and niacin 1.1 mg have also been reported in finger millet; see Table 1 (Saleh *et al*., 2013).

Despite the desirable nutritional qualities of finger millet, utilization of nutrients is limited by the presence of phytates, phenols, tannins and enzyme inhibitors (Sripriya and Chandra, 1998). These effects can be reduced through processing techniques that increase bioavailability of minerals like calcium and iron. These techniques include grinding/milling, popping, roasting, malting and fermentation (Singh and Raghuvanshi, 2012). Supplementary feeding programs in Colombia, Kenya, Nigeria, Senegal and Sri Lanka have effectively used nutrient-dense finger millet recipes with acceptance from participants (Singh and Raghuvanshi, 2012). Composite flours that combine wheat, finger millet and legume are a good option for providing a wider variety of nutrients and consumer acceptable qualities (Lupien, 1990).

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One of the challenges to African scientists is to enhance the productivity and utilization of finger millet. In Eastern Africa, particularly in Kenya, Uganda and Ethiopia, researchers are working to increase productivity, utilization and nutritional enhancement of this highly nutritious food and nutrition security crop.

Research interventions for enhanced finger millet production, utilization and marketing in Africa

Finger millet is categorized as a neglected and underutilized species (NUS) (Chadha and Oluoch, 2007; Kahane *et al*., 2013). One of the Plant Genetic Resources for Food and Agriculture's measures of sustainable use is to promote use of locally adapted crop varieties and underutilized species including finger millet (FAO, 2004). Germplasm improvement is a key step to achieving this objective. Much effort has been undertaken to develop finger millet for the varied agro-ecological niches of Africa (Bennetzen *et al*., 2003; Wanyera, 2007; Dida *et al*., 2008; Oduori, 2008), and there is on-going research in Eastern Africa to develop finger millet varieties with superior traits including high yield; pest, disease and Striga weed resistance; and adaptation to local growing conditions. Additionally, breeders are working on improving traits desirable for marketing and utilization, discussed in the next section.

Finger millet germplasm evaluation and variety improvement

Successful crop improvement requires the ability to identify and access genetic diversity including new or improved variability for target traits. Plant genetic resources are the raw materials for the development of improved cultivars (Upadhyaya *et al*., 2007). In crops with large germplasm collections such as finger millet, mini core collections (10% of core or 1% of the entire collection) have been suggested (Upadhyaya and Ortiz, 2001). These are composed of a smaller number of well characterized accessions which are given priority for use in crop improvement (Upadhyaya *et al*., 2009). A finger millet mini core collection of 80 accessions has been developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. Accessions ranked highly for desirable traits including grain yield are recommended for adoption in areas where finger millet is commonly grown, after undergoing multi-location testing to verify their agronomic and utilization potential. Enhanced germplasm evaluation for targeted traits would enable breeders to develop high yielding cultivars with a broad genetic base (Upadhyaya *et al*., 2006).

To date, small millets have been improved through conventional breeding due to their self-pollinating nature. However, there is need to assess the efficacy of other types of breeding procedures including biotechnology, in order to develop resistance against biotic and abiotic stresses and continue to improve quality for wider consumer acceptance and utilization. Studies to determine field performance potential of finger millet germplasm may be complemented by marker assisted selection for rapid trait identification and incorporation into improved germplasm. In a study employing Random Amplified Polymorphic DNA (RAPD), a higher genetic diversity was observed among 12 wild finger millet accessions, indicating that they contain a large proportion of genetic variation (Fakurdin *et al*., 2004) which may be exploited for genetic improvement of finger millet in Africa.

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Finger millet breeding strategies in Eastern Africa include germplasm evaluation for resistance to lodging, blast disease (*Magnaporthe grisea*), Striga weed (*Striga hermonthica* (Del.) Benth), improved grain quality and yield, and acceptability for use with post-harvest technologies (Oduori, 2007; Wanyera, 2007). In Kenya, researchers are investigating the efficacy of ethrel (a phytohormone) for finger millet hybridization (Ashraf Bhat *et al*., 2010). Purple pigmentation and other morphological traits are used to detect successful crosses. The development of an efficient hybridization protocol and exploration of finger millet molecular biology, especially the application of marker-assisted selection, could significantly increase finger millet yields (Oduori, 2007).

The construction of a finger millet genetic map has been viewed as an important step towards mapping and transferring traits of agronomic importance (Dida *et al*., 2006). A genetic map of finger millet has been generated using restricted fragment length polymorphism (RFLP), amplified length polymorphism (ALP), expressed-sequenced tag (EST) and simple sequence repeat (SSR) markers. Additionally, molecular diversity parameters have shown higher values in African accessions of finger millet which are useful for parental selection, conservation and utilization (Arya *et al*., 2013). Consequently, a finger millet genomics project, the Bioinnovate Project, will provide researchers with enhanced tools for variety improvement in Kenya. The knowledge gained and molecular tools developed will be utilized by breeders to complement conventional breeding efforts.

Genetic transformation is now a widely used method for exotic gene transfer into commercial crop cultivars to enhance various agronomic attributes, and finger millet should be no exception. Transgenic finger millet lines exhibiting a high level of resistance to the leaf blast fungus have been successfully produced in India (Ignacimuthu and Ceasar, 2012). They are bred with exotic resistance and appear promising for varietal improvement of finger millet in Africa. A comparative analysis has also been carried out to determine the relationship of the finger millet genome with that of rice (*Oryza sativa*). Results showed that information and resources available from rice and other grasses could be readily exploited due to the high colinearity between finger millet and rice, with traits such as blast and drought resistance being of immediate interest to finger millet breeders (Srinivasachary *et al*., 2007).

Finger millet seed production and dissemination

In most countries, production of improved crop varieties is regulated by governmental agencies. However, this oversight typically does not apply to landraces or local varieties, which are exchanged freely between neighboring farmers and sold in local markets. In Kenya, farmers can acquire finger millet seed from neighbors, local markets, agricultural input stores, and research institutions including the Kenya Agricultural and Livestock Research Institute (KALRO) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Finger millet is self-pollinating, which limits chances of cross pollination (Dida *et al*., 2007). Therefore, on-farm seed production is a viable option for increasing access to improved seed. Tamil Nadu Agricultural University (TNAU) in India is implementing the seed village program to promote quality seed production, a concept which could be adopted in finger millet growing areas to facilitate easy access to seed without compromising on

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quality. It is a program where trained groups of farmers are involved in seed production to cater for their own needs, and those of other farmers within the same or neighboring villages. The objective is to increase seed production to meet local demand at the appropriate time of year and at a reasonable cost. In areas with marginal rainfall, adoption of seed quality enhancement techniques such as on-farm seed priming for direct sown finger millet has the potential of reducing time to flowering and maturity by 6 days resulting in significant yield increases and improved food security (Kumar *et al*., 2002).

Finger millet crop management

Finger millet provides farmers with a reliable access to food and nutrition in environments with erratic and scanty rainfall, and low soil fertility levels. This is attributed to its wide genetic adaptation and ability to grow successfully in diverse soils, varying rainfall regimes, diverse photoperiods, in marginal, arid and mountainous terrains where major cereals have low success (Padulosi *et al*., 2009). Additionally, it is often the grain left in storage after the major cereal grains have been destroyed by storage pests. Indeed, studies have determined that finger millet stores for 10 years or more without damage by storage pests (United States National Research Council, 1996; Adekunle, 2012), a major limiting factor for food security in Africa. Despite these desirable qualities, finger millet yields in Africa have steadily declined in countries such as Uganda, Ethiopia and Kenya (Kidoido *et al*., 2002; FAO, 2006; Dida *et al*., 2008; Oduori, 2008). Finger millet production constraints in Eastern Africa include low soil fertility, environmental and nutrient stresses, pests and diseases, including blast disease (*Magnaporthe grisea*), and Striga weed (*Striga hermonthica* (Del.) Benth) (Wanyera, 2007; Oduori, 2007), among other constraints. Adoption of improved varieties and management practices such as use of fertilizers could improve finger millet yields (Oduori, 2008). Application of NPK along with micronutrients and FYM at the rate of 7.5 – 12.5 tha^{-1} increases yield of finger millet (Thilakarathna and Raizada, 2015). Finger millet is also known to benefit from residual fertility from the previous crop. Therefore, recommendations should consider crop management systems that include rotations with high-residue producing crops. Maintenance of surface residue cover combined with reduced tillage results in greater soil organic carbon and nitrogen, and has the potential of improving soil productivity (Mahli and Lemke, 2007).

Other soil fertility replenishment approaches have been developed based on naturally available resources and cropping systems. Zapata *et al*., (2002) recommended direct application of indigenous rock phosphates which are potentially important locally available phosphorus (P) sources for resource-poor farmers in extremely P deficient soils in Africa, Asia and Latin America. Studies have also shown that incorporation of green manure including *Tithonia diversifolia* could increase the availability of N, P and K (Partey *et al*., 2010). Tens of thousands of farmers in East and Southern Africa who have adopted these technologies have become food secure (Sanchez, 2002).

Intercropping finger millet with leguminous crop species such as Desmodium (*Desmodium intortum*) is also a strategy which is effective for the control of pests and increasing soil fertility thereby contributing to higher yields and economic returns

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(Midega *et al*., 2010). The effect of intercropping on soil fertility varies with management practice. Chu *et al.* (2004) determined that N transferred from peanut (*Arachis hypogea*) in an intercropping system made a contribution to the N utilization of rice (*Oryza sativa*), especially in low N soils. It is estimated that legume roots contribute between 5-15 kg N ha^{-1} to soil N under intercropping (Nnadi and Haque, 1986). Benefit-cost ratios indicated that legume-millet rotations were profitable in eastern Uganda (Ebanyat *et al*., 2010). Research is on-going in Kenya to determine the agronomic and economic benefits of finger millet-legume intercropping in farmers' fields. The activity is funded by the Collaborative Crops Research Program of the McKnight Foundation. Results of these studies will enable farmers to make informed choices on their production strategies for improved soil fertility, increased yields, improved nutrition and health of the farm families, and increased income generation from sale of the companion crops.

Finger millet processing and utilization

Nutrition plays an important role in the national development of any country; therefore, nutritional quality of food crops needs to be considered in addressing the problem of food insecurity and malnutrition. Millets are nutritionally superior to most cereal crops grown and utilized in Africa and provide much needed diet diversity (Kannan, 2010). Finger millet is well recognized for its anti-diabetic, anti-tumorigenic, and anti-atherosclerosis effects, as well as anti-oxidant and anti-microbial properties (Devi *et al*., 2014). Due to the growing public awareness of potential health benefits of phytochemicals, polyphenols and dietary fiber, there is increased need to identify new food sources with desirable functional characteristics to meet growing demand. Finger millet is one of the crops that can fulfill these requirements (Devi *et al*., 2014) and efforts should be made to increase awareness of the nutritive value, health benefits and variety of food products that finger millet can provide (Singh and Raghuvanshi, 2012).

Finger millet products are often made using composite flours, and have been well accepted in Colombia, Kenya, Nigeria, Senegal, Sri Lanka and Sudan. They are nutritionally superior to their staple grain counterparts, and thus can be successfully used for supplementary feeding programs in various institutions and homes in Africa (Onofiok and Nnanyelugo, 1998; Singh and Raghuvanshi, 2012). The nutritional properties of traditional cereal fermented products including finger millet could also be enhanced by increasing their nutrient and energy density. In India, East and West Africa, products made from fermented finger millet are popular across different demographics (Nout, 2009; Mugocha *et al*., 2000). Fermentation increases the rate of availability of iron, manganese and calcium in finger millet products (Makokha *et al*., 2002) while mineral fortification combined with dephytinization increases the mineral status of the product (Nout, 2009).

Although maximum utilization of the nutrient potential of the finger millet is limited by the presence of phytates, phenols, tannins and enzyme inhibitors (Shobana *et al*., 2013), these effects can be reduced by using processing techniques like popping, roasting, malting and fermentation (Mugocha *et al*., 2000; Nout, 2009). The use of these techniques not only decreases the content of phytates but increases the content of compounds that improve bioavailability of certain minerals like calcium and iron which

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is significant especially among mothers and young children (Hotz and Gibson, 2007). Processing techniques such as fermentation are also known to increase the content of major organic acids including lactic and acetic acids (Sripriya and Chandra, 1996). Composite flours made from finger millet can be used for preparation of various nutrient dense recipes which would effectively be used in supplementary feeding programs (Singh and Raghuvanshi, 2012).

Finger millet commercialization and marketing strategies

Increasing finger millet productivity and value-added product development will depend on increased consumption of millet-based products through commercialization and marketing. Therefore, there is need to improve processing technologies including compositing, fermentation, malting and steaming to enhance the quality of the end-products. Diversification of end-use products would also enhance commercialization of finger millet. Its excellent malting quality makes it suitable as a raw material for the brewing industry and local production and processing would save on foreign exchange currently required to import malting products (Taylor *et al*., 2006). Better presentation and packaging of ready-to-use finger millet products such as noodles and cookies will increase appeal to urban consumers. Indeed, marketing and presentation of finger millet as a healthy product with superior nutrient quality will increase its utilization among men, women and youth who are increasingly conscious about their health and dietary well-being (Shobana *et al*., 2013).

Several studies have highlighted the contribution of neglected and underutilized crop species such as finger millet towards generating income in both domestic and international markets (Chadha and Oluoch, 2007). In India, adding value to millet nearly tripled farmer incomes and generated new employment opportunities, particularly for women (Vijayalakshmi *et al*., 2010). There is increased interest internationally in new foods and products with the potential to contribute to health and nutrition. This is an opportunity to develop markets for non-staple crops from which poor communities would benefit. Promoting *niche* markets through denomination of origin (DO), eco-labelling, fair trade, organic, and Slow Food Initiatives (Kahane *et al*., 2013) may be particularly useful to increasing the attractiveness of finger millet products.

Finger millet technology dissemination and adoption

Farmer adoption of technologies depends on agronomic superiority of a given technology as well as farmer perceptions and attitudes. In general, the uptake of agricultural technologies by smallholder farmers in Sub-Saharan Africa has been slow. Subsequently, knowledge, perceptions and attitudes of potential adopters towards innovations have played a major role in either facilitating or slowing rate of technology adoption (Meijer *et al*., 2014). The pathways usually considered to introduce new technologies are public meetings *(barazas*), radio programs, farmer field schools (FFS), field days, farmer teachers, fellow farmers, printed materials (e.g. leaflets and fliers) (Murage *et al*., 2011) and most recently, farmer research networks (FRNs) (Nelson *et al*., 2016). Under FRNs, farmers are organized in groups that engage in collaborative research with researchers and development organizations with the objective of increasing the ability of rural communities to engage in the research and innovation

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processes. They are exposed to targeted options that respond to their interests, and they can provide data on the performance of those options for the benefit of others in similar socio-ecological contexts (Nelson *et al*., 2016). The pathways mentioned above are opportunities for finger millet farmers to facilitate learning and knowledge sharing across farmer groups with similar production agendas, interests and constraints. In Kenya and Uganda, the FRN approach has been adopted to fulfill the above objective among finger millet farmers under the Finger Millet Project funded by the Collaborative Crops Research Program of the McKnight Foundation (CCRP). Under the program, researchers, development partners including non-governmental organizations and community-based organizations, agricultural extension staff and farmers work together to develop, implement and evaluate a given technology for the benefit of all stakeholders. It is expected that the approach will foster increased finger millet production in the areas where it is grown.

Improved production technologies are increasingly targeting women farmers. Finger millet contributes significantly to the incomes of rural households, particularly women (Tenywa *et al*., 1999). Since gender dynamics shape and influence the perceived uses and benefits of a given technology, dissemination strategies must include women, in order to enhance overall utilization (Mudege *et al*., 2015). Women play an instrumental role in the creation of diverse diets, ending poverty and enhancing agro-ecological resilience (Bezner-Kerr and Mkandawire, 2012). Their bargaining power when accessing inputs should be enhanced (Marenya *et al*., 2015) to ensure they benefit from the production technology. Inequitable social norms in finger millet production including gendered allocation of labor should be addressed to better achieve the goals of agricultural productivity and food and nutrition security (Njuki *et al*., 2016).

Conclusion

Collaborative efforts between stakeholders including farmers, researchers, national and international funding agencies, governmental and non-governmental agencies, product developers and entrepreneurs to increase production and utilization of finger millet will improve its visibility as an alternative to mega-crops with the potential to improve food and nutrition security in Africa. Specifically, the following interventions are necessary to achieve these objectives:

- Creating awareness of finger millet as a “novel” food and nutrition security crop across regions, countries, communities, farmer groups and networks.
- Enhanced production and productivity by increasing the acreage allocated to finger millet production.
- Enhanced research and development to develop improved technologies and practices for increased production, productivity, utilization and marketing of finger millet and millet-based products.
- Adoption of improved varieties and management practices for increased finger millet yields; improved processing, product development, utilization and dissemination of appropriate technologies that result in quality, market-ready, instant-use products with mass appeal across gender and age-groups.

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- Sensitization of communities on the health and nutrition benefits of finger millet, at household level and as a component of institutional (schools, hospitals, etc) feeding programs.
- Exploiting the industrial potential of finger millet in commercial enterprises including the brewing industry due to its superior malting qualities.
- Use of finger millet residues and by-products in livestock production, particularly poultry feeding.
- Use of social media platforms as a networking tool between stakeholders (researchers, producers, processors, traders, consumers, national and international partners) for dissemination of emerging technologies on finger millet production, product development, utilization, and marketing.

Enhancing finger millet production, utilization and marketing will ensure that it takes its place as a crop that has great potential to make significant contributions to food and nutrition security hence supporting the livelihoods of people across Africa and around the world.

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