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Finger Millet: Food Security Crop in the Arid and Semi-Arid Lands (ASALs) of Kenya

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Abstract This paper aims at highlighting the positive attributes of finger millet. It reviews the works from peer-reviewed articles, agricultural research and development reports from national and international institutions. Primary data were obtained through preliminary survey conducted in the month of March, 2016 at the Kenya Agricultural and Livestock Organization (KALRO), Kibos office, Kisumu County, Kenya. The study has revealed that the crop has the ability to grow under adverse agro-climatic conditions such as those found in the ASALs. The ASALs of Kenya cover about 80% of the total land area and is home to about 38% of Kenya's population. Strong case has therefore emerged for stepping up the efforts towards the improvement of finger millet production to boost food security in the country. Through investment in agricultural research and development; and adoption of improved finger millet varieties especially in the ASALs, food production would increase significantly leading to reduced incidences of food poverty.

Keywords Finger Millet, Food Security, ASALs, Kenya

1. Introduction

Finger millet (*Eleusine coracana (L.)* Gaertn) is a staple food crop grown by subsistence farmers in the semi-arid tropics and sub-tropics of the world under rainfed conditions [38, 39]. The name is derived from the seedhead, which has the shape of human fingers. [37] report that, locally, the crop is called *ragi* (India), *koddo* (Nepal), *dagussa tokuso, barankiya* (Ethiopia), *wimbi, mugimbi* (Kenya); *bulo* (Uganda); *kambale, lupoko, mawale, majolothi, amale, bule* (Zambia); *rapoko, zviyo, njera, rukweza, mazhovole, uphoko, poho* (Zimbabwe*); mwimbi, mbege* (Tanzania) and *kurakkan* (Sri Lanka).

The crop is largely consumed by marginalized inhabitants of semi-arid Asia and Africa and sold to provide subsistence farmers with additional income [8]. The crop ranks third in cereal production in semi-arid regions of the world after sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) [14]. It is highly valued by local farmers for its ability to grow in adverse agro-climatic conditions, where cereal crops such as maize (*Zea mays*), wheat (*Triticum spp.)* and rice (*Oryza sativa*) fail and has been noted to tolerate wide variety of soils. [4] has outlined the ecological requirements for the crop: it requires annual rainfall ranging from 500- 1000mm, which is well distributed throughout the growing season; adapted to a wide range of soil conditions though it prefers fertile, well-drained sandy to loamy soils with P.H ranging from 5-7. Finger millet also grows on lateritic or black heavy vertisols and has some tolerance for alkaline and moderately saline soils. In terms of altitude, the crop is found between 1000-2000 metres above sea level in eastern and southern Africa and up to 2500-3000 metres above sea level in the Himalayas.

Nutritionally, finger millet is primarily consumed as porridge in Africa but in south Asia as bread, soup, *roti* (flat bread) and to make beer. Interestingly, new food products made from finger millet are also becoming popular among younger people, including noodles, pasta, vermicelli, sweet products, snacks and different bakery products. In some nutritional components, finger millet is a superior crop compared to some major cereal crops especially polished rice [38].

The crop was domesticated in western Uganda and the Ethiopian highlands at least 5000 years ago before introduction to India approximately 3000 years ago [28, 39]. Today the crop is ranked fourth globally in importance among the millets after sorghum, pearl millet and foxtail millet (*Setaria italica*) [38, 39]. Finger millet is cultivated in more than twenty five countries, mainly in Africa (Ethiopia, Kenya, Sudan, Zambia, Malawi, Rwanda, Burundi, Mozambique, Eritrea, Zimbabwe, Namibia, Senegal, Niger, Nigeria and Madagascar) and Asia (India, Nepal, Malaysia, China, Japan, Iran, Afghanistan and Sri Lanka).

Annual world production of finger millet is at least 4.5 million tons of grain, of which Africa produces perhaps 2 million tons [25]. India is a major producer of *ragi* in Asia [20, 40], with a production of 2.1 million tonnes and

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productivity of 1.3ton/hectare (t/ha). More than 50% of the crop area in India (1.6 million ha) is in Karnataka (0.9 million ha) where the productivity (1.9t/ha) is higher than the national average. Other finger millet growing states in India include Tamil Nadu, Andhra Pradesh, Orissa, Maharashtra, Uttarakhand and Jharkhand. In Eastern Africa, the Major producers are Uganda, Kenya and Ethiopia [20].

1.1. Why the Crop Matters

Eleusine coracana plays an important role in the dietary habits and economy of subsistence farmers. Staple foods prepared from the grain are major sources of minerals and nutrients and are especially important for pregnant women, nursing mothers and children [24]. Finger millet is 3-5 times nutritionally superior to the widely promoted rice and wheat in terms of proteins, minerals and vitamins [3]. A study by [4] aimed at determining the mineral and photochemical constituents of finger millet revealed that the crop contains minerals which are of great significance to the human body. Minerals are inorganic nutrients usually required in small amounts from less than 1-2500mg per day ant their presence is necessary for maintenance of certain physiochemical processes which are essential to life [35]. The study indicated that *E. coracana* has:

a crude fiber value of 3.10±0.03% (w/w), a crude protein value of 10.28±0.01% (w/w), a Zinc value of 0.22±0.01mg/g, a potassium value of 14.19±0.03mg/g and a sodium value of 6.86±0.02mg/g. Crude fiber enhances digestibility, lowering blood cholesterol and blood sugar [9]. It is known to reduce the risk of diseases such as obesity, diabetes mellitus, breast cancer and gastro-intestinal disorders [16, 22]. A study by [40] on "value added products from nutri-cereals (*Eleusine coracana*)" revealed that the insoluble fiber from finger millet helps in gallstones prevention. The study proved that including insoluble fiber in the diet lowers the risk of getting gallstones by 17% compared to women whose diet lack in fiber. This gallstones protection is dose related, with every 5g increase in insoluble fiber the risk drops by 10%. The plant is a moderate source of protein [4]. Finger millet contains important amino acids vis-a-viz isoleucine, leucine, methionine and phenyl alanine [40]. It also contains tryptophan amino acid [28]. These amino acids are often absent in starch-based diets of some subsistence farmers. Zinc is essential in the activation of certain enzymes such as dehydrogenase, alkaline phosphatase and carboxypeptidase. Zinc containing organic compounds is employed as a stringent and antifungal agents; it aids wounds healing and the metabolism of nucleic acids and insulin [5]. Potassium is important in regulation of water and electrolyte balance and acid-base in the body and for the nerve action and functioning of the muscles; while sodium aids the transmission of nerve impulses as well as the maintenance of osmotic balance of cells [22].

Studies elsewhere have revealed that *ragi* is most recognized nutritionally for being a good source of minerals. The crop is a good source of minerals such as magnesium, iron, calcium and phosphorous [40]. Magnesium is not only helpful in reducing the severity of asthma and migraine attacks, but also helps to reduce high blood pressure, diabetes, atherosclerosis and heart attack. It helps to relax blood vessels, enhances nutrient delivery by improving the blood flow and maintains the blood pressure and thus further protects the cardiovascular system [22, 40]. Phosphorus is important for energy production and is an essential component of Adenosine Triphosphate (ATP). It forms an essential part of the nervous system and cell membranes. [4] observes that iron content in finger millet is 0.11±0,01mg/kg while that of calcium is 1.13±0.01mg/g. Iron is very vital in the formation of haemoglobin in the red blood cells. Deficiency of iron leads to anaemia. *E. coracana* could be used to improve the anaemic condition of a patient. Calcium is essential for bone and teeth formation and development thus making it ideal for weaning in children, pregnant women, nursing mothers and the elderly [24]. Other studies have revealed that postmenopausal women with signs of cardiovascular disease like high blood pressure, increased cholesterol and obesity can benefit from eating whole grains especially *wimbi* six times a week.

Studies on the nutrient requirements for the crop have revealed encouraging results. In a study to determine the acclimation responses by finger millet to low nitrogen (N) stress, [16] points out that the crop has high nitrogen use efficiency, defined as grain yield per unit of available nitrogen. The study revealed that many farmers reported that the crop can grow well without any added N or with only residual N. A more formal investigation carried out by the All India Coordinated Small Millet Improvement Project (AICSMIP) indicated that while finger millet responds well to Urea N application at 90kg/ha, the cost benefit ratio was highest between 0 and 30kg N/ha. This is significantly lower N requirement than corn, for which optimum application rates can be greater than 200kg/ha. [16]. Other works have confirmed this observation. The species will produce 5tons/ha under optimum conditions and requires very little nitrogen application. Some reports indicate the most economic rate of application of between 20 and 60kg/ha. [28]. Fertilizer rates of 20kg/ha has been found to be the lowest economical levels at which good yield response would be realized for both sorghum and finger millet for medium potential areas. However, for the lower potential areas, application of 50kg/ha of nitrogen is recommended or farm yard manure. The given rates translate into 2 (50) kg bags of NPK (20:20:0) or Diammonium Phosphate (D.A.P) and 2 (50) kg bags of Calcium Ammonium Nitrate (C.A.N) for top dressing [26]. Furthermore, the crop is able to grow on marginal lands with low soil fertility.

Other positive traits of finger millet include being drought tolerant, disease resistant; effectiveness in suppressing weeds and have a long shelf-life. *E. coracana* has a moisture content of 6.99±0.02% [4]. This indicates that the seed can be stored for a longer period without spoilage. The crop has longer storage life, and can be termed as famine reserve [40].

From the foregoing discussion, it is evident that the crop has enormous benefits. As a food crop, it can greatly reduce incidences of food insecurity especially in the ASALs of Kenya.

1.2. Food Security: Global, Regional and National Outlook

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life [6, 12, 13]. Globally, the number of hungry people rose from 800 million people to over one billion following the 2007/2008 food price spike in the world [34]. In 2010, the regional distribution of people suffering from hunger were as follows: 578 million in the Asia Pacific region; 239 million in sub-Saharan Africa; 53 million in Latin America and the Caribbean; 37 million in North Africa; and 19 million in developed countries [2]. The latest FAO estimates indicate that about one in every nine people in the world still has insufficient food for an active and healthy life. The vast majority of these undernourished people live in developing countries, where an estimated 791 million were chronically hungry in 2012–14 and about one in eight people or 13.5% of the overall population remains chronically underfed. In Africa, more than one in four people remain undernourished – the highest prevalence of any region in the world [13]. For the case of Kenya, preliminary results of the 1997 Welfare Monitoring Survey (WMS) indicated that the incidence of rural food poverty was 51%, while overall poverty reached 53% of the rural population. In urban areas, food poverty afflicted 38% and overall poverty 49% of the population. The overall national incidence of poverty stood at 52% [27]. According to available estimates, the number of poor increased from 3.7 million in 1972-3 to 11.5 million in 1994. Thereafter, numbers increased to 12.5 million in 1997 and is now estimated to have reached some 15 million [15].

It is against this backdrop that this paper tries to explore ways of improving the food situation in Kenya, especially among the inhabitants of the ASALs. Promotion of finger millet production would help in making the majority of the citizens, food secure. Because of its ability to tolerate drought under poor soil conditions, *E. coracana* is deemed an important crop to increase food security in the ASALs [35].

2. Kenya's ASAL Situation: Is Finger Millet the Answer?

Eleven out of 72 districts in Kenya are classified as arid, 19 as semi-arid and another six as those with high annual rainfall but with pockets of arid and semi-arid conditions [32, 33]. These districts cover about 467,200 square kilometers or about 80% of the country's total landmass [18], and are characterized by generally hot and dry climate. 30 districts have an evapo-transpiration rate of more than twice the annual rainfall in 30% of the district's area. The ASALs are part of the eastern Sudano-Sahelian belt which has diverse land types, including coastal plains, upland plateaux and isolated hill ranges, mostly at altitude of below 1600m [32]. The arid districts are characterized by high ambient temperatures with a wide diurnal range. In most districts, evapo-transpiration rates are more than twice the annual rainfall. These districts receive low and erratic bimodal rainfall that is highly variable both in space and time [37]. In most cases, rain falls as short high intensity storms that produce considerable runoff and soil erosion. Average rainfall figures are deceptive in these circumstances because there tends to be a few years of rainfall well above average whilst the probability of occurrence is low. Approximate rainfall expectancy in the arid districts ranges from 150-450 mm in a year. The soils are highly variable but generally shallow, of light to medium texture, with low fertility and are subject to compaction, capping and erosion. Only a few areas have volcanic soils and alluvial deposits which are suitable for crop production. Heavy clays also occur, but cultivation is difficult due to their poor workability as well as problems of salinity and sodicity. Water availability and accessibility is highly variable and is a considerable constraint to production. The arid districts are mainly inhabited by pastoralists and agro pastoralists. Large areas of the arid districts are suitable only for nomadic livestock production.

The semi arid districts are found in the Agro-ecological zones (AEZ) IV and V-VI, and receive between 500 and 850mm of rainfall annually. They are further subdivided into four categories, based on agricultural potential. These are a) semi-arid areas with mixed rain-fed and irrigation agriculture and high economic and political disparities; b) semi-arid areas with encroaching agro-pastoral use by marginalized smallholders; c) semi-arid areas with predominantly pastoralist use in the economic and political periphery; and, d) semi arid areas that include protected areas and their surroundings. Kajiado, Narok, Mbeere, Mwingi, Kitui, Machakos and Makueni are considered semi arid. Also covered under this category is the entire coast, except Tana River district and some small part of central Kenya [32].

In AEZ IV, the main farming system is mixed crop-livestock production. Crops are grown to meet household subsistence needs and surplus is sold for cash to supplement household income. Local breeds of livestock predominate, with bulls mainly being used as a source of draft power for ploughing and transportation. Livestock are, in general, an insurance against crop failure and are usually allowed to graze fields after harvest. Some farmers also use animal manure on their fields. Inadequate rainfall and a high incidence of pests pose high risks. To minimize these risks farmers keep livestock, practice mixed cropping, and plant more drought tolerant crops such as cow and pigeon peas [30].

In AEZ V-VI, the main farming system is the maize/cowpea/pigeon pea. This system is practiced in the low-lying areas which have been rapidly settled and sub-divided into family farms in the last one or two decades. Almost all the farmers grow maize, but the rate of failure is very high. Soil erosion, low fertility and frequent droughts are the major production constraints. The zone is ideally suited for sorghum and millet but maize is increasingly grown. Ownership of livestock, especially goats, is widespread, a quarter of the households own no livestock and depend primarily on subsistence cropping and the provision of labour. Where they exist, animals are grazed communally and are moved away from the homestead during the dry season. Examples under this zone include parts of Keiyo, Marakwet, Tharaka, some parts of Kilifi, parts of Baringo and West Pokot. Semi-arid areas also host most of the protected areas such as game reserves, national parks and forest areas [31, 32].

The ASALs are home to about 38% of the Kenya's population [33]. Recent estimates indicate that some 60% of the country's livestock are found in the ASALs of Kenya [37]. This means that ASALs are nationally important in terms of supporting rural livelihoods. The Kenyan Government acknowledges that a third of the projected increase in agricultural food production is expected to come from the ASALs [Keya, 1998 as cited in [37]]. The influx of human population from the high potential areas of Kenya to these ASALs has accelerated over the years [36]. Thus, it would seem that the ASALs will continue to play a very important role in terms of human settlement as well as production of subsistence food crops for ever increasing human population [30]. The major environmental factors limiting crop production in these ASALs of Kenya are high potential evaporation and highly variable and unreliable rainfall (both temporally and spatially). Apart from environmental limitations, the new farming communities in the ASALs lack the indigenous knowledge in selecting crops and farming strategies well suited to the stabilization and maximization of food production in their diminished rainfall circumstances. Sorghum and finger millet were the most important food crops for Kenyans until maize was introduced. National Food Policy [1981, as reported by [24]] points out that maize has gradually replaced sorghum and finger millet as a source of food as eating habits continue to change. Maize is grown mainly in the high potential areas of the country. It is also grown in the marginal areas but climatic conditions have limited the rate of expansion of its production. The frequency of maize failures is high and has been estimated at 33% in Ecozone IV, 43% in Ecozone V and 51% in Ecozone VI [24]. The effects of crop failures could, however, be minimized by the use of drought tolerant crops such as finger millet. Finger millet is well adapted to semi-arid conditions where maize crop often fails to reach physiological maturity in five out of eight seasons because of erratic rainfall or drought [26].

With the increased population pressure in the high and medium potential areas, and as people continue to migrate to the agriculturally marginal areas, agricultural production from marginal areas is expected to become an important feature of Kenya's agriculture. Finger millet has the potential of enabling Kenya achieve broad self sufficiency in food in these marginal areas. Additionally, rapid population growth in Kenya is raising the demand for locally-grown foods especially in the dryland regions where finger millet is a key cereal crop. Related to this is the fact that, while the majority of poor people are still located in the rural areas, an increasing share of population is migrating to urban areas in search of non-farm jobs. This is raising the demand for foods supplied through commercial markets rather than subsistence production. In recent years the demand for finger millet in Kenya's crop/livestock systems has risen [21]. This has created new opportunities for the crop in the marketplace. As incomes rise across the country, diets are changing and the demand for livestock products (meat, milk) is increasing. This growing demand is increasing the market value of dryland crop residues (stover) as well as grains are vital feed stocks for cattle, goats and chicken. While the grains are used for human consumption, the stover is excellent source of dry matter for livestock especially in dry season. Finger millet straw makes good fodder and contains up to 61% total digestible nutrients [38]. A strong case therefore emerges for stepping up the efforts towards development of technologies (germplasm improvement and agronomic management), markets and institutions to advance the case for finger millet in the dryland tropics in Africa, generally and Kenya, specifically.

3. Finger Millet Production in Kenya

Millet production in Kenya thrives well in marginal areas, owing to its drought tolerance [23]. The main types of millet grown include bulrush, finger millet, foxtail and proso. Kenya largely produces finger millet variety. Finger millet (known as *wimbi* in East Africa) has historically been grown by small holders in Kenya to meet their subsistence food requirements. *Wimbi* is predominantly cultivated in western Kenya around Lake Victoria and some parts of the Rift Valley. The famers' primary goal is to satisfy household needs and where possible, generate a surplus for sale. The crop is grown on either pure or mixed stands. Farmers mainly grow their local types which are differentiated by colour; either brown or black [24]. According to Chrispus Oduori, Kenya Agricultural and Livestock Organization (KALRO) principal researcher based at Kakamega, more than 30,000ha in the Western region of the country is under finger millet; and that more than 65,000ha are under the crop nationally. The crop is grown mainly in Kisii, Migori, Busia, Homa Bay, Kisumu, Siaya, Machakos and Kericho counties. It should be noted that, although several types of millets are grown in Kenya, most production statistics on millets is often lumped together. In terms of regions, millet is mainly produced in Nyanza, Eastern, Rift valley and Western provinces of Kenya. Other regions which produce the crop include some parts of Central and Coastal provinces (see Table 1). Eastern province has the highest potential. This is demonstrated by the fact that in 2002 and 2003 production years, Eastern province produced over 50% of millet [11].

The data presented in Table 1 indicate that there was decline in millet production in all the provinces considered except Rift valley. This, points to the fact that Rift valley province also has a great potential to produce more millet. This is reinforced by the fact that, in Kericho (Part of Rift Valley), the area under finger millet cultivation increased from 2,300ha to 7,000ha in 1984-85 production periods. This translated into increased production from to 4,347,000kg to 9,030,000kg [26].

Table 1. Kenya Millet Production statistics (2002-2003)

Province	Production (Metric Tons)	
	2002	2003
Central	44	34
Nyanza	12973	12139
Western	11500	8341
Coast	398	70
Eastern	45211	33601
Rift valley	6413	9843
Total	76539	64028

Source: Export Processing Zone Authority, 2005

The data available from the Ministry of Agriculture reveal that the area under millet increased significantly from 53,155ha in 2008 to 104,576ha in 2009 yielding 626,856 (90kg) bags up from 426,928 (90kg) bags the previous year. In 2007-2008, the area under the crop had fallen from 128,114ha to 53,155ha resulting into a decline in the yield up from 1,328,877 (90kg) bags to 426,928 (90kg) bags. Similarly, the 2005-2006 production periods recorded an increase in acreage and yield while the 2006-2007 production periods showed reduction in hectareage while the yield increased [23]. The trend in 2006-2007 points to the possibility that improved varieties may have been used.

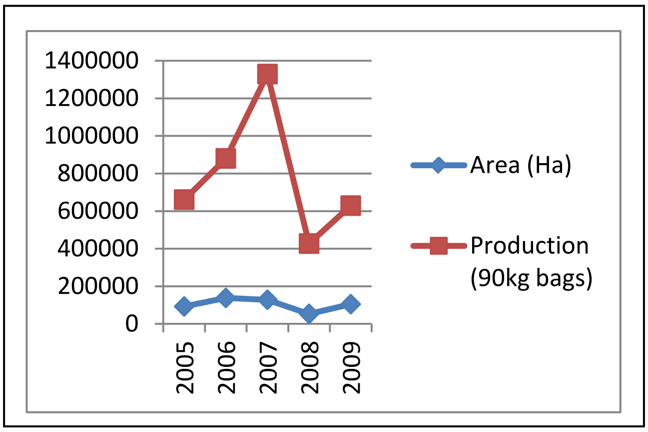

Figure 1. Trends in Millet Production (2005-2009). Note: Figure drawn with data from Ministry of Agriculture, 2010

Figure 1 indicates that production and hectareage under millet has been fluctuating over the years. This calls for an immediate intervention to ensure steady production to meet the demand which is ever-increasing. The growing affluence has led to growing demand in urban markets for value-added products. For example, the demand for finger millet porridge in Kenya far exceeds local supply. Kenyan processors regularly search for finger millet grains in neighbouring Tanzania and Uganda. There is, therefore, need to improve production technologies to bridge the widening gap between demand and supply [21].

3.1. Finger Millet Varieties in Kenya

From the local and world germplasm collections, finger millet varieties have been improved over the years. Among the medium maturing varieties, P224, Gulu-E, Serere and KA-2 have shown a yield potential of more than 2000kg/ha under good management. The varieties are recommended for medium potential areas at an altitude above 1500 metres above sea level. Other improved varieties with good yield potential include IE 1010, EKR-227 and P283, which are recommended for the lower midland areas [26]. The international Crops Research Institute for Semi-arid Tropics (ICRISAT) has also released KNE-479 and KNE-1034 genotypes, which can endure the harsh conditions of semi-arid areas such as Machakos County (specifically the Katangi area) [35]. A preliminary survey at the KALRO-Kibos revealed that improved high yielding varieties such as Okhale-1 and U-15 have also been released into the market. By using improved varieties and better agronomic practices, the yields can improve greatly. Giving small scale farmers access to higher yielding finger millet varieties can contribute to economic development and poverty alleviation in Kenya. Farmers who adopt the improved varieties will not only have increased production that can be sold, they also can share the seeds with other farmers.

Ekalakala is a local variety that although with a lower yield potential is early maturing and drought tolerant and is recommended for the drier areas along the lake shores [26]. In a Technical Report (R8030) by Department for International Development (DFID), local landraces from Busia, Kisii and Teso districts are identified. These are Ikhulule, Khayoni, Agriculture and Maderekasabale (Busia); Obokoro, Emumware, Aran, Ebonit, Eleurot and Eblue (Teso); and Enaikuru, Enyakundi, Enyandabu, Endere, Morogi, Marege, Omokoni and Amatugi (Kisii). These local cultivars have some important positive traits which can be exploited for improvement. For instance, Enyakundi and Marege are resistant to blast; while Ikhulule, Obokoro, Emumware, Enaikuru, Enyakundi and Enyandabu are high yielding locals. The report reveals that the local varieties with early maturity traits include Enaikuru, Enyakundi, Enyandabu, Endere and Aran [7]. From Migori County, especially in Kuria Sub-county, the local landrace with high yielding traits is Bhoke (Preliminary survey at KALRO-Kibos).

3.2. Constraints to Finger Millet Production in Kenya

In spite of the preference for finger millet grain in Kenya, its uptake both in area and production, have not been expanding but rather declining. The factors which have contributed to the decline have to be understood and addressed if production is to be increased.

According to Mbogoh [1982, as cited in [24]], finger millet has the greatest labour requirement as compared to other crops. Most of the labour input is required for weeding and land preparation. These two operations are labourious. Weeding, because of the close spacing of finger millet; and land preparation, because of the fine seedbed tilth required due to the small size of the finger millet seed. The high labour requirement greatly increases the comparative cost of finger millet vis-à-vis other competing crops especially maize which is considered to be the competitive crop in most *wimbi* growing regions (areas). Women are often responsible for manual post-harvest processing, grain threshing and milling [28]. A study funded by the United Kingdom's DFID in 2004, surveyed three districts in Western Kenya (Kisii, Busia and Teso) which produce the bulk of finger millet in Kenya. The investigation showed that high demand for labour was cited by farmers in all the three districts as limiting finger millet production. Besides, the yield per hectare (ha) for finger millet is also lower than that for maize. Farmers are now adopting more competitive crops and this has resulted into decline in production.

Low level of technology employed in finger millet production: This stems partially from the general lack of incentives to farmers to enable them invest in the purchased inputs; and partially from a lack of appropriate technological recommendations at the farm level. Improved production technology has either not been developed (due to inadequate research work) or has not reached the farmers (due to poor dissemination from research stations). The finger millet production scenario is characterized by a negligible use of improved seeds, fertilizers, agro-chemicals and a low level of mechanization. This is because agricultural inputs such as improved seeds, fertilizers, pests and weed control chemicals do not reach the farmers when they need them. This has been attributed to the inadequacy of the general inputs supply system in Kenya. In addition, there are no appropriate technologies for planting, weeding, harvesting and threshing. A strong breeding programme similar to that of maize is also lacking. Unlike other popular cereals like maize and rice which have been hybridized, farmers who grow finger millet depend solely on non-hybridized varieties that are very low yielding, thus discouraging them from expanding their acreage [14]. The current low level of technology continues to produce poor yields of finger millet which in turn mean poor returns to farmers' efforts. Inadequate extension services and poor dissemination of information to the farmers due to weak research-extension linkage and past approach to research which has mainly been on research stations has been a major technical constraint [26]. This neglect by researchers and policy makers has been accompanied by dwindling production area in many regions.

The means of transport are either lacking or too expensive for smallholders. The situation is worsened by poor road network or inaccessible rural roads when wet. Generally, the transportation problem discourages production in excess of what farmers need and what can be sold locally.

Utilization and marketing: The negative growth in the production of finger millet could be attributed to poor marketing and its limited use. Unlike maize which is sold through the National Cereals and Produce Board (NCPB), finger millet is largely produced for the local market and home consumption [19]. The use o finger millet in production of beer, bread, animal feed and in preparation of other recipes can increase the consumption, hence demand for the crop.

Inappropriate crop husbandry: Many of the improved varieties have been developed for a higher level of management than the farmers for whom they are intended can manage. Most farmers continue broadcasting the crop. Additionally, most farmers who farm finger millet are using unimproved local varieties [29]. Those who adopt row planting practise poor spacing and dense plant population is a common feature especially with farmers in the lower marginal areas where water stress is a major constraint. Past results have shown that it is possible to attain yields of up to 4000kg/ha at a closer spacing of 10cm x 10cm with a plant population of 1 million per ha. However, too close spacing has a higher incidence of lodging due to weak plants and the efficiency of weeding might also be affected [26].

Blast disease: Finger millet is caused by the fungus *Magnaporthe grisea* (anamorph *Pyricularia grisea*). It is the most destructive disease of finger millet because of its aggressiveness [1, 7]. In East Africa, grain yield losses exceeding 80% have been reported in some years [1]. The disease affects the crop at all stages of growth, from seeding through grain formation. Blast infection is favoured by cloudy skies, frequent rain and drizzles, which support accumulation of dew on leaves for a long time. In the tropics, blast spores are present in the air throughout the year thus favouring continuous development of the disease. Hayden [1999, as cited in [1]] has observed that the fungus also establishes better in soils with high levels of nitrogen. The rate of sporulation increases with increasing relative humidity (90% or higher) and for pathogen germination, the optimum temperature should be 25-28°C [1]. The disease is characterized by appearance of lesions on the leaves, nodes and heads. Under blast disease-conducive conditions, lesions on the leaves of susceptible lines expand rapidly and tend to coalesce, leading to complete drying of infected leaves. Besides attacking the leaves, the fungus may also attack the neck causing neck rot. When a neck is infected, all the parts above the infected node may die. When this occurs, yield losses may be large because grain formation is inhibited and/or formed grains may be shriveled. In such cases, yield losses may be as high as 90% [1, 10].

Weeds: Weeds are plants we have not found use for that has negative effects or influence on useful plants or crops we grow [1]. Common finger millet weeds include *striga weed, black jack, nut sedges, Johnson grass, poison ivy, wild finger millet, couch grass, oxalis sp., wondering jew, nut grass, commelina b., amaranthus, mexican merigold, cocklebur, common dandelion and bermuda grass* [7]. Under poor management conditions, weeds are enemy number one as competitors for light, nutrients and water. Weeds that grow taller than finger millet compete heavily for light, rendering the crop unable to utilize its full potential in processing its own food. Consequently finger millet plants etiolate, produce small heads and become susceptible to lodging. Weeds are better competitors for nutrients than crops because of their more efficient root system and fast growth. They deprive the crop plants of essential nutrients; plants become weak and give poor yields. Some weed species produce certain chemicals or hormones that interfere with the growth of finger millet. Nut sedges and Johnson grass are known to produce allelopathic chemicals that inhibit growth of finger millet. Weed management is one of the most expensive finger millet farming activity faced by farmers. Weeding normally takes up to 50% of all labour put into finger millet management and as a constraint it limits the area that a household can sow. Hand weeding is usually undertaken by women and children resulting in drudgery and withdrawal of children from school during the weeding seasons. It is costly due to the time involved.

Land degradation and loss of soil nutrients either through soil erosion or continuous cultivation has significantly lowered finger millet production in most areas. Farmers are forced to spend a lot of resources on fertility enhancement. Some farmers who cannot afford adequate fertilizers have in most cases withdrawn from finger millet production or suffered severe losses.

4. Conclusions

Apart from meeting the food requirements of the population of the cultivation catchment, finger millet has sound nutritional and medicinal values. These properties, however, have not been focused to the residents of the non-finger millet growing regions. Though consumption patterns of finger millet are very specific and continue to remain region-specific, their popularization in the broader range is essential. Processing finger millet using traditional as well as contemporary methods for preparation of value-added and convenience products would certainly diversify their food uses. Their exploitation for preparation of ready-to-use or ready to cook products would help in increasing its consumption among non-millet consumers. This can address the problem of food insecurity.

The World Summit on Food Security has a target of 70% more food production by 2050, requiring annual increases of 44 million tons, 38% above current annual increases [28]. Climate change will cause additional difficulties as many regions are becoming drier with increasingly severe weather patterns. The frequency and increased intensity of extreme climatic events such as drought have become additional challenges for global agriculture, which is already facing higher demand due to both population increase and new consumption habits. Finger millet has the potential to meet these challenges, given their drought tolerance and ability to grow under low input conditions.

The global population is predicted to increase to around 9 billion people by 2050. With changing diets due to rising incomes, a recent analysis relating calorie and protein consumption to Gross Domestic Product (GDP) estimates that food production needs to increase by 100-110% [34]. This, together with the need to conserve other land uses such as forests and wetlands, for other ecosystem services such as carbon storage and biodiversity, poses a real challenge. Clearly, our current crop production systems will need to adapt to meet these changing pressures. The adaptation may either be planned or autonomous. Planned adaptation is more at the governmental level, and involves changing the decision-making environment through developing infrastructure, providing relevant information to farmers; and developing technical improvements through publicly-funded research. Research in this area should be intensified and it should target crops with high economic potential such as finger millet. This crop is essential for feeding the poor, majority of whom, are in Kenya. Autonomous adaptation, on the other hand, is more at the individual farmer level, and involves changes in agricultural practices that may occur by trial and error, farmer's experience or by changes in the decision making environment resulting from planned adaptation. Sasson notes that, within this context there are four broad areas of adaptation of crop production systems as climates change:

- ❖ New crops being introduced and previous crops being phased out
- ❖ Development of new varieties of existing crops
- ❖ Evolution of crop management practices
- ❖ Dealing with climate uncertainty through the provision of information

These adaptations will involve many trade-offs and possibly some synergies, at different scales, requiring decisions to be made.

Finger millet can have a strong impact on the livelihoods of Kenyans. Detailed characterization of finger millet varieties is therefore required to support farmers' decision making. Agronomic and past harvest technology packages should be developed or released in order to enhance performance and quality. Prerequisites for enabling the crop to raise food security in the country include farmers having improved access to seed and information as well as favourable policies supporting the development of agricultural sector.

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