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The Current Status of Yam (*Dioscorea* Spp) Research in Ethiopia: A Review Paper

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Abstract
Root and tuber crops give the highest rate of dry matter production per unit area of land compared to other crops. They are major calorie contributors. Yams (Dioscorea spp) are among tuber crops which possess medicinal properties to cure many ailments and used in the preparation of stimulants, tonics, carminatives and expectorants that can be used as industrial raw materials. Indeed, they are rich in dietary fiber, carotenoids and anthocyain content. They play a major role in food and nutrition security of producers and consumers. Yam and other tuber crops producing areas have not encounter frequent drought and producing farmers have economical advantage due to their high market values. Yam (Dioscorea spp) has given a minimum attention by agricultural research systems. It is among a group of crops labeled as "orphaned crops", which have not received research attention for a long period of time. Whereas, there are some research and genetic improvement works have been made in the country. This paper reviewed these research works which were done using molecular tools like AFLP, SSR and ISSR markers including phenotypic traits studies. Hence, these traits are the basis of molecular assisted breeding. The reviewed research results and recommendations implied that a presence of high genetic and species diversity in Ethiopian yam. However, the genetic erosion due to biotic and a biotic factors and low research emphasis towards yam (Dioscorea spp) were the major challenges to boost its' productivity and use it as industrial crops through value addition and, extraction of important bio-chemicals for medicinal values.

Keywords: Yam, Orphan, Diversity, Phenotypic, Molecular

Historical background of yam *(Dioscorea* spp)

Roots and tubers refer to any growing plant that stores edible material in subterranean root, corm and tuber. They are the most important food crops after cereals and are of very ancient origin in the tropics and subtropics (Asha and Nair, 2002) [5]. These crops have contributed to the human existence, survival, and socio-economic history. Food yams are believed to have originated in the tropical areas of three separate continents, Africa, South East Asia and South America.

Yam belongs to the oldest monocotyledonous family *Dioscoreaceae* (Coursey, 1967) [9].The family *Dioscoreaceae* is a natural group of tuber forming tropical vines and is usually grouped with Liliales (Burkill, 1960) [7]. The areal storage organ of *Dioscoreaceae* is the bulbil. They are perennial plants with a strongly marked annual cycle of growth (Coursey, 1983) [8].

Yams (*Dioscorea* spp.) are among the most important tuber crops in Ethiopia, especially in humid areas where there is heavy year-round precipitation (Kay, 1987) [16]. It is known by different vernacular names in different locations of the country such as Boye by Dauro people; Kocho or Wocheno, Oromo; Bohe, Wolayita; Kuso, Yem; and Boina, Sidama (Edosa Etisa, 1996). Yams have become an important cash crop in most localities and are of preferred food for respected guests. Yams are also served during the traditional celebration which coincides with the peak harvesting time and thus allowing farmers to earn profit from the market. Hence, yam is important not only for household food security, but also as a source of cash income and profit (Muluneh Tamru 2006) [21]. Several species of Dioscorea grow in different parts of Ethiopia; not all are edible. Eleven described *Dioscorea* species, (both wild and cultivated), are found in the country (Mie'ge and Sebsebe Demissew, 1997) indicating the wide diversity of the species in the country. The species *D. alata* L is not indigenous to Ethiopia but originated in Southeast Asia. In Ethiopia, it is sterile and grows only in cultivation.

The genetic resource of yam *(Dioscorea* spp)

The term 'yam' refers to all members of the genus *Dioscorea*, which contains over 600 species (Hodeba *et al.*, 2008). Many wild yam species contain toxic and/or other bioactive chemicals and some of these are cultivated for pharmaceutical products (Coursey, 1967) [9].

About 10 species of yam are commonly cultivated for food, while a number of others are harvested from the wild in times of food scarcity (Bhandari *et al*., 2003). Cultivated species include *D. alata* L., *D. cayenensis* Lam., *D. rotundata* Poir. *D. esculenta* (Lour) Burk, *D. bulbifera* L., *D. nummularia* Lam., *D. pentaphylla* L., *D. hispida* Dennst, *D. trifida* L. F and *D. dumetorum* (Kunth) Pax. They are annual or perennial herbaceous vines with edible underground tubers (Nweke *et al*., 1991) [25]. It is indicated that approximately 200 species of yam are distributed throughout the tropics and subtropics (Ayensu, 1972) [6]. Although highly variable in appearance both between and within species, all yams share a common growth habit of thin, twining vines and a shallow, widely radiating root system, both of which die and are renewed each year. All economically important species are tuberous, producing one or more underground tubers.

Yams are superior to many others as an important medico food used by about 300 million people throughout the world (Arnau *et al*, 2010). As per source of dietary nutrients, *Dioscorea* species rank as the world's fourth most important root crops after potato, cassava, and sweet potato. Yams are one of the principal sources of energy for many people in the tropics. In contrary to most root and tuber crops, yam is a preferred crop that can be stored up to four to six months at ambient temperature. This characteristic contributes to the sustaining of food supply, particularly in the difficult, food scarce, periods at the start of the wet seasons. By virtue of its excellent palatability, it is a high value crop, cultivated throughout the tropics, part of sub tropics and temperate zones (MoA, 2010).

The existence of diverse farming systems, socio-economics, cultures and agro-ecologies have endowed Ethiopia with a diverse biological wealth of plants, animals, and microbial species, particularly crop diversity. Yams (*Dioscorea* spp.) are among the most important tuber crops in the country, especially in humid areas where there is heavy year-round precipitation (Kay, 1987) [16]. Several species of *Dioscorea* grow in different parts of Ethiopia though all are not edible. Eleven described *Dioscorea* species, (both wild and cultivated), are found in the country (Mie'ge and Sebsebe Demissew, 1997) indicating the wide diversity of the species. The species *D. alata* L is not indigenous to Ethiopia but originated in Southeast Asia. In Ethiopia, it is sterile and grows only in cultivation. The set of species is composed of *D. Cayenesis, D. rotundata, D. abyssinica, D.praehensilis and D. sagitifolia* (Wilkin *et al.*, 2001). These species are indigenous to Ethiopia and occur all-over sub-Saharan Africa from 500m to 1800m altitude, especially in seasonally dry areas (Miège and sebsebe Demisew 1997). Indeed, the cultivated yam species *D. bulbifera* (aerial yam), *D. abyssinica* and *D. schimeriana* are native to Ethiopia (Westpal, 1975) [30].

The major production constraints of yam (*Dioscorea* spp)

Germplasm of many horticultural and perennial crops are mainly vegetative propagated crops. They are usually conserved in open field condition. The seeds of these crops like yam, cassava and sweet potato are rarely produced. Major constraints to field gene banks include large area requirement, expensive to establish and maintain the germplasms, the natural hazards of farming like disease, insect pest and humans handling lead to loss of valuable genotypes. Among pests, yam beetle and aphids are the major insect pest problem observed in the country. The other challenge is emphasis given to yam and, other root and tuber crops research is very low or absent in contrary to their high importance to producers, consumers and countries economy.

The major objectives of yam (*Dioscorea* spp) breeding

The major breeding objectives in yams are getting higher yield, good tuber quality (oxidation rate, taste, texture, dry matter content), early maturity, resistance against pest and diseases; anthracnose and nematode resistance, round to oval tuber shape varieties, shallow tuber, dwarf/ and compact plant types that can be produced without staking and more shelf life.

The present yam (*Dioscorea* spp) research achievements in Ethiopia

The yam *(Dioscorea* spp) accessions developed through open field and bi-parental crossing

Yam is a multi-species, polyploid and vegetative propagated crop, exclusively propagated by means of its areal, small tubers or small pieces of tuber. Earlier studies of other countries on yam improvement using controlled pollination indicated the presence of limited incompatibility, abortion, sterility and the resulted produced genotypes were few. However, botanical seeds obtained from open pollinated field contain greater genetic diversity that can give better chances of selection (Amanz etals, 2011) [3]. The genetic diversity available in the germplasm can be exploited by selection and hybridization. Vegetative propagation is a good tool to utilize the heterosis expressed in F1 generation. Once a desirable clone is identified, it can be easily maintained through vegetative propagation for many years without any genetic deterioration. Thus, selection can be made for yield, palatability, flavor and nutritional quality from a large number of cultivars and breeding lines (Shirly, 2018).

Considering to this, observation of yam (*Dioscorea spp*) flowering and botanical seed germination for its' genetic improvement and conservation activities were conducted using 60 yam germplasms of six different species collected tubers from different major growing regions of Ethiopia. Among plants observed in 60 yam germplasms, 21, 12 and 27 genotypes were male, female and none flowering respectively. This implies that female plants are small in yam population compared to male yam plants. In this study, 1000 botanical seeds were collected from open field. It is indicated that, germination percentage of yam botanical seeds were 85% with healthy and, vigor yam seedlings. The range of maturity date and tuber weight variability obtained from each transplanted seedling was from 6 to 12 months and 2g to 3800 g respectively. The tubers produced from botanical seeds showed three types of flesh colors which were white, pale yellow and purple (Atnafua, 2021) [1]. This indicated that a presence of possibility of increasing yam genetic variability using its' botanical seeds. The genetic erosion is the major problem in this crop. Hence, it will be an alternative way for conserving yam and other root and tuber crops germplasms using their botanical seeds to minimize their loss at field gene banks due to biotic and abiotic factors (Atnafua, 2021) [1]. Currently, yam crosses from selected parents were developed for high yield and better nutritional content and these are found at field evaluation.

a b c

Fig 2(a, b, c): Yam (*Dioscorea spp*) seedlings, plant and tubers produced from its' true botanical seeds

The yam (*Dioscorea* spp) varieties developed for production

The cultivated yams are exclusively vegetative propagated crop. As a result, cultivars are clones of an ancestral plant, but spontaneous somatic mutations may have contributed to the diversity and productivity of modern cultivars. In the country, most of its improvement work was done through collection, characterization and evaluation of germplasms found in major producing areas of the country. Based on this, 4 high yielding yam varieties were released for wide agro-ecological production and high anthocyanin content. These varieties were released by Hawassa, Jima and Bako Agricultural research centers. The nutritionally rich high antocyanin content purple yam was released by Hawassa agricultural research center for conception (MOA, 2020) [24]. Purple fleshed yams are a rich source of anthocyanins, which have medicinal value as anti-oxidant, anti-mutagenic, anti-diabetic and anti-carcinogenic properties. It is a source of essential micro-nutrients and phyto-chemical compounds. (Archana, 2018) [4]. The studies indicated that purple yam has high health value and such kind of tubers need to be popularized as a natural source of anti-oxidants (Padmaja and Jyothi, 2018). These varieties were being distributed to producing area of the country.

The morphological genetic diversity studies of yam (*Dioscorea* spp)

The awareness of existing plant genetic diversity is fundamental for effective management of crop genetic resources. The variability obtained in the genome of a species can be grouped in to visible and non-visible characteristics. Ethino-botanical classification, morphological, biochemical and molecular characterization are techniques used for measurement of genetic diversity. Morphological characterization is highly recommended at the beginning prior to biochemical and molecular studies. Morphological markers allow assessment of genetic variability based on individual phenotypic difference (Mondini *et al*, 2009) [22].

The morphological and molecular assessment of Ethiopian yam diversity was done and described by some authors. According to Muluneh Tamru (2006) [21], the morphological variation of eighty-four yam (*Dioscorea* spp) accessions collected from Sidama and South regions that means from Sidama, Gamo Gofa, Gedio, and Wolayita areas were evaluated based on thirty-two qualitative morphological traits. The author reported that morphological groups revealed through cluster and principal component analysis were largely consistent with farmers' landrace classification, mainly to maturity time. However, there was no morphological difference between some landraces managed as different by farmers. Based on these results, Muluneh suggested that further studies are required on the yam classification system, morphological and molecular marker-based analysis of genetic diversity through covering areas which were not included in his studies.

Atnafua and Endashaw, (2020) [2] studied yam germplasms phenotypic diversity collected from 10 major producing areas of Ethiopia. The collection areas included Gamogofa, Sidama, Dauro, Gedio, East Wolega, Jima, Kafa, Wolayita and Kembata, the collected germplasms were characterized using 45 morphological traits. They indicated that presence and absence of spines on stems and roots, number of male and female inflorescence, stem length, twining direction, and flesh color were the major traits for species identification. Based on this, the collected germplasms grouped in to 6 species. The tuber flesh color and tuber shape revealed differences among different species. The yam tubers of *D. praehensilis* and *D. alata* had finger like appearance while tubers of *D. rotundata, D. cayenensis and D. abyssinica* were long with oval shape. The flesh color of *D. abyssinica* and *D. praehensilis* were purple. Though *D. cayenensis* and *D. alata* revealed yellow and white tuber flesh colors respectively. It is indicated that anthocyanins and carotenoids are pigments found in yams that give their distinctive tuber flesh colors (Martin, F. and Ruberté, R. 1976) [18]. B-carotene and Xanthophyll esters are responsible for the yellow flesh color of *D. cayenensis.* The identified *Dioscorea* species were subjected to qualitative morphological characterization. They indicated the presence of important heritable phenotypic trait which helps to attain genetic improvement of the crop. Most of morphological variations among the genotypes were contributed by young petiole color, tendency of tuber to branch, tuber flesh color, color of tuber after cooking and flavor of cooked tuber. Morphological and organoleptic traits can be taken as useful characters for identification of yam cultivars. Morphological characterization of Ethiopian yam accessions showed that Wolayita regions had wide genetic diversity and most yam landraces from Wolega revealed different genetic bases. They recommended and concluded that collection and selection of yam genotypes has to consider germplasms of Wolega and Wolayita regions for breeding and improvement activities of the crop.

Limitations and need of molecular assisted breeding in yam (*Dioscorea* spp)

Molecular markers used to identify variation at the DNA level and exhibit adequate polymorphism to distinguish between genotypes (Kumar *et al*., 2009) [17]. Molecular analysis can complement traditional approaches in identifying duplications. Molecular tools can help improve to study related to origin, phylogenetic relationship, geographical distribution, hidden genetic diversity and predictions on susceptibility of the crop to any particular disease. It is important to minimize duplicates and has to be done complementary to germplasm conservation methods. Thus, yam is indigenous crop with great food and nutritional value of producing area has to be supported by molecular markers for better conservation techniques to minimize its genetic loss and future use of germplasms. Indeed, it has to be greatly supported by tissue culture techniques for germplasm conservation and multiplication for better production and better use of the crop. However, the crop has given low attention in any aspects of its research and development activities.

The genetic diversity analysis of Ethiopian yam (*Dioscorea* spp) using molecular markers (AFLP, SSR, ISSR)

There are some limitations associated to morphological traits. The limitations led to the development of molecular markers. Molecular marker techniques are based on naturally occurring polymorphisms in DNA sequences. Thus, these markers had several advantages over conventional phenotypic characterization.

Understanding the molecular basis of essential biological phenomena in crops is vital for effective conservation, management, and efficient utilization of their genetic resources (Linda, *et al*, 2009). The launch of the polymerase chain reaction (PCR) was a step forward for molecular marker techniques and made possible many fingerprinting methods. Among all markers, RAPD, amplified fragment length polymorphism (AFLP), inter simple sequence repeat (ISSR), Simple sequence repeat (SSR) and most recently genotyping by sequencing (GBS) markers are applied widely. Except GPS, they do not require the knowledge of genome sequences and the techniques used are comparatively simple, rapid and cost effective (Elshire *et al*., 2011) [11]. In this aspect, the present review on yam germplasms molecular markers-based study stated that a previous works on its' genetic diversity analysis using AFLP, ISSR, SSR markers.

Regarding to this, sixty-two yam (*Dioscorea* spp) accessions diversity study using AFLP markers indicated that Ethiopian yams are distinct from West Africans (Muluneh Tamru, 2006) [21]. He also suggested need of further studies on cultivated and wild yam species using co-dominant molecular markers by including more samples from Wolayita, Gamogofa and also extending to other localities in the south and south western parts of the country to cover areas that were not covered by his study.

The other research done by Wendawek Abebe (2008) [20], yam (*Dioscorea* spp) genetic diversity was studied using morphometric analysis, molecular markers namely AFLP and microsatellites. The plant materials used for morphometry were 40 dried herbarium specimens of *D. abyssinica, D. praehensilis, D. bulbifera, D. cayenensis,* two accessions of *D.schimperiana* and one accession of *D. bulbifera* were included for comparative studies. Characterization and evaluation study using Amplified Fragment Length Polymorphism (AFLP) on forty-three yams (*Dioscorea* spp) of Ethiopia did not reveal clear species boundaries between the Guinea yam accessions of Sheko origin and their wild relatives. (Wendawok Abebe *et al.*, 2012). He recommended that taxonomy studies of *Dioscorea* species using other markers. Additionally, he suggested that future studies should be done at the population scale and in a broad range of geographical regions taking the diversity within each member of the Guinea yams.

The degree of genetic diversity and the relationship among and within Ethiopian yam germplasms collections were determined using SSR (Atnafua and Endashaw, 2021). The locations considered were 11 districts. The polymorphism percentage among populations of different districts ranged from 98.53% (Wolita) to 47.06% (Kembata) with a mean value of 82.21. This highest level of polymorphism of SSR techniques indicates that molecular marker is very useful for yam molecular characterization studies. Ethiopian yam genotyping based on this molecular marker showed, landraces of Gamogofa district exhibits high genetic distance to the majority of yam landraces of other considered areas and similarly yam germplasms of Wolita gave high genetic distance to Wolega and Gamogofa districts. Thus, it indicates importance of giving consideration to these distantly related populations of Gamogofa, Wolita and Wolega during improvement of the crop through breeding. Though, landraces of Kembata revealed less genetic distance from other localities. The high genetic variability was obtained with in Jima and Gedio yam landraces. Accordingly, it is vital to observe these germplasms during selection activities to increase yam production and productivity.

The polymorphic percentage was high among *Dioscorea* species. In this study the highest polymorphic percentages were recorded within *D. abyssinica* followed by *D. praehensilis and D. rotundata.* Similarly high genetic diversity was recorded within *D. abyssinica* species (Atnafua and Endashaw, 2021). According to Coursey (1967) [9], Ethiopia is considered the center of origin for *D. abyssinica*, which is found widely distributed in the savanna region of West Africa. Miege'e and Sebsebe Demissew, (1997), indicated that *D. abyssinica* is widely distributed in the southern, western and northern part of the country in woodlands or wooded grasslands between 1000m and 1800m above sea level. In this study species of *D. rotundata* and *D. cayenensis* were grouped in different cluster groups. Minoguna *et al*., (1998), stated that the Guinea yams are distinct but related species and the varietals groups of *D. cayenensis* were genetically distant from those of *D. rotundata.* Similarly, Muluneh Tamru (2006) [21] indicated that these two species are distinct groups.

Kedra *et als*, (2018) used ISSR marker for yam diversity study. They reported that a presence of *D. cayenensis/D. rotundata* complex and *D. bulbifera* showed high genetic variation. In *D. cayenensis/D. rotundata* complex, the highest genetic diversity was found within Gedeo population, which indicates that this population can be considered as a source of diverse individuals in future improvement of the crop. On the contrary, East Wellega population showed the least diversity hence it needs special attention for conservation. Cluster and principal component (PCO) analyses showed clustering of most of the accessions to their respective species and in some cases, to their geographic origin. However, they failed to differentiate between different guinea yam (*D. cayenensis/D. rotundata* complex) types.

In general, the above preceding studies indicated presence of high level of genetic variation in Ethiopian yam populations which implies importance of each population as a valuable genetic resource for future yam improvement programs. Thus, wise use of genetic diversity present in Ethiopian yam (*Dioscorea* spp) is crucial.

Conclusion and Recommendations

The genetic diversity is high among yam (*Dioscorea* spp) population. Currently, there is high genetic erosion of this tuber crop due to different natural and human factors. Hence, the germplasm conservation activities of yam both using *Insitu* and *Exsitu* methods are needed. Additional studies has to be done with aspects of its' medicinal and nutritional values which will have a great impact to use it for industrial purposes. Indeed, important genetic traits have to be identified using marker assisted selection for producing economically vital varieties like dwarf yam without stakes and resistant varieties to yam beetles. The improved storage and sprouting methods of yam product need a due consideration and studies.

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