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FINGER MILLET (*ELEUSINE CARACARA (*SUBSPECIES *CORACANA)* (L.) GAERTN) PRODUCTION AND TISSUE CULTURE: A REVIEW

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Abstract: **Finger millet is one of neglected crops and it's native to east Africa. The yields of finger millet are low in Ethiopia due to different constraints including: lack of improved varieties, little research emphasis given to the crop, non-adoption of improved technologies, poor attitude to the crop, disease, lodging, threshing and milling problem are some of the most serious production constraints in finger millet production in Ethiopia. The main objective of this review is to know finger millet production and its applications.**

Keywords: **Finger millet, Regeneration, somatic embryogenesis, Ethiopia.**

1. INTRODUCTION

The term "millet" is given to different warm-season annual grass crops around the world that are harvested as grain for human food or animal feed. Millets are similar to sorghum forage in their productivity and feed value. There are several advantages of millets more than sorghum when grown for forage, including non-prussic acid potential. In addition to this, they are tolerant to soil with high pH conditions. Millets are generally considered as negligible crops in another place, but in India, Africa, and China they have a great importance and solve hunger problem of many people in those countries. When compared to other cereal grains, millets can grow well on less fertile soils and non-suitable growing conditions (Upadhyaya *et al.*, 2008), such as in dry areas, temperate, subtropical and tropical regions (Baker, 1996). Millets are the third most important cereal crops in Africa after maize and sorghum. They are grown in the harsh semi-arid tropics of Africa where inadequate rainfall and lack of irrigation make production of other cereal crops difficult to sustain. A general impression is that research to improve millets has generally lagged worldwide because they are not grown as food crops in the developed world and in Africa, they are considered as "poor man's crops"(Mywish *et al.*,1998).

The millets consist of five genera of the Panaceae family (*Panicum, Setaria, Echinochloa, Pennesetum* and *Eleusine).* The most important cultivated species are: Proso millet (*Panicum miliaceum*), Foxtail millet (*Setaria italica*), Japanese barnyard millet (*Echinochlo afrumentacea*), Finger millet (*Eleusine coracana*) and Kodo millet (*Paspalum scrobiculatum*) (Pragya and Rita, 2012). Finger-millet (*Eleusine coracana)* gains its name from the head of the plant, which bears some similarity to splayed hand (Roger, 2012). Finger millet is one of the most cultural foods and native to East Africa. However, in spite of its importance to the livelihoods of millions of small-holder farmers in East Africa, its valuable nutritional and processing properties, the growing demand exceeding supply, and its regional and international trade potential, finger millet has largely been neglected by national and international research organizations and major donors to agricultural research in sub-Saharan Africa. This neglect has contributed to a lack of realization of the potential productivity of finger millet.

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Increased production, utilization and trade of finger millet in East Africa are currently limited by a number of constraints (Mgonja *et al*., 2005).Crop damage by insects is minimal but pests such as birds and *Striga* weed are a constant serious threat to the crop (Esele, 1989). The most serious biotic constraint is the blast disease caused by the fungus *Magnaporthe grisea*. Blast affects finger millet at all growth stages, particularly causing major losses through neck and Panicle infections (Mgonja *et al.*, 2005). Finger millet blast disease is by far the most devastating, causing over 50% yield loss (Esele, 1989). Other constraints to finger millet production include poor incentives and marketing arrangements – low pricing, poor and inaccessible market channels, inaccessibility to credit facilities and inadequate improved processing and product development facilities at commercial levels (Mgonja *et al*., 2005).

To fulfill the strong upsurge in demand of cereal globally, it is necessary to adopt innovative technologies and approaches for new varieties generation, among which is transgenic plants creation with desirable traits. Although especially in the developing world, millets are economically essential, there has been observed little genetic improvement on the specific use of wide- or cross- hybridization among species that are closely related. Direct transfer of the desirable traits to millets via efficient or optimum transformation technique has helped to alleviate the incompatibilities resulting from inter-specific hybridization. Thus, it is possible to overcome crossing barriers and asexually introduce genes from unrelated sources into crop plants. At first, owing primarily to their recalcitrance to *in vitro* regeneration along with their resistance to *Agrobacterium*-mediated infection, it was challenging to genetically engineer monocots generally and cereals specifically. However, for major cereals like rice and maize, there have been established efficient transformation protocols. As soon as efficient or optimum regeneration has been developed, the prerequisite of gene transfer to millets would be facilitated (Plaza-Wüthrich and Zerihun Tadele, 2012).

2. LITERATURE REVIEW

2.1. DESCRIPTION AND TAXONOMY OF FINGER MILLET (ELEUSINECORACANA)

Finger millet (*Eleusine coracana* subsp. *coracana*) and its wild relatives are the members of *Chloridoidea*, one of the primary subfamilies of the grass (*Poaceae*) family. The cultivated *E.coracana* is a tetraploid species (2n=4x=36) derived from its wild ancestor *E. coracana* subspecies *Africana*. It is highly self-pollinated and has 36 or 72 (2N) chromosomes (Rachie, 2011).Finger millet has different common names in different countries such as ragi and mandua (India); koddo (Nepal); finger horse (Germany); petit mil, eleusine cultivee, coracan, koracan (France); bulo (Uganda); kambale, lupoko, mawele, amale, bule (Zambia); poho, rapoko, zviyo, njera, mazhovole (Zimbabwe); finger millet, African millet, koracan (England); in different localitieis of Ethiopia it is known by different names dagussa, tokuso (Amara region), barankiya (Borena), dagusha (Tigray), daguja (oromia) and wimbi, mugimbi (Kenya). It is an important staple food in parts of eastern and central Africa and India (Yilma Kebede and Abebe Menkir, 1986).

2.2. MORPHOLOGICAL STRUCTURE OF FINGER MILLET

Finger millet is a feathered annual crop, which grows to a height of 30–150 cm and is harvested in 75–160 days. Leaves are narrow, grass-like and able to produce many tillers and nodal branches. The panicle comprises a group of digitally arranged spikes often known as fingers. The spikelets are made up of four to ten florets arranged on the finger. All florets are perfect flowers with the exception of the terminal ones which may sometimes be infertile. The grain is oblong to round and oval shape, reddish brown, creamy white, and dark brown in color with the grains' surface finely roughened. Finger millet grain has a good aroma when roasted or cooked and understandably possess a number of health promoting qualities. The grain is a crop that is particularly valuable for areas experiencing famine as it can be stored for years without insect damage (Prem, 2012).

2.3. ORIGIN AND DISTRIBUTION OF FINGER MILLET

Recent reports indicated that the diversity of finger millet is originated in East Africa (FAO, 1998). It is widely known in African highlands, especially Ethiopia and/Uganda, recognized as the main center of origin, while the Indian sub-continent was mentioned as secondary center. For more than 5000 years, the crop has been cultivated on both continents but separated both morphologically and genetically. Wild finger millet (subspecies *africana*) is native to Africa but has migrated to several warmer parts of Asia and America (Prem, 2012).

In the late Aksumite period (100 BC to 300 AD), the crop was one of the dominant crops. Further, it is on record that the late Aksumite populations were largely occupied with food processing and production and that the cultivated crops range which includes finger millet was notably like that exploited in the region in more recent times. In Ethiopia, especially in

the northern part of the country, finger millet has an old history of domestication, and its cultivation has been from time immemorial. The strong relation and values that the crop has to the livelihood of the people in the Tigray region of Ethiopia is expressed in the traditional songs, sayings and poems that are transferred from generation to generation through oral traditions and continues to expand the crop's biological adaptation and use value attributes (National Research Council, 1996).

2.4. CULTIVATION OF FINGER MILLET

Cultivation of finger millet has become more extensive in lieu of its geographical adaptation and in comparison to other millets. It is capable of surviving different tropical weather conditions, drought, humidity and heat. In several parts of eastern and southern Africa, as well as in South Asia, it is an important staple crop. Besides this, the actual estimated area and global production is not available with the exception of India and Africa. The global annual planting area of finger millet is estimated at around 4- 4.5 million hectares, with a total production of 5 million tons of grains, of which India alone produces about 2.2 million tons and Africa about 2 million tons. The rest comes from other countries in South Asia.

The important finger millet growing countries in eastern and southern Africa have been especially the sub-humid regions of Ethiopia, Kenya, Malawi, Tanzania, Uganda, Zaire, Zambia and Zimbabwe. Similarly, in South Asia the crop is largely grown in India, Nepal and, to some extent, in Bhutan and Sri Lanka. Additionally, in both China and Japan, finger millet is reportedly grown to a limited extent (Prem, 2012). Finger millet is often cultivated in semi-arid and arid agro ecology, where it is frequently affected by drought (Masresha Fetene *et al*., 2011). It is extensively cultivated in the tropical and sub-tropical regions of Africa and India is known to save the lives of poor farmers from starvation at times of extreme drought (Dagnachew Lule *et al*., 2012). It is indigenous to Ethiopia and occupies 304,758 ha of land with production of 305,101 tons (CSA, 2008). It is grown more or less throughout the country though mainly cultivated in the mid and low altitude of regions of Gonder, Gojam, Wollega and Tigray where it constitutes 10 to 20% of the total cereal production (Yilma Kebede and Abebe Menkir, 1986).

The yields of finger millet are low in Ethiopia due to different production problems including: lack of improved varieties, little research emphasis given to the crop, non-adoption of improved technologies, poor attitude to the crop, disease like blast which is the most serious disease, lodging, threshing and milling problem are some of the most serious production constraints in finger millet production in Ethiopia .The other problems faced by this crop are blast diseases and downy mildew, which is caused by fungal diseases and drought stress. Hence, the main stresses that the crop suffers are drought and blast. This can be very severe and the losses could sometimes goes up to 60%. Leaf blast is not very common but neck and finger blast are common and cause a risk to maximum yield loss (Yemane Tsehaye and Fassil Kebebew, 2002; Kebere Bezaweletaw *et al.*, 2006; Erenso Degu *et al*., 2009; Andualem Wolie, 2009)..

The major attributes of finger millet are its adaptability to adverse agro-ecological conditions with minimal inputs, tolerant to moisture stress, produced on marginal land where other crops cannot perform and tolerant to acidic soil and termites (Barbeau, and Hilu, 1993). Furthermore, it has high nutritional value and excellent storage qualities (Dida, 2007) and the grain has high malting properties (Rachie, 2011). Therefore, finger millets represent one of the critical plant genetics resources for the agriculture and food security of poor farmers that inhibit arid, infertile and marginal lands (Dagnachew Lule *et al.*, 2012).

Finger millet has a relatively wide range of adaptation within moderate temperatures and moisture ranges. It is most widely cultivated on hilly, lateritic soils in the 500-1000mm rain fall belt of the tropics and subtropical regions. It has high yielding potential producing highest mean yield among the millets in Africa and India, and is frequently grown both dry and irrigated on lands where moisture is insufficient for other crops (Rachie, 2011).

2.5. IMPORTANCE OF FINGER MILLET

Finger millet is used for making a number of dishes and drinks, especially in the rural areas. The non-distilled local beer (*Tella*) and the porridge made from the crop allegedly cure diseases like diarrhea and malaria, and assist in the healing of fractured bones. Although various crops like barley, maize and sorghum can be used in preparing *Tella*, at wedding ceremonies and other religious festivals conducted in central and western Tigray, the *Tella* used must be made of finger millet. *Tella* is also essential for labor group workers, at weeding and harvesting. Finger millet is also used by the Muslims in preparing non-alcoholic local drinks (*karibo*). The traditional drinks *Tella* and *areki* (distilled liquor) are also

an income source both in certain parts of the rural areas and in small towns. To complement the household income, women farmers usually engage in these kinds of activities. All of the unleavened bread (*kita*) and the leftovers after the purified *Tella* is taken away is also used in feeding animals. In the rural areas, finger millet is consumed as *enjera* which is tasty and easily digested (National Research Council, 1996).

Finger millet provides food grain and straw which are appreciated animal feed, particularly in the rain fed areas. Among the major food grains, finger millet is the most nutritious crops for minerals (calcium and iron), protein, and amino acids (methionine, an amino acid lacking in the diets of hundreds of millions of the poor who live on starchy foods like plantain, cassava, maize meal and polished rice); and provides calcium 8-10 times beyond rice or wheat. Finger millet carbohydrates reportedly possess the unique characteristics of slower digestibility and are potentially food for long sustenance. The excellent malting qualities have contributed to the grain uniqueness in expanding its range of utility in value addition and food processing (Prem, 2012).

Nutritionally, finger millet is good source of different nutrients, minerals and fiber. Total carbohydrate content of finger millet has been reported to be in the range of 72 to 79.5%. About 80 to 85% of the finger millet starch is amylopectin and remaining 15 to 20% is amylase. Non-starch polysaccharide account for 20 to 30% of the total carbohydrates in finger millets. Reducing sugar in the range of 1.2 to 1.8% and 0.03% non-reducing sugar is found in finger millet. The *in vitro* starch digestibility of native finger millet is 71.67%. Total dietary fiber insoluble dietary fiber and soluble dietary fiber content in finger millet is 12, 11 and 2%, respectively. Finger millets have hypoglycemic effect, which is attributed to high fiber content. High fiber diets containing complex carbohydrates are slowly digested and absorbed, thus bring reduction in postprandial glucose. The second major component of finger millet is protein. It has nearly 7% protein but large variations in protein content from 5.6 to 12.70% have been reported (Pragya and Rita, 2012). Finger millet is a popular food among diabetic patients in different countries. Its slow digestion indicates low blood sugar levels after a finger millet diet thereby reacting as a safer food for diabetics. It has also anti-oxidant and antimicrobial properties (Palanisamy *et al*., 2011).

Despite all these positives, at national and global levels, finger millet remains a neglected crop. In many European, South and North American countries, the crop is hardly known. Recently, there has been a rapid decline in the production of this neglected crop, raising the apprehension that finger millet grain may become a rare commodity (Prem, 2012). Thus *in vitro* culture functions uniquely in competitive and sustainable forestry and agriculture, and is successfully applicable in plant breeding, as well as in the rapid introduction of improved plants. This becomes true through plant tissue culture technology.

2.6. PLANT TISSUE CULTURE AND ITS ADVANTAGE

Plant tissue culture is the production of plant cells, tissues, or organs on specially formulated nutrient media under aseptic environment and controlled conditions of temperature, humidity and light. Under the right conditions, there can be regeneration of an entire plant from a single cell. Plant tissue culture is a method that has been applied for about more than 50 years. There are different types of tissue culture techniques based on the part of the plant (explants) used (Evans *et al*., 2003). As a fundamental science, plant tissue culture development was closely associated with plant hormones discovery and characterization, and has further enhanced our comprehension of plant growth and development. In addition, to be able to have a cultured growth of plant cells and tissues as well as control their development forms the basis of a number of practical applications in agriculture, horticulture, industrial chemistry and is a prerequisite for plant genetic engineering (Fowler, 1987).

The green revolution is regarded as resulting, at least partly from Mendelian genetics application to crop improvement. This has led to yields maximization of most crops cultivated under conditions that reduce disease and insect pressure and on soils supplemented with inorganic fertilizer. During the 1960s, it was observed that within a few decades, production of green revolution grains would be overwhelmed by increase in world population. Thus, the advancement of alternate strategies for boosting plant productivity was regarded as essential. *In vitro* approaches for manipulating plant differentiation growth and development, including haploid plants production from cultured anthers, plants regeneration from cell cultures, isolation of protoplast, culture and fusion of haploids were taken as essential parts of this new technology. Cell culture coupled with molecular biology for crop improvement has been known as the ‘genetic engineering revolution’ (Wagramer, 2004).

Plant tissue and cell cultures are usually initiated from pieces of whole plants. During the past few decades tissue culture techniques have been developed that could be used for the improvement of crop plants. Comparatively, monocotyledons are regarded as difficult *in vitro* material. The potential value of cell, tissue culture as tool for use in the improvement of crop plants has been described (Green, 1977; Vasil, 1987).

Tissue culture technology is used for the production of doubled haploids, cryopreservation, propagating new plant varieties, conserving rare and endangered plants, difficult to propagate plants, and to produce secondary metabolites and transgenic plants. The production of high quality planting material of crop plants and fruit trees, propagated from vegetative parts, has created new opportunities in global trading, benefited growers, farmers, and garden owners, and improved rural employment. However, there are still major opportunities to produce and distribute high quality planting material, e.g. crops like banana, date palm, cassava, pineapple, plantain, potato, sugarcane, sweet potato, yams, ornamentals, fruit and forest trees. The main advantage of tissue culture technology lies in the production of high quality and uniform planting material that can be multiplied on a year round basis under disease free conditions anywhere irrespective of the season and weather. However, the technology needs high capital, labor and energy investment. Although, labor is cheap in many developing countries, the resources of trained personnel and equipment are often not readily available. In addition, energy, particularly electricity, and clean water are costly. The energy requirements for tissue culture technology depend on day temperature, day length and relative humidity, and they have to be controlled during the process of propagation. Individual plant species also differ in their growth requirements. Hence, it is necessary to have low cost options for weaning, hardening of micro propagated plants and finally growing them in the field.

Plant tissue culture techniques have a vast potential to produce plants of superior quality, but this potential has been not fully exploited in the developing countries. During *in vitro* growth, plants can also be primed for optimal performance after transfer to soil. In most cases, tissue cultured plants outperform those propagated traditionally. Thus *in vitro* culture has a unique role in sustainable and competitive agriculture and forestry, and has been successfully applied in plant breeding, and for the rapid introduction of improved plant. The improved resistance to diseases and pests enables growers to reduce or eliminate the application of chemicals (Wagramer, 2004).

2.7. REGENERATION AND SOMATIC EMBRYOGENESIS

Regeneration of whole plants from callus cultures occurs in two general path ways, via organogenesis and embryogenesis. The later gives rise to most plants of unicellular origin and production of clonal plants, enabling crop improvement by means of tissue culture to become more effective. Regeneration via somatic embryogenesis of major cereal crops including corn, rice, sorghum, and wheat has been reported, but embryogenesis and regeneration from callus cultures have been inconsistent in cereals. Thus an observable challenge for cereal tissue culture workers is to systematically develop *in vitro* technologies for faster and more expected production of embryogenesis and plant regeneration. The capability of gametophyte cells to form *in vitro* embryos which are competent to develop or to regenerate is a particular characteristic of plants. In this consideration, microspore and somatic embryogenesis can be regarded as model system to investigate the mechanisms of plant embryogenesis and development, and the whole process of plant cell differentiation. The fact that the embryos can develop from microspore or somatic cells also demonstrate the genetic program for embryogenesis can be completed outside of sexual reproduction (Henry *et al*., 1994).

Current progress in plant genetics and biotechnology is highly dependent on the use of *in vitro* cultures. Hence the establishment of effective *in vitro* plant regeneration systems enabling a rapid production of fertile, genetically ‘solid’ plants is of great interest to plant biotechnologists. Among the various *in vitro* systems applied, somatic embryogenesis (SE) is of special importance. It offers opportunities for *in vitro* production of true to type plants by clonal propagation as well as regeneration of genetically modified plants by genetic transformation, and somatic hybridization and *in vitro* mutant induction and selection. Moreover, SE is a useful tool in basic research on totpotency and on the fundamental processes of plant morphogenesis. Thus, the possible broad applications of SE in both basic and applied research have stimulated studies on the determination of *in vitro* conditions for the induction of somatic embryos, and their further development into complete plants. According to this, an increasing number of protocols describing efficient *in vitro* systems based on regeneration via SE are being published. Remarkable progress in the development of *in vitro* systems is enabling induction of SE in many economically important plants, as well as in model species. In recent years efficient protocols on SE induction and plant regeneration have been accessible also in *Arabidopsis thaliana* (L.) Heynh, a model

organism in plant genetics and embryogenesis (Malgorzata, 2004). One of the most important prerequisites for genetic manipulation of plants *in vitro* has been the ability to grow somatic cells in sterile plant growth medium and to regenerate plants from these cultures (Litz and Gray, 1995).

Somatic embryogenesis is developmental process by which somatic cells undergo reorganization to generate embryogenic cells. These cells then go through a series of morphological and biochemical changes that result in the formation of somatic or non-zygotic embryo capable of regenerating plants. Somatic embryogenesis represents a unique developmental pathway that includes a number of characteristic events: dedifferentiation of cells, activation of cell division and reprogramming of their physiology, metabolism and gene expression patterns. Somatic embryos can develop indirectly, through callus tissue (ISE) or directly from explants tissue (DSE).Somatic embryos developing via direct somatic embryogenesis are formed from competent cells of explants, contrary to indirect somatic embryogenesis, are able to undergo embryogenesis without dedifferentiation or callus formation. It is believed that both processes are extremes of one continuous developmental pathway (Carman, 1990). Distinguishing between direct somatic embryogenesis and indirect somatic embryogenesis can be difficult (Emons, 1994) and both processes have been observed to occur simultaneously in the same tissue culture conditions (Turgut *et al*., 1998).

Direct somatic embryogenesis called primary somatic embryogenesis, and somatic embryogenesis through callus is called secondary somatic embryogenesis in the culture of somatic embryos. A much higher efficiency of secondary somatic embryogenesis over primary somatic embryogenesis has been indicated for many plant species (Raemakers *et al*., 1995; Akula *et al*., 2000; Vasic *et al*., 2001). Some cultures are able to retain their competence for secondary embryogenesis for many years and thus provide useful material for various studies, as described for *Vitis rupestris* (Martinelli *et al*., 2001).

Somatic embryogenesis on culture of 'embryonic' explants is the most common method and regular feature of plant regeneration in all the major species of cereals and grasses (Park and Walton, 1989; Vasil, 1988).

Genetic improvement of the crop depends on the combined manipulation of tissue culture techniques (Das and Misra, 2010). Production of transgenic plants with desired qualities is possible by genetic transformation of the desired genes in to the selected plants through the methodology of tissue culture. Efficient callus formation and regeneration is an important requisite to perform *Agrobacterium*-mediated transformations for producing transgenic plants (Anjaneyulu *et al.*, 2011). *Agrobacterium tumefaciens*-mediated genetic transformation has been successfully demonstrated with a wide range of important crop species (Litz and Gray, 1995). One of the most important prerequisites for genetic manipulation of plants *in vitro* has been the ability to grow somatic cells in sterile plant growth medium and to regenerate plants from these cultures (Christianson, 1987).Theoretically, the regenerants are derived from single, totipotent cells and this has been demonstrated with several species. However, under certain growth conditions (and particularly with organogenesis), morphogenesis can involve more than one cell (Christianson, 1987). It is generally considered that somatic embryos are derived either from single cells or from single cells within a pro embryonic mass. Somatic embryogenesis, therefore, is a more efficient pathway for studies involving production of genetically transformed plants. And also Helen *et al*., 2019 were done somatic embryogenesis of four cultivars and get 95-100% of callus induced. These embryogenic calluses are a prerequisite for genetic improvements of this crop.

3. CONCLUSSION

Finger millet is one of the most important crops and used to make several dishes and drinks, particularly in the rural areas of Ethiopia. It cures different diseases such as diarrhea and malaria, and assists healing of broken bones. In addition to this, it grows at higher temperatures and in soils with higher salinity compared to other cereal crops. Optimum conditions for growing finger millet are temperatures ranging from 11 to 27 ◦C, soil pH of 5 to 8.2, and mediumrainfall.

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