



# Biodiversity and Conservation of Plant Genetic Resources on Socotra

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## Abstract

Yemen with its unique geographical location, diverse agro-ecological zone, harbors wealth of plant genetic resources. Socotra, an island in Yemen, is one of the most important agro-ecological region in the country because of its large biodiversity base in crops and endemic natural plant species. The main aim of this research is to explore the biodiversity of endemic germplasm of finger millet and natural plant species on Socotra, modes of conservation and utilization as sources to follow up the present situation of genetic resources and to use them in breeding programmes to improve their genetic architecture and to be used as useful sources of study for the university students, researchers and specialists.

**Keywords:** biodiversity, conservation, genetic resources, Socotra

## INTRODUCTION

Yemen with its unique geographical location, diverse agro-ecological zone and long history of agricultural development, harbors wealth of plant genetic resources. Out of the 3418 plant species in the flora of the Arabian Peninsula, 2810 are found in Yemen (Bawazir, 2001). Much efforts had been made and still underway to improve genetic architecture of plant genetic resources in Yemen with more emphasis paid to natural plant species on Socotra.

Despite the ancient ethnic and commercial links between Socotra and Hadhrmout, Mahra and Dhofar regions of the Arabian mainland, therefore, it is tempting to look to the tropical east Africa or to the Indian subcontinent, where finger millet and other economic natural plant species are much more important plant types than in Arabia, for the origin of Socotra materials. There are certainly also long standing trading links with Somalia and Indian coasts. This is a problem that the morphological comparison of Socotra materials, the Arabian mainland, northeast Africa and Indian coasts may elucidate. More emphasis should be paid to investigate morphological comparison of these endemic plant species in these regions in order to know the past region of these germplasm which have a considerable content of Socotra vegetation.

Socotra, Galapagos of the Indian ocean, is distinguished by wide genetic base and biodiversity. Flora of Socotra constitutes more than 800 plant types. Out of 415 endemic plant types found in flora of Yemen about 236 plant types are endemic of Socotra but not elsewhere of the world which constitutes about 36% of total flora of Socotra, some of them carry the name of the island (Ministry of Tourism and Environment, 2002). Most of endemic plant types were recorded on Socotra island since past time as early as the beginning of the last century (Balfour, 1903 and Popov, 1957).

National and international missions were then carried out to explore endemic plant types which have diverse economic importance, though these investigations were conducted at duration of long and so far intervals.

Many expeditions back to 1969 were launched by the Agronomy and Plant Breeding Section at El-kod Agricultural Research Centre P.D.R.-Yemen, as a part of an International Board of Plant Genetic Resources (I.B.P.G.R.) and F.A.O activities, to fill major collecting gaps for several crops and natural plant species in the Arabian peninsula by strengthening natural genetic resources programmes in the region. Crops and natural plant species including endemic

plant types had been collected extensively on Socotra and limited areas of mainland( Balfour , 1903 ; Popov,1957; Cronk, 1985; Bawazir,1988; Mu'Allem,1988; Mukred *et al* ,1991 ; Bazara'a *et al* , 1992, Jabeli, 1995 and Badeeb,1996)

According to records on International Union for Conservation of Nature ( IUCN ) red – book, Yemen has about 18 endemic plant types which are threatened by genetic erosion and disappearance out of which more than 10 endemic plant types found on Socotra . In this respect more emphasis should be paid to collect and conserve these eroded and disappearing plant types.

## Methodology

The authors visited the island for a couple of days during March 2014, where they studied and classified certain types of endemic plant species (table 1) and finger millet based on observations on nursery and at natural locations of their growth. Literature reviews were also used extensively by the authors to study and describe such plant species.

## RESULTS AND DISCUSSION

### Biodiversity of finger millet germplasm

Millet is the most important staple cereal food in Socotra as recently as mid of the 20<sup>th</sup> century. Nearly all the millet produced is finger millet *Eleusine coracana* , which is , locally, called(Bombah), with a very minor terraces grown by little millet *Pennisetum rigidum*. It is extensively cultivated on areas where water is abundant , but it is confined now to some villages on a very limited and much reduced areas as terraces where date palms are grown and on mountains around Haggier and at Haggier itself and it is also grown in the eastern part of the limestone plateau. This crop is traditionally cultivated by women in this island. Soil is prepared for cultivation of finger millet by setting fire in the pits of wood and animals dung and then mixing the ash with dried soil. Seeds are then sown generally in November when cool winds of northern monsoon blow, on terraces; irrigation is usually done by hand. The seedlings are watered daily until some 20 days after germination when they reach hand-span height when most of greenery is twisted off and they are divided into tillers, plants dug up and transplanted Three months after sowing, the main tiller is harvested. Mostly, grains of finger millet is consumed as human food in this island in a form of sticky porridge where grounded grains are mixed with boiled water and in rare cases with milk, whereas straws are fed green to livestock or dried.

Early surveying and collecting germplasm of finger millet in Socotra was carried out by Popov(1957)who reported in a visit in 1953 that finger millet is seemed to be found at one site , in the northern foothills of the Haggier which are said to be property of the Sultan and are perhaps in experimental stage. This may be unlikely as Popov was too late in the season to state a clear idea of the extension of finger millet cultivation on this region or properly that year may be dry one. Mu'Allem(1988) described local cultivars of millet belong to *Pennisetum glaucum* and *Pennisetum setaceum* (pearl millet ) ,*Pennisetum rigidum* (little millet ) and *Eleusine coracana* (finger millet). They are tall with small heads and reduced tillers. Finger millet is a medium in height with small heads split into five branches . Three local cultivars were identified namely ;messeibli(or Dokhon), kanab and Hiba, which are a pearl millet type, finger millet type and little millet type respectively. Messeibli is local name for the pearl millet type all over the country, but it is known as Dokhon in the coastal areas of Hadhrmout governorate . Hiba is the local name for the little millet (early maturing type) . Bombah is the local name of finger millet in Socotra .

During the period 1989 and 1990 ( Bazara'a *et al* ,,1992 ) seed samples were taken in one village in 1989 and two others in 1990. All three are in the foothills of the Haggier at the altitude 50-250(masl)at Shidahah (15km-east –southern of Hadiboh), Ihali, (12 km.east of Hadiboh) and Di-ishel(20km east of Hadiboh ) . In spite there is no recognition of different named varieties , moderate differentiation has been recognized probably because farmer has traditionally keeping back his own best grains for sowing the following season.

Recent comprehensive cereal germplasm collecting in the region by IBPGR has only yielded 11 samples compared with hundreds of sorghum, pearl millet and wheat samples from isolated area of eastern coast of Yemen and southern coast of Oman. Wild species including crop relatives have been collected extensively in Socotra and limited areas of the mainland (Mukred *et al* 1991).

### Biodiversity of natural plant species germplasm

National and international missions were carried out as early as the beginning of the past century ( Balfour , 1903 ) to explore the endemic plant species on Socotra including , trees, shrubs, herbs, and land grasses which have different

**Table 1.** Some of endemic plant species on Socotra

Species	Region
<b>Acanthaceae :</b> <i>Trichocalyx obavatus</i> Balf . f.	widely spread on Socotra island
<b>A gavaceae :</b> <i>Dracaena cinnabari</i> Balf . f.	grown on foothills , widely spread on Momi region .
<b>Aloeaceae :</b> <i>Aloe perryi</i> Baker <i>Aloe squarrosa</i> Baker <i>Aloe forbessi</i> Baker	grown on rocky and slopes of Haggier , Glunsia and Magderion
<b>Apocynaceae :</b> <i>Adenium obesum</i> .ssp <i>Sokotranum</i> ( forssk Schult & Roem )	widely spread on Socotra region
<b>Burseraceae :</b> <i>Boswellia ameero</i> Balf . f. <i>Boswellia elongata</i> Balf . f. <i>Boswellia socotrana</i> Balf . f. <i>Boswellia nana</i> Hepper <i>Boswellia popoviana</i> Hepper <i>Commiphora oraifolia</i> Balf.f. <i>Commiphora planifons</i> Balf.f. <i>Commiphora socotrana</i> Baf.f.	Haggier and Hadiboh
<b>Caryophyllaceae :</b> <i>Haya obovata</i> Balf.f.	grown on rocky regions
<b>ConvoLvaceae :</b> <i>Metaporana obtusa</i> Balf . f. Staples	grown on lowlands
<b>Cucurbitaceae :</b> <i>Dendrosicyos socotrana</i> Balf . f.	rocky foothills and coastal plains .
<b>Euphorbiaceae :</b> <i>Euphorbia abdelkori</i> Balf . f. <i>Euphorbia arbuscula</i> Balf . f. var. <i>montana</i> <i>Euphorbia spiralis</i> Balf . f. <i>Jatophora unicostata</i> Balf . f. <i>Coroton socotranus</i> Balf . f.	abdelkori region . plain lands and rocky regions slopes and rocky region Riged , Haggier and Shabahani highlands
<b>Fabaceae :</b> <i>Indigofora socotrana</i> Vierh <i>Traverniera sericophylla</i> Balf . f.	grown on Socotra plateau grown on coastal plains
<b>Laminaceae : ( labiatea )</b> <i>Leucas flagellifolia</i> Balf . f.	grown on rocky region
<b>Mimosaceae :</b> <i>Acacia sarcophylla</i> Chiov	coastal plains of Socotra and abdelkori
<b>Moraceae :</b> <i>Dorestenia gigas</i> Schweinf	Slope hills .
<b>Punicaceae :</b> <i>Punica protopunica</i> Balf . f.	Haggier , Dair Afont and Glunsia
<b>Scrophylariaceae :</b> <i>Graderia fruticosa</i> Balf . f.	Slope hills
<b>Vitaceae :</b> <i>Cissus hamaderoensis</i> A.R.Smith <i>Cissus subaphylla</i> Balf . f. Planch	widely spread on lowlands high and slope rocky region .

economic importance, such as medical, human food, livestock feed, perfumes and other ornamental plant species. Passport information of some of the most interesting endemic plant species in Socotra (table 1) are described below:

### **Acanthaceae**

*Trichocalyx obavatus*, is a shrub known locally as (Al' hul). It is an endemic plant species grown widely on Socotra island. It belongs to family acanthaceae. It is used for animal grazing.

### **Agavaceae**

*Dracaena cinnabari*, locally known as dragon's blood tree, belongs to family agavaceae. This tree is considered as one of the most important endemic plant species originated on Socotra and Canary islands. The name of this tree is more related with the name of Socotra island since immemorial. It grows on high mountainous areas. Its height is ranged from 6 – 9 meters. It has a branched crown of umbrella shape. Local people make injuries on its stem to collect red sticky material which is used locally for diverse medical purposes such as, treatment to control abortion bleeding in woman, treatment of eye diseases, strengthening teeth, used as tooth pastes, treatment of stomach pains, decoration of house walls and as staining, ornamental and detergent materials.

### **Aloeaceae**

Plant species; *Aloe perryi* Baker, *Aloe squarrosa* Baker, *Aloe forbesii* Baker are the three Aloe species which are considered as endemic plant species on Socotra grown widely on rocky and slopes of hilly areas of Haggier, Glunsia and Magderion. *Aloe perryi* and *Aloe squarrosa* are locally known as (Taif). *Aloe perryi* is morphologically beautiful juicy plant. It has thick leaves carried on short stem. Leaves colour is green to red covered by thorns on their edges. Its flowers are red born on long branches. The juice which is extracted from the leaves is called aloin, which has blackish to brown colours with bitter taste. This juicy material is collected during drought period. Aloin is used locally for medical purposes as in case of stomach pains, skin diseases, treatment of swollen injuries. This juicy material has been also exported since hundreds of years to countries of Arabian Gulf and India.

### **Apocynaceae**

*Adenium obesum* sub species *Sokotranum* is locally known as (Treemo or Asfed). It is one of the plant species which spreads abundantly on Socotra. A white juicy material secreted by stem is known as gum. This material is widely used for medical treatments as in case of malaria fever, skin diseases and swollen injuries.

### **Burseraceae**

Though there are about 25 types of frankincense on Socotra, but mostly five of them are to be the most important endemic plant species of Socotra, belong to the family burseraceae namely, *Boswellia ameero*, *B. elongata*, *B. socotrana*, *B. nana* and *B. popoviana*. *Boswellia ameero* is the most famous and wide spread species. It is locally known as (Ameero or Sumato), grown on Haggier and Hadiboh. The height of this tree may exceed 3 meters. It has stem branched at the top, composite leaves and axial flowers. The medical active material of this tree is the liquid gum which is secreted by the stem and branches. The gum is used for production of perfumes and paints. It may be used for production of medicine as treatments of cough, throat infection, injuries, skin diseases, piles, poisonous cases and fumigation of infant's cloths. Leaves of this plant type are also used as forage for live – stock during drought season.

Three plant species namely *Commiphora oraiifolia* Balf. f., *Commiphora planifons* and *Commiphora socotrana* are considered to be endemic species grown on Socotra mainly on Haggier and Hadiboh, these are locally known as (at'khen), whereas *commiphora oraiifolia* is known as (Aqsa). A material which is secreted by these species is used for perfume production and medical purposes such as anti – gasses cases of lung's infection, controlling menses abnormality and pile's infection.

### **Caryophyllaceae**

*Haya obovata* Balf. f. is a creepy perennial herb type, grown as endemic herbaceous species on Socotra. It belongs to family caryophyllaceae. It has oval leaves. It is widely grown on rocky lands of the island.

### **Convolvulaceae**

*Metaporana obtusa* Balf. f. Staples is locally known as (Sa'lhel). It is a small tree belongs to family convolvulaceae. It

is an endemic tree grown on plains and lowlands of Socotra , its flowers are white . It is used for goat grazing and as fuel for cooking .

### **Cucurbitaceae**

*Dendrosicyos Socotrana* is locally known as ( Qum ' heen ) . It is famous of it's swollen stem at the bottom . It is threatened by declination or degradation because local people are extensively using it for grazing animals during drought season . It is mainly grown at slopes and foothills .

### **Euphorbiaceae**

Plant species ; *Euphorbia abdelkori* Balf . f . *Euphorbia arbuscula* Balf . f. var . montana are endemic plant species of Socotra . *E . abdelkori* is locally known as ( Free' gel ) . It is a small juicy tree . It spreads on slopes of rocky lands at abdelkori regions . This species has long stem which is more longer than the leg of a mature man . It secretes yellow liquid . This liquid may suffer the eye soon it touches it . *Eupherbia arbuscula* Balf . f . is locally known as ( Em'tta ) . This is morphologically beautiful tree . It has a crown of umbrella shape and a slivery cylindrical stem . It secretes a white liquid juice when it is cut . This liquid is used for medical treatments . It is an endemic tree of Socotra only but not elsewhere of the world . Local people considered it as poisonous plant so they throw it's juice on the sea for catching fishes soon they are paralyzed and float on the surface of the sea . It is grown widely on plains and rocky lands . *E . spiralis* is a dwarf tree . Its stem is covered by thorns . It is grown mainly on slopes of rocky lands. Plant species *Jatophora unicostata* is locally known as (Sibrah) It is a small tree grown widely on coastal plains and slopes of rocky lands at Rigid , Haggier and Shabahani regions . It is well distinguished by it's huge stem and star – shape leaves . It secretes gummy materials through it's leaves and branches which are used for medical purposes as in case of treatment of wounds caused by cuts . *Coroton socotranus* is locally known as ( mer'err ) . It is a small tree , widely spread on plains and rocky high lands . it's wood are used for cooking purposes and house construction . This species is also used for animals grazing .

### **Fabaceae**

*Indigofera socotrana* Vierh is locally known as ( Gorsh'ohen ) It is a shrub or small tree grown mainly on Socotra plateau . It may be grazed by animals on limited areas . *Traverniera sericophylla* Balf . f . is a creepy herb . It has triple leaflets . It is locally known as ( Emhi tett ) . It is grown on coastal plains of Socotra as an endemic species . It is believed to be threatened by declination and disappearance .

### **Laminaceae ( Labiatae )**

*Leucas flagellifolia* Balf . f . Guerke , is locally known as ( Ash'fthen ) . It is a creepy perennial harb . It has thorny leaves It is widely spread on rocky lands .

### **Mimosaceae**

*Acacia sacrophylla* Chio, is prostrate perennial shrub or small flowering tree. It is locally known as (Tum'hoor) . This plant species is found in shrubland and mostly on dry deeper soil of coastal plains of Socotra and Abdelkori. Its leaves and pods are browsed by animals. It is nicely used to control invading of sands. It seems to be more tolerance to drought than other Acacia forms on these regions. It is used to produce gum.

### **Moraceae**

*Dorestenia gigas* Schweinf, is locally known as ( Kur'tob) . It is juicy small tree. It has a huge stem of 2 meters in length and width, similar to a bottle in shape. It grows on caves of sever slopes of hills where it is difficult to be reached by goats for grazing. This plant species is considered to be relative to fig plant.

### **Punicaceae**

*Punica protopunica* Balf . f , is locally known as ( Ru'haini). This small tree is a wild plant type related to pomegranate so it is known as Socotri pomegranate. In the past time scientists considered it as genetically eroded and declining plant species though it is available abundantly. It is indigenous plant species of Socotra but not elsewhere of the world.

Medical active parts are fruits and roots. Skin of its fruits are used as medical treatment for stomach diseases such as diarrhea, colon infection, anti-worms and uterus bleeding. It is widely spread on Haggier, Dair A font and Glunsia.

### Scrophylariaceae:

*Graderia fruticosa* Balf . f, is a small tree or shrub, locally known as ( Bee'shi ). It is an endemic plant species. It has tubular red flowers.

### Vitaceae

Plant species ; *Cissus hamaderoensis*, (A.R.Smith), and *Cissus subaphylla*, Balf . f Planch, are locally known as (Attur'hun) . *Cissus hamaderoensis* is a juicy shrub widely spread on lowlands. It is fired and left to coal and then used for feeding goats during drought season. It is also grinded and then used as treatment for wounds which infected camels. The wood are collected to be used as fuel for cooking purposes. The plant may be also visited by bees . *Cissus subaphylla* is an endemic plant species of Socotra. It has cylindrical stem. It is grown mainly on rocky highlands.

Though these studies and investigation were conducted at different periods with duration of long and so far intervals, many success and valuable scientific information were recorded on surveying, collecting and classification of such plant types. This leads to open encouragement on studies of wild life and tourism in this island. Local people interviewed recently proved the importance of these natural species so they attempted to collect these species which showed genetic drift and declination. It may be interesting to note that a pioneering work was executed by local family on collecting disappearing and declining species and grow them on plastic pots on her own nursery at Hadiboh in order to transplant and conserve them laterally on permanent land. This strongly approved the important interest on such plant types by the local people on Socotra.

### Genetic erosion

Finger millet now seems to be grown only by some older women who have better water supply of a pump keeps the main labour of watering easier. Cheap substitutes for finger millet such as wheat flour and rice have become invisibly available, this leads local people to change their old main food style of finger millet and move towards such newly introduced food style of wheat flour and rice. This may be considered as one of the main reasons of the declination of finger millet cultivation on Socotra. A similar situation is produced in the highland of the Yemeni mainland in case of wheat cultivation which seems to be decreasing because of the availability of imported cheap wheat flour. Older people are doubtful about the continuing supply of cheap import of wheat flour and rice in addition to the better taste and health giving properties of finger millet which are preferred to that recent introduced substitution by older people in Socotra island, so for these reasons they continue to grow finger millet, though in small pockets and limited terraces as a precaution.

As there is limited variation in the population of local landraces of finger millet on Socotra, intra-population selection is not expected to lead to substantial improvement in grain yield. Farmers in this case adapt exotic high yielding varieties as in case of maize in the coastal regions of the country which led to loss of valuable maize landraces for ever. In contrast, case is not yet dangerous in finger millet, particularly on Socotra where local landraces of finger millet are persistent and under no longer of being replaced by exotic germplasm. Farmers are satisfied with the performance and adaptation of their local cultivars of this crop and practice a yearly cycle of seed selection for next crop in their own field (Mua'alleem, 1988). Keeping seed back by the farmers as tradition to sow them the following year may lead to moderate differentiation. Practice of such tradition may, on contrast, lead to loss of some valuable varietal traits and eventually the crop may face cases of genetic erosion. To avoid such situation recurrent seed selection for purity and development of breeder seeds , registered seeds, foundation seeds and commercial seeds are to be recommended for distribution by seed multiplication project and handed over to the farmers .

However other reasons were also mentioned by interviewers such as long intervals of drought, heavy rains , randomized and over-grazing which cause soil and plant species erosion, lack of good infrastructure and well future enhancement on culture of natural species and wild life on the island and low level of practicing and encouragement of wild tourism. These factors, in all, may lead local people and farmers as well, on Socotra to pay no response to take care on cultivation of most economic natural and growing plant types and their wild relatives which eventually caused decline and genetic erosion of such plant species. To overcome such situation of genetic erosion and declining of these plant species, urgent expedition must carried out to explore and conserve, as soon as possible, these declining endemic plant species.

It is undoubtedly true that the more palatable forage and browse species are declining in abundance . Herbaceous species are very rare now in parts of the plateaux. Particular attention should be paid to these species in future

collecting mission. The same has also happened to other species that much used for food and medicine, highly regarded species, woody species, shrubs and trees with most obvious potential.

### Conservation

It may be emphasized that threat of genetic erosion in finger millet and endemic natural plant species is increasing. Evidences of serious genetic erosion on these endemic germplasm were recently recorded by (Cronk , 1985 . Mukred *et al*, 1991 ; Bazara'a *et al* , 1992 and Badeeb , 1996 ).

Though collecting finger millet, a disappearing crop on Socotra and other endemic germplasms of trees, shrubs, herbs, and land grasses were carried out as recent as the last decade of the 20<sup>th</sup> century, but in any case most of these collection had not been conserved properly and had lost.

Much efforts must be paid to explore more parts of this unique island and collect valuable landraces of finger millet and endemic plant species and wild relatives. In situ conservation of collected germplasm may then be practiced on nursery and eventually transplanted on permanent land. Seed multiplication stage must carried out to produce genetically pure breeder seeds foundation and commercial seeds and make them available to local farmers, being finger millet crop is not included in the national seed multiplication programmes.

Use of long-term ex-situ conservation is needed, so cooled storage room, deep-freezer chests central or regional gene banks are required for storage of so collected germplasm in forms of seed or tissue-culture of plant parts.

### Future enhancement

Germplasm so collected, conserved and then evaluated, may be used as sources to follow up the present situation of genetic resources on Socotra .The wild relatives may be used in breeding programmes by plant breeders to improve the genetic architecture of the landraces. The material so evaluated may be utilized as useful sources for study by the university students, researchers and specialists and also as a base of national botanical garden in the country.

### Recommendation

- 1- There is need to explore all sites of this unique island to collect valuable land races and wild relatives adaptable to the agro-climatic condition of the island.
- 2- Training, technical co-operation and financial support are strongly needed to establish comprehensive programme of classifying accessions properly and to document genetic resources data.

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### References

- Badeeb AS (1996). Medical plants in Socotra island . First International Conf . on Socotra , Present and Future University of Aden , Republic of Yemen P.P.101-115 .
- Balfour IB., (1903). Botany of Socotra and Abd-elkori . In Natural History of Socotra and Abd-elkori . edited by Forbes , H . O . Bull . Liverpool Museem P .P . 598 .
- Bawazir AA., (2001) Genetic variation in population of cereal crops in the southern coastal zone of Yemen. Plant Genetic Resour. Newsletter 127:44-45.
- Bazara'a, M.;L. Guarino, A.G.Miller , M. Morris and . N.Obadi. (1992) Finger millet on Socotra : a disappearing crop. Plant Genet Resour. Newslettet 88/89:67-68.
- Cronk, QCB., (1985). Socotra ( P.D.R.Y ) . Conservation Strategy for Sustainable Development (Report of WWF ) .

- Jabeli SA . (1995). Plant Life on Socotra Island ( 3<sup>rd</sup> . ed ) Univ . of Aden . Republic of Yemen .  
Ministry of Tourism and Environment . (2002). Wild Plants From Yemen. Ministry of Tourism and Environment, Sana'a  
Republic of Yemen.
- Mu'allem ABS (1988). Genetic Resources of cereal crops in P.D.R. Yemen.2.Barley, millet and maize. Plant Genetic  
Resour. Newsletter 72 : 32 – 33.
- Muk'rad, AW, Guarino L., Mua'llem AB., and Al-Ghaz AS (1991). Crop collection in P.D.R Yemen, 1988-1989. Plant  
Genetic Resour. Newsletter 83/84:29-30.
- Popov, G.B. (1957). The Vegetation of Socotra. J.Linn.Soc.(London) 55: 706 - 720 .