BIODIVERSITY OF DATE PALM

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Summary

The date palm (*Phoenix dactylifera*) is the dominant component upon which the sustainable biophysical and socio-economic structures of the oasis ecosystem are based; a fruit tree with unique nutritional, biochemical and biophysical characteristics, a rich source of aesthetic and cultural values, and a genetic resource. The date palm is the only indigenous wild desert plant definitely domesticated in its native harsh environment. Along with the camel (*Camelus dromedarius*), the date palm was responsible for opening the vast desert territories for human activity and the development of oasis agro-ecosystems. The oasis represents the climax of rigorous management of scarce water and land resources in alliance with the date palm. *Phoenix dactylifera* is composed of genetically discrete clones representing thousands of cultivars without the benefits of a dynamic mutation-recombination system. It is closely related to a variable aggregate of wild and feral palms distributed over a desert belt across the Middle East and North Africa. Genetic diversity and genetic structure of the gene pool complex of date palm have been shaped and greatly altered by natural and human selection, clonal propagation, and spatio-temporal exchange and movement of germplasm. Traditional oases continue to play a vital role in the maintenance and enrichment of date palm genetic resources and their genetic diversity through multiple processes and dynamic conservation practices. However, a better understanding of the intra-specific genetic variation of date palm and its distribution in oasis agro-ecosystems is essential for the conservation and sustainable use of its biodiversity. If properly designed and

implemented, strategies for conservation and sustainable use of date palm biodiversity will minimize anthropogenic disturbance, interference and impact, optimize ecosystem functions, and result in integrated protection of environmental resources of fragile oasis agro-ecosystems. Sustainability and provision of multiple services of these ecosystems depend largely on a highly diverse genetic base of date palms. In-depth assessment of the genetic vulnerability of date palm to climate change, desertification and salinity stress requires knowledge of the extent and distribution of its genetic diversity, both of which depend on the species evolution and unique breeding system, past genetic bottlenecks, and ecological, geographical and anthropogenic factors.

1. Introduction

Biodiversity of date palm refers to variation within the species, while genetic diversity represents the heritable variation that can be found within and between oases, populations, and cultivars of the date palm throughout its distributional range. The pool of genetic variation is the basis for selection as well as for the date palm improvement as a functional genetic resource within the oasis agro-ecosystem. Therefore, conservation of genetic diversity is essential for present and future functioning of the oasis agro-ecosystems and for the survival of human communities therein. Recently, there has been increasing awareness of, and interest in, the need to adopt a holistic view of dynamic conservation and sustainable utilization of date palm within its natural habitat, the oasis. Spatiotemporal dynamics in genetic diversity is generally recognized in the date palm; however, the extent and distribution of which depend on a number of interacting factors including the trees evolution and breeding system, ecological and geographical factors, past bottlenecks, and anthropogenic factors.

A thorough understanding of date palm genetic diversity and how it is structured in different oases, populations and cultivars is essential for its dynamic conservation and sustainable use. It will help farmers, scientists and policymakers determine what to conserve as well as where to conserve, and will improve our understanding of the taxonomy, origin and evolution of this unique fruit tree. Additionally, this knowledge is essential for germplasm collecting and use of the cultivated species and its wild relatives. The vast array of adaptive genetic variation available in date palm, which is generally quantitative and responsive to habitat differences, often reacts to biotic, abiotic and anthropogenic factors. Genetic diversity studies on date palm have clearly demonstrated that there is a clear association between population characteristics and the environments (i.e., oases) in which they grow; whereas, ecological factors largely determine the extent and distribution of genetic diversity in its wild relatives. However, plasticity has apparently been sufficient to allow genetically similar date palm cultivars to grow and produce in widely differing oasis environments. Ecotypic differentiation in date palm affects many plant traits such as the relative rates of development in this slow-growing tree, resistances to biotic and abiotic stresses, edaphic responses and response to soil fertility, and adaptation to different management practices (e.g., cultivation, irrigation and harvesting methods) as well as differences in fruit quality.

Local date palm cultivars with outstanding adaptation to climatic, edaphic, and management factors, are the products of centuries of interaction between farmers, the genetic and breeding systems of the date palm, and the environment. The breeding system of date palm as well as several ecological pressures affect the distribution of intra-population variability and determine the genetic composition of cultivars within oases. In addition, selection for ecological adaptation may have resulted in the accumulation of differences in originally identical clones grown in oases with different environmental and management factors. The breeding system of date palm profoundly affected allele distribution; whereas, the mating system, floral morphology and mode of reproduction all impacted the extent and distribution of genetic diversity. Wild palm species often have breeding systems different from those of the domesticated species, and therefore raise different problems with respect to their biodiversity, collecting, maintenance and regeneration in field genebanks or horticultural gardens. Partitioning of genetic diversity within and between oases, populations, and date palm cultivars is an important factor to be considered in biodiversity studies and genetic resources conservation efforts of date palm. The data on the extent, structure and distribution of date palm genetic diversity is necessary in managing both *in situ* and *ex situ* conserved genetic resources. So far, deliberate *in situ* conservation of cultivated date palm and its wild relatives have been rather limited.

2. The Eco-geographical and Societal Settings

The earliest records of date palm cultivation date from about 7,000 years ago in Eridu in southern Mesopotamia; however, cultivation probably began thousands of years earlier. Date palm culture spread from its centre of origin to the wider centre of diversity, encompassing Arabia Deserta, Arabia Felix, the Fertile Crescent, and North Africa. Especially with the rise of Islam, its cultivation increased in importance; it spread to Spain, and from there was carried to the New World. Historically, date palm trees have been integral component of farming systems in oases throughout arid and semi-arid parts of the Middle East and North Africa (MENA). More recently, date palm trees are being produced equally well in small orchards or in large-scale commercial plantations. Currently, date palm cultivation is centred in a rainless belt of the deserts south of the Mediterranean Sea and in the southern fringes of the Middle East, from south Iran in the east to the Atlantic coast of North Africa in the west. The date palm is adapted to areas with long, hot summers with little rain and low humidity, but with abundant underground water. These conditions are mainly found in oases and river valleys in the arid sub-tropical deserts of the MENA countries. Date palm flourishes where other fruit production would be marginal at best. Several factors, including its resilience, requirement for limited inputs, long-term productivity, and multi-purpose attributes, all contributed to the special affection for, and the habitat created by the tree.

Date palm cultivars throughout the oases of MENA derive their importance from their local adaptation to climatic, edaphic and socioeconomic conditions and due to the quality of their fruit. In addition to its local and regional commercial value, the date palm plays an important role in the diet and social life of communities across the oases of MENA. The date palm had great spiritual and cultural significance and achieved its greatest esteem in Middle Eastern cultures. It was depicted on ancient Assyrian and Babylonian tablets, including the famous Code of Hammurabi, which contained laws regulating date culture and sale. There are many references to the date palm in pre-Islamic chronicles, but it became more prominent ever since. The tree and the fruit have been revered because of the numerous horticultural, nutritional, medicinal, economic, architectural, environmental characteristics, and uses. The columnar architecture in the Mediterranean region, for example, is thought to have been inspired by the use of date palms as building material.

The precise number of date palm cultivars throughout the world is unknown since ecotypes exhibit homogenous traits and differ mainly by the fruit characteristics.

However, of the estimated ~120 million date palms in the world, over two-thirds are in MENA countries, and approximately 800 different kinds of dates are available in these countries; these account for 60% of the worlds production. The development of date palm culture usually is limited by water availability. Nevertheless, date palms are being grown in traditional oases or modern-day plantations in many countries around the world, including Iraq, Kuwait, Bahrain, Saudi Arabia, United Arab Emirates, Oman, Yemen, Jordan, Syria, Israel, Palestine, Egypt, Libya, Tunisia, Algeria, Morocco, Mauretania, Senegal, Sudan, Somalia, Spain, Canary Islands, USA, Australia and New Caledonia. However, south of the great Sahara Desert of North Africa, increasing rainfall imposed a barrier to any extension of date palm culture which has been limited to small plantings along the northern edge of the equatorial rain belt from Senegal and the Upper Niger to Sudan (Darfur and the Blue Nile provinces). Until very recently, there was no record of date palms in Africa south of the equator; however, new plantations have been initiated in the Namibian Desert. In addition, recent plantations have been initiated in Southern Australia; whereas, earlier attempts to introduce date palm into the desert valleys of Central Asia failed due to low temperatures.

3. The Oasis Agro-ecosystem

"Oasis" is a Greek word for watered green fertile land in the desert where the "oasis effect" is manifested as cooling caused by vegetation. Under the harsh desert environment, especially in MENA, farmers use their adaptive ingenuity which was accumulated over millennia to create sustainable palm-based agricultural systems. These systems are usually managed through local resource management institutions that enable farmers to make judicious decisions for sustainable resource use and to maintain stable and productive oasis agro-ecosystems. The oasis agro-ecosystem was patiently developed and evolved over millennia into a very complex ecological, social, and economic infrastructure. It is the final optimization of the interaction between cultural references, engineering constraints, economic limitations, and climatic diversity of an environment equally hostile to human, animal and plant life. Most of the unique oasis agro-ecosystems are found in MENA countries; although these oases cover a relatively small land area of about 1 million ha, however, they support the livelihood of about 10 million inhabitants, where the most important crop is date palm. Some of the notable oases in MENA are Al-Qatif and Al Ahsa in Saudi Arabia; Al Ain, UAE; Buraimi, Maghta, and Bahla in Oman; Bahraiya, Farafra, and Siwa in Egypt; Ghadames and Kufra in Libya; Ouargla, Taut, and Timimoun in Algeria; Tozeur and Tamerza in Tunisia; and Tafilalt and Ourzazat in Morocco (Figure. 1). The importance of cultivars in each oasis is related to the climatic conditions, the number of trees for each cultivar and the quality of the fruit.

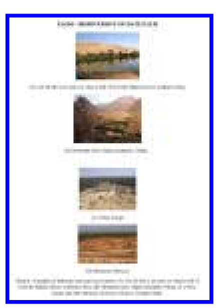

Figure1. Examples of different oasis agro-ecosystems: (A) Um El-Maa, an oasis (or what is left of it) in the Sahara Desert, southern Libya, (B) Mountain oasis, Hajar mountains,

Oman, (C) Siwa, Egypt, and (D) Ourzazat, Morocco. (Source: Google Earth).

The oasis agro-ecosystem is a standard model for a spatially heterogeneous, three-story inter-cropping system of date palms, fruit trees and annual crops. The composition and configuration of the three-story system creates different profiles of horizontal wind speed, relative air temperature and relative air humidity. Date palms, fruit trees, and annual crops approximately intercept 20, 20 and 40% of daily net radiation, respectively. Highly adapted cultivars of date palm, fruit trees, and annual crops are managed through refined social practices and institutions. The indigenous knowledge associated with this diversity and its management is crucial to ensure a sustainable life in the oases. Although agriculture in the oasis agro-ecosystem is mainly limited by the availability of suitable irrigation water, however, even with sufficient water, its use under the usually hot dry climate is often not sustainable, leading to soil salinization as a consequence of inappropriate irrigation and drainage techniques.

Oases in the major center of origin and diversity of date palm (i.e., lower Mesopotamia and eastern Arabia) typically cover thousands of hectares, contain a large number of date palm and other fruit trees, and are composed of a mixture of adapted cultivars. However, oases away from the center of origin are smaller in size, may cover a few hectares, and contain a few date palm cultivars. Historically, these oases have been developed by transport of seed and, occasionally, offshoots from existing oases. The mode of propagation impacted the level of diversity and varietal composition in the new oases. In the case of elite selections, propagation by transported offshoots resulted in dissemination of genetically identical or nearly-identical cultivars to various parts of a country or region. In the case of non-commercial or less desirable cultivars, seed dissemination resulted in the establishment of more localized and adaptive cultivars. Human selection of elite types traditionally was based on fruit characteristics and this would be the main selection pressure; however, some natural selection pressure in the new oases may have occurred due to resistance or susceptibility to biotic and abiotic stresses. Similarly, natural selection could have been applied on the non-elite cultivars that originated from seed.

The botanical composition and floristic inventory contained in even relatively small oases are rich and highly diverse. For example, 14-17 different date palm cultivars and a total of 107 different plant species have been recorded in three small oases in the northern mountains of Oman. In addition, the number of crops was very high in comparison with other small-scale cropping systems found under arid or semi-arid conditions. In this mountainous region, a completely different form of agriculture has persisted for millennia. Date palms and annual crops are cultivated in oases that are watered either by springs or by *aflaj*, tunnel systems dug into the ground or carved into the rock to tap underground aquifers. Both systems require the oases to be located at the foot of cliffs, below plateaus, which accumulate the scarce rainfall of a large area (i.e., water harvesting) and never developed a serious salinity problem.

4. The Genus *Phoenix*

The genus *Phoenix* was considered as monotypic because different *Phoenix* species hybridize readily and produce fertile hybrids. Therefore, there have been disagreements between various taxonomic treatments and some confusion about species nomenclature and validity of their taxonomy. The taxonomy of the genus *Phoenix* has not been well established in the literature until relatively recently. Date palm (*Phoenix dactylifera* L.)

is a long-lived dioecious monocotyledonous fruit tree plant (2n=36). It belongs to the Arecaceae (or Palmae) family. The genus *Phoenix* is the only member of the tribe *Phoeniceae*. Dioecy is a rare sexual system in flowering plants, with only 4-6% of all plant species being dioecious. The trunk in *Phoenix* spp. varies from a single to many trunks forming a clump. Trunks range in size tremendously; some species have rudimentary trunks, while trunks of other species reach more than 30 m in height. *Phoenix* spp. may be distinguished from other palms by a number of morphological features: the leaves have feathery surfaces; the basal leaflets are modified into spines; there is a terminal leaflet for each leaf; and there is a central fold or ridge on the leaflets which causes them to remain erect at all times. The inflorescences in the *Phoenix spp.* arise among the leaves; the small, pale yellowish flowers are borne singly; the sepals of each flower are fused into a cupule (cup-shaped structure), and there are three petals per flower. In this dioecious plant, male and female flowers are born on separate plants. Female flowers have three carpels, only one of which matures; whereas, male flowers usually have six stamens. The fruits of *Phoenix* spp. are drupes of variable sizes, depending on the species, and each fruit has a single grooved seed.

4.1. The Wild Species

This long history of exploitation of and selection pressure on date palm may have resulted in the disappearance of "wild" *P. dactylifera*. There may be a few apparently "wild" groves still growing around oases, springs, or seepage areas, but most of the trees that currently exist are the end result of human or natural selection over thousands of years. This includes trees which have are not currently cultivated, and may appear to be growing wild in oases and abandoned gardens. Cultivated date palm is closely related to a variable aggregate of wild and feral palms distributed over southern, warm, and dry Middle Eastern as well as the north-eastern Saharan and north Arabian deserts. These spontaneous dates show close morphological similarities and parallel climatic requirements with cultivated date palms. In addition, they hybridize with the cultivated species, produce fertile offspring, and are interconnected with them by occasional hybridization. Botanists place these wild dates with *P. dactylifera* L. The wild forms produce basal suckers just as the cultivated species, but differ from them by their smaller fruits which contain relatively little edible pulp and are non-palatable or even indigestible. Wild and cultivated date palms also differ in their mode of reproduction. Sexual reproduction is the rule in the wild species while cultivation resulted in a shift to vegetative propagation. This has led to the fixation of desired highly heterozygous female clones.

Phoenix dactylifera was well suited for the shift from sexual to vegetative propagation since it produces easily transferable suckers. It is often difficult to decide whether non-cultivated material is genuinely wild or whether it represents weedy forms or secondary seedlings derived from cultivated clones. Also, it may be impossible to delimit the pre-agriculture distribution of the wild date palm; however, there is strong evidence suggesting that the wild *dactylifera* forms are indigenous to the warm and dry parts of the Middle East. Although 19 species of *Phoenix* have been named, most taxonomic treatments of *Phoenix* considered 12 of these species as taxonomically valid. There is a general agreement that *P. acaulis, P. canariensis, P. dactylifera, P. paludosa, P. reclinata*, *P. rupicola*, and *P. sylvestris* are widely accepted as species.

Phoenix dactylifera is the main Middle Eastern representative of its genus which comprises 12 recognized species distributed over Southwest Asia and Africa. The only other wild date palm which occurs in the Eastern Mediterranean region is *P. theophrasti*, a narrow endemic confined to the island of Crete and several small areas in coastal southwest Turkey. Although smaller in size, it is similar in appearance to *P. dactylifera* and before being validated as a species it was considered as a distinct *P. dactylifera* population native to or naturalized in that region. As a narrow endemic, *P. theophrasti* is considered a threatened species due to its restricted distributional range and destruction of its natural habitat. Three wild *Phoenix* species grow on the fringes of traditional date palm cultivation in the Old World and they may have enriched the gene pool of the cultivated species through spontaneous hybridizationt. These are: *P. atlantica* which grows near the Atlantic shores of North Africa, and it is apparently involved in the formation of some Moroccan date palm cultivars; however; *P. atlantica* may represent only feral populations of *P. dactylifera* and may not be considered as a valid species; bushy *P. reclinata*, which is found in southern Arabia and in Africa south of the Sahara desert, and it most probably hybridizes with *P. dactylifera* on the southern fringes of date palm cultivation; and finally, *P dactylifera* occasionally hybridizes with *P. sylvestris*, a non-suckering tall, 'rain palm' not adapted to deserts but to wetter, tropical climates which comes in contact with the cultivated date palm in the Indus Valley, the eastern border of its distribution. *P. sylvestris* may reach 20 m in height and produces edible fruit that can be used to make sugar and other products, and its leaves are used in basketry.

Other wild species include: *P. canariensis*, endemic in the Canary Islands, is adapted to more moderate climatic conditions and cooler temperatures than some of the other *Phoenix* spp. It has a stout single trunk of about 20 m in height. It is widely planted as an ornamental in the US and the Mediterranean region; *P. rupicola*, the Cliff date palm, has a thin trunk of about 7 m in height, is native to northern India, and is considered as a horticultural palm; *P. pusilla*, is native to southern India and Sri Lanka, and is about the same size and general appearance as *P. rupicola* but with a shorter trunk. The fruit and the pith of its trunk are edible; *P. reclinata*, the Senegal date palm, is a variable species native to tropical Africa, with thin, clustering trunks that may reach 10 m in height, and is widely planted as an ornamental; *P. paludosa*, the Mangrove date palm, another ornamental palm, is similar in appearance to *P. reclinata*, and is native to swampy areas in southeast Asia; *P. acaulis*, native to northern India and Burma, has short, clumping stems; *P. roebelenii*, the Pygmy date palm, is native to Southeast Asia and is grown as an elegant ornamental and has both single and clustering trunks; and *P. loueiri*, is native to northern India and southern China, is a poorly understood species with short stems that is often confused with *P. acaulis*.

4.2. Modes of Reproduction

New date palm cultivars, usually, are a result of a continuous selection process carried out by farmers in their orchards following sexual reproduction. Propagation by seeds must have been practiced long before the practical benefits of clonal (vegetative) propagation were realized by early date palm farmers. Propagation by seed is much faster than vegetative propagation; seeds germinate easily and are available in large numbers. Occasionally, seeds germinate under their mother trees and this leads to large levels of genetic diversity within populations, especially with natural pollination. Propagation by seed usually produces equal numbers of male and female plants; however, male-biased sex allocation commonly occurs if female plants were left to be wind-pollinated. Date palm has been classified as dioecious without recognizable sex chromosomes and, until recently, without karyological distinction between male and female plants. Recently, however, a first substantial evidence of sexual cytogenetic differentiation between male and female plants in date palm has been reported.

Date palm seed produced by natural (i.e., wind or insect) pollination, usually results, upon germination, in highly heterogeneous population of seedlings. However, date palm growers became aware of the importance of artificial pollination when they noticed the effect of pollen grains of certain male cultivars on the size of fruits and seeds (xenia) and on the time of fruit ripening (metaxenia) of female cultivars. Male trees are selected for fruit quality (xenia and metaxenia effects) and they are exchanged between farmers even across long distances. Pollen grains of more than one male are sometimes mixed and then used for pollination. Also, farmers do exchange seed, seedlings or offshoots; this may result in genetically mixed populations of date palm within orchards and oases.

The dioecism and the long time span for a date palm to reach sexual maturity have led to selection procedure based on clonal propagation (offshoots) of females from elite date palm cultivars. Although this practice promotes genetic uniformity, it accelerates the process of genetic erosion, and enhances the vulnerability of those elite cultivars to biotic and abiotic stresses. Nevertheless, propagation by offshoots is the only method to maintain genetic integrity of date palm cultivars; these offshoots are produced from axillary buds at the base of the trunk during the juvenile life of the palm. Traditional vegetative propagation using offshoots has many limitations. Elite or endangered cultivars, especially those resistant to biotic stresses, cannot be propagated quickly enough and distributed *en mass* to farmers. Usually, offshoots develop slowly and in limited numbers varying from 20 to 30, depending on the cultivar during the life time of a female date palm tree. Therefore, alternative (micro)-propagation methods have been developed to overcome this limitation. However, micro-propagation techniques, particularly those involving excess callus formations, could lead to high levels of soma-clonal variation. Genetic uniformity of clonally-propagated date palms is a major concern, especially when somatic embryogenesis and callus formation are used. Large-scale commercial micro-propagation and distribution of genetically-uniform (or almost uniform) date palm cultivars to farmers across large geographical regions have been practiced in several MENA countries since the early 1990s. However, it is required to demonstrate the true-to-type character of the produced plants as an important part of the quality assurance. The latter is usually based on specific markers capable of genetically distinguishing between phenotypically similar cultivars.

Recent research on the *in vitro* induction of hermaphrodism in female date palm flowers showed that the staminodes (i.e., rudimentary, sterile or abortive stamens) can be induced to display a new and high capacity to proliferate under particular *in vitro* conditions. This induction can be achieved without blocking carpels normal development, leading to morphologically typical hermaphrodite flowers. These findings strongly suggest that dioecious plants may have evolved from a hermaphrodite ancestor. Such hermaphrodism control can provide new prospects and opportunities for the investigation of *in vitro* self-fertilization process. It can also be useful in improving our understanding of the genetic mechanism involved in sex organ development in date palm. Recent developments suggested that the procedure is expected to reveal novel and important traits that can only be detected in homozygous plants. In addition, the early sex determination on natural or man-made crosses will enable breeders to more efficiently create breeding male and female populations reflecting the diversity generated by sexual recombination.

4.3. The Trees and the Fruit

The generic name (*Phoenix dactylifera*) is an ancient Greek name, already quoted by Theophrastus, as the one by which the Greeks used to call plants belonging to this genus;

it derives from *phoenix* which means "Phoenician;" the traders who supposedly have spread date palm around the Mediterranean. Its specific name is composed of *dactylus* (from Greek *dactylos*) which means date, and *fero* which means "I bear." Therefore, the name transliterates into "date-bearing." The tree is an imposing palm with a very slender trunk of up to 30 m in height conspicuously covered with the remains of sheaths from fallen or removed leaves. When fully grown, a palm can have 20-30 leaves clustered together forming a loose crown-shaft. The leaves are pinnate, up to 6 m long, the upper leaves are ascending, while the basal leaves are recurved (curved backward or downward), the segments are coriaceous (resembling leather), linear, rigid and sharp pointed, and blue-green in color. The tremendous advantage of the date palm tree is its resilience, its long term productivity, and its multipurpose attributes. In spite of the innumerable uses and great value of the date palm, especially for desert dwellers, some of its unique characteristics (i.e., slow growth, dioecy, the slow offshoot-based propagation system and the difficulty of predicting adult characteristics of the seedlings) have severely restricted the improvement of this ancient tree crop.

One of only a few palms capable of surviving in the extreme dry heat of the desert regions, date palms have been cultivated for millennia for their sugar-rich, nutritious fruit. All palm fruit are considered drupes and are highly variable in their morphological, physical, and chemical characteristics. The drupe has one seed, which can vary in size, shape, colour and quality of the flesh. The one-seeded fruit consists of a fleshy mesocarp covered by a thin pericarp; a hard endocarp surrounds the seed or pit. The fruit are arranged on spikelets bearing 20-60 individual fruits, and the spikelets are attached to a stalk to form a bunch. The number of bunches per tree varies from 5 to 30, depending on the cultivar, nutrition, management and age of the tree. The date itself is a highly energy food for people and feed for livestock. The fruit, depending upon the cultivar and its growing conditions vary in size, weight, colour, shape, texture, softness and maturity, thus offering wide scope for selection. Date palm trees are very productive and the fruit yield may range from 100 to 200 kg/tree/year; however, some researchers reported yields as high as 400 kg/tree/year. Estimates vary as to the number of date palm cultivars in the world and in each major date-producing country. However, 10 countries (Algeria, Egypt, Iran, Morocco, Oman, Pakistan, Saudi Arabia, Sudan, Tunisia, and United Arab Emirates) account for the majority of trees and date production in the world.

Dates are unique in that they constitute a set of properties and characteristics, which distinguish them from all other fruits. Dates are consumed in at least three major stages of maturity (i.e., khalal, rutab, and tamar). Fruit morphology and quality traits of dates were the subject of descriptive and often incomplete studies. However, more recent studies described chemical composition of a limited number of date palm cultivars as influenced by the ripening stage. Other studies presented multivariate fruit descriptors for a small number of cultivars. The sweetness and texture of date fruit is closely related to the maturity and ripening stage. During the growth and development of the fruit, several external and internal changes in texture, colour, and chemical composition are observed. A large number of phytochemicals contribute to the nutritional and organoleptic properties of date fruit. The pharmacological properties may be attributed to the presence of a high concentration of minerals and various other phytochemicals of diverse chemical structures. A fully tree-ripened date is self preserving for months and can be stored or transported as a concentrated food source. Recently, varietal differences as to fruit ripening and quality have been documented for a limited number of date palm cultivars. A number of studies attempted to quantify the phenotypic variation and partition genetic diversity into its components for elite date palm cultivars from several MENA countries. Some of the desirable quality traits in the fruit of date palm include glossy black color (cv. Abbada), late maturity (cv. Barhee), firm texture (cvs. Bedraya, Deglet Beida, Deglet Noor, Thoory, and Hoffa), tolerance to moisture (cvs. Dayri, Medjool, Tadala, and Halawy), superior quality (cvs. Amir Haj, Deglet Noor, and Kush Zebda), and long fruit stalk (cvs. Hoffa, and Kush Zebda). Eco-geographical regions that can be described as "hot spots" for certain variants of fruit quality traits can be identified from published records. Unique variants of quality traits (e.g., semi-dry and red fruit color) are present with high frequencies in certain eco-geographical regions but not in others, whereas a highly desirable trait variant (e.g., ovate fruit shape) is widespread in the Arabian Peninsula.

Surplus dates are made into cubes, paste, spread, date sugar, jam, jelly, juice, syrup or vinegar. Cull fruit are dehydrated, ground and mixed with grain to form a very nutritious stockfeed. Dried dates are fed to camels and horses in the Sahara desert. Young leaves are cooked and eaten as a vegetable. In India, date seeds are roasted, ground, and used to adulterate coffee. The seeds are soaked in water until soft and then fed to livestock. The seed contains 6-8% non-drying oil suitable for use in soap and cosmetic products. In addition, the seeds may be processed chemically as a source of oxalic acid and are burned to make charcoal for silversmiths, and they are often strung in necklaces and beads. The fruit, because of its tannin content, is used medicinally as a detersive and astringent in intestinal troubles. In the form of an infusion, decoction, syrup or paste, the seed is administered as a treatment for sore throat and colds.

5. The Date Palm (*Phoenix dactylifera*)

The date palm (*Phoenix dactylifera*) is the dominant component upon which the sustainable biophysical and socioeconomic structures of the oasis agro-ecosystem are based. The fruit tree, besides its unique nutritional, biochemical, and biophysical characteristics, is a rich source of aesthetic and cultural values. It is the only indigenous wild desert plant definitely domesticated in its native harsh environment; along with the camel, the date palm was responsible for opening up vast desert territories for human activities and the development of the oasis agro-ecosystems. The tree is the tallest of all *Phoenix* species, reaching heights of more than 30 m. In cultivation, it usually appears as a single trunked tree; the offshoots are usually removed for propagation. The fruit is the largest of any *Phoenix* species reaching up to 100 mm x 40 mm in length and width, respectively.

5.1. Center of Origin and Center of Diversity

The date palm has been cultivated since antiquity; however, its progenitor may or may not still exist in the wild. Nevertheless, the wild progenitor was used by humans long before actual cultivation began in lower Mesopotamia, the presumed centre of origin and a sizable centre of diversity of the species. However, the specific centre of origin of *P. dactylifera* within lower Mesopotamia is somewhat unclear, and a multi-disciplinary approach, combing evidence from historical, cultural, archaeo-botanical and ecological sources, is needed to resolve this issue. Another viewpoint, supported by ecological observations, suggested that the eastern parts of Arabia Deserta may be considered as a (*secondary*) centre of origin of date palm. It is argued that conditions of a hot, dry land with wet, saline soils to which date palms are adapted are found precisely in this part of Arabia Deserta. Additional support for this viewpoint is found in paleo-botanical data and archaeological, historical, and cultural (anecdotal) information. Throughout the warm, dry parts of MENA, "wild" *P. dactylifera* palms, with their inedible and unpalatable small fruits, thrive in gorges, wet rocky escarpments, and seepage areas in wadi beds and near brackish springs where they constitute a conspicuous element of local vegetation.

Exploitation of the date palm by man probably began as simple gathering of the fruits, fronds, trunks, and other usable parts of the tree. At that point in its evolutionary history, there must have been considerable genetic diversity in date palms. Later, trees were probably planted along the network of irrigation canals in ancient Mesopotamia. Selection of trees with superior traits probably also originated in ancient times, along with clonal propagation by offshoots; further innovations would have included the development of management practices such as hand pollination. The existence of feral date palms throughout the current range of date palm cultivation, especially in the southern, warm and dry MENA deserts, points to the possible occurrence of true "wild dates" in these areas.

Spontaneously growing dates occur throughout the entire region of date palm cultivation. Unique among them are those found in the piedmonts of the Zagros Mountains (and the lowlands of Khuzistan) and the southern part of the Dead Sea Basin, representing the eastern and western arcs of the Fertile Crescent, respectively. However, some of these feral date palms represent secondary escapees. Taxonomically, "wild dates" are contained within *P. dactylifera*, and were described as being similar to the cultivated species but producing smaller, unpalatable fruits and reproducing sexually, as opposed to the typical vegetative reproduction in cultivated date palms. However, in some areas of MENA deserts and in Baluchistan, dates seem to be genuinely wild and occupy primary habitats. Based on available evidence, it can be concluded that in the centre of origin and centre of diversity of *P. dactylifera,* a variable complex of wild forms, segregating escapees, and cultivated clones is genetically interconnected by occasional hybridization.

5.2. Domestication of the Date Palm

The domestication syndrome in date palm, as well as in other clonally-propagated crops, has been poorly understood. Man-made selection obviously acted on the genetic diversity available in the wild progenitor of the date palm to increase yield, fruit size and palatability, reduce branching (offshoots), and to facilitate propagation. Presumably, the mixed sexual-clonal propagation system (see below) acted on the sexual traits, impacted the genetic structure of populations, and may have resulted in the accumulation of domesticated traits in the date palm. The date palm was one of the first five fruit trees to be domesticated along with olives, grapevine, fig, and pomegranate as members of the "first wave" of domesticated fruit trees. Then, a few thousand years later, was followed by the domestication of almonds, apricots and pistachios as members of the "second wave" of domesticates in the Old World. These are either predominantly or obligatory outcrossing fruit tree species. Domestication of the date palm has led to the increase in fruit size and pulp quality and to a shift from sexual to vegetative propagation; the latter resulted in the immediate fixation of desirable fruit (and tree) traits in highly heterozygous female cultivars.

The earliest records of domesticated date palm (i.e., under cultivation) in Mesopotamia go back to ~ 7,000 Before Present (BP), however, there is ample evidence suggesting that date culture began thousands of years earlier. The ruins of Mohenjo Daro, along the Indus River in the Sind, yielded 5,000-year old date palm seed; whereas during those times, the date palm was used in the construction of the Temple of the Moon god in Ur (lower Mesopotamia). Also, the date palm is shown in the bas-reliefs at Nineveh, the capital of the Assyrian Empire (in northern Iraq) and in the ruins of Palmyra, an ancient oasis in the heart of the Syrian Desert. From its centre of origin, the date palm culture had spread, within a relatively short time after its domestication, to Arabia Deserta, Arabia Felix, the Fertile Crescent, Egypt, North Africa, and western India.

5.3. Evolution of the Date Palm under Domestication

Date palm evolved under domestication in a manner unlike most other fruit trees, especially those growing under its canopies in oasis agro-ecosystems. The tree has characteristics that adapt it to varied conditions, but differ from many other plants that are found under the same conditions. The date palm grows well in sand, but it is not arenaceous. Its roots have air spaces and may grow well where soil water is close to the surface, but it is not aquatic. It tolerates saline conditions, but it is not a true halophyte. Its leaves are adapted to hot, dry conditions, but it is not a xerophyte.

Diversity of the wild progenitor and wild relatives, the diverse ecologies of domesticated date palm, and the pressure of an age-old and intricate mix of natural and man-made selection resulted in complex and diverse evolutionary trajectories of the date palm under domestication. The interaction between sexual reproduction and clonal propagation must have shaped the evolutionary dynamics of the date palm. Sexual reproduction was not totally replaced by clonal propagation, and has been used by farmers since its domestication. This practice is more common in traditional oasis agro-ecosystems and resulted in a mixed clonal-sexual reproductive system under which date palm populations become a mixture of interlinked sub-populations. Sex becomes a factor in the reproductive system when farmers decide to select, save, transplant, and then clonally-propagate "outstanding" volunteer seedlings they observe upon seed germination. This practice allowed farmers to exploit the advantages of sexual reproductive and clonal propagation systems.

Evolution of many plant species, including the date palm, under strict clonal propagation is more dynamic than is usually thought. Somatic mutations, for example, are so frequent that strict genetic identity of clones is not guaranteed over many generations. These mutations create necessary genetic variation that contributes to adaptive evolution of clonally-propagated plant species. The effect of biased clonal propagation of female plants on the reproductive biology of the date palm led to the development of specialized cultural practices (i.e., hand pollination) to counter mate limitations. In date palm, as well as in other dioecious plants, mate limitation may interact with gender-dependent cost of sex. In date palm and several dioecious plants, the cost of flowering in males is lower than the cost of flowering and fruiting in females. Nevertheless, selection for clonal propagation has not always modified sexual fertility or the mating system in dioecious plants. Some date palm cultivars have evolved parthenocarpy, but because parthenocarpic fruits are smaller and grow more slowly than fruits of hand-pollination, this laborious cultural practice persisted for millennia and guaranteed the production of high quality fruit.

The initial spread of date palm germplasm was probably made by seed, which was much easier to transport than offshoots before the domestication and use of the camel in transporting offshoots between scattered habitable desert locations. Vegetative propagation and increase of selected clones could have been practiced after seedling populations were established in a given area. This gave rise to the many local cultivars that are found in oases scattered all over MENA countries. The greater role of hybridization in date palm evolution may have been triggered by the discovery of sexuality in that fruit tree. Early farmers must have collected pollen from "elite" male plants and performed artificial cross-pollination of female plants. The discovery of xenia and metaxenia effects must have led to further improvements of the fruit. The earliest record of artificial cross-pollination in palm trees was found in the cuneiform texts of Ur, in lower Mesopotamia, some 4,500 years ago, and later from bas-reliefs in Ashurnasirpal palace in Nimrud some 3,000 years ago.

5.4. Genetic Diversity

The date palm, as a clonally-propagated perennial fruit tree, is unique in that it is composed of genetically discrete clones representing highly heterozygous cultivars without the benefits of a dynamic mutation-recombination system. The strong artificial selection and clonal propagation of date palms in oasis agro-ecosystems greatly altered their original genetic structure. Date palm (bio)diversity and its link to the properties of the oasis agro-ecosystem have cultural, intellectual, aesthetic and spiritual values that are important to the general public.

Available empirical evidence indicates that the genetic structure of date palm populations is governed by at least three main factors. These are the environmental characteristics of the region of cultivation (i.e., oasis), isolation by distance, and the biological characteristics of the date palm tree. However, the history of cultivation and the cultural practices may play strong roles in the structuring of genetic diversity of date palm populations. Factors other than geographical distances play an important role in affecting the gene flow and genetic structure of date palm populations worldwide. These factors include the exchange of propagation and/or pollination material, and seed dispersal. The impact of these factors and their interaction is reflected on the level of population differentiation and, especially on fruit quality traits. For a successful date palm industry; accurate estimates of genetic diversity and its partitioning; for trunk, foliage and fruit quality traits, within and among the gene pool of date palm in its center of origin and center of diversity are important considerations. This is particularly critical for the long-term survival of date palm plantations due to the long-life span of each generation and, in particular, due to the high cost of maintaining mature female trees.

Discrimination among closely-related cultivars and clones for genetic diversity studies is often extremely difficult. Identification of date palm cultivars is usually based on fruit morphology. However, morphological traits are often unreliable and may not precisely correlate with the genotype of the date palm. These traits often are influenced by environmental conditions or they vary with the developmental stage of the date palm. However, a number of frond and leaflet morphological qualitative and quantitative traits of a selected number of elite cultivars have been reported to be stable and did not exhibit variation in response to environmental or management factors. Such morphological traits can be used as stable descriptors of date palm cultivars and for cultivar identification at any growth stage.

Biochemical markers (i.e., isozymes), due to their low level of polymorphism, appear to be of limited value in quantifying the genetic diversity of date palm populations. Molecular markers are more precise and can accurately identify date palm cultivars and quantify their genetic diversity and phylogenic relationships. Molecular (i.e., DNA-based) markers have been extensively used to study the genetic variation of date palm cultivars. These include Randomly Amplified Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), and microsatellite markers. Newly isolated microsatellite markers are expected to provide a valuable and highly informative resource for genetic mapping and diversity analysis in date palm.

Although most variation estimated for multiple fruit quality traits at a regional level was found to reside among populations, substantial differences were found in genetic diversity components among and within populations. However, several studies, based on isozyme and microsatellite markers, reported larger within-population than between-population genetic diversity levels of date palms in several North African countries (e.g., Algeria, Tunisia, Morocco, and Sudan). Therefore, it is postulated that the long-term intra- and inter-country selection for specific traits resulted in a highly diverse germplasm in the center of origin and center of diversity of date palm. The overall partitioning of genetic diversity, based on biochemical and molecular markers, and fruit quality traits, suggests that date palm cultivars represent a complex gene pool within which historical movement of germplasm, recent introductions and human selection are shaping the genetic structure. The strong artificial selection and clonal propagation of perennials like date palms greatly alters their original genetic structure. Although the date palm may not be immediately threatened by genetic erosion, several reports indicated that the level of genetic diversity as to the number of cultivars in oases is declining due to interacting anthropogenic, biotic and abiotic factors. In addition, the status of genetic diversity in North African countries is aggravated by the threat of destructive diseases such as the vascular fusariosis disease commonly known as "*Bayoud*" and caused by *Fusarium oxysporum f.sp. albedinis.*

5.5. Genetic Resources

Palm diversity is greatest in the tropics and subtropics, where palms are of great ecological and economic importance. However, palms in general are recognized as an increasingly threatened family, with a total of 222 species identified by the Palm Specialist Group of the Species Survival Commission as highly threatened with extinction. Nine genera, in addition to *Phoenix* (i.e., *Chamaedorea, Sabal, Livistona, Dypsis, Arenga, Caryota, Pritchardia, Ptychosperma* and *Licuala*) contain 257 species and represent only 6% of the total generic diversity, account for 37% of all cultivation records, and contain 22 highly threatened species. However, there are no highly threatened species in *Phoenix*, *Livistona, Arenga*, and *Caryota.* On the other hand, 127 genera (or 75% of recorded genus diversity) with 436 species (or 48% of recorded species diversity) account for only 27% of all cultivation records. This may suggest that current palm collections are numerically dominated by a set of genera that contain proportionately fewer threatened species.

Cultivated date palm is closely related to a variable aggregate of wild and feral palms distributed over the southern, warm and dry Middle East as well as the north-eastern Saharan and north Arabian deserts. These spontaneous dates constitute a major part of date palm genetic resources, and show close morphological similarities and parallel climatic requirements with the cultivated clones. In addition, they are inter-fertile with the cultivars and are interconnected with them through occasional hybridization. Traditional date palm production is based on thousands of distinct cultivars exhibiting a wide range of adaptation, growth habit and fruit characteristics. The strong artificial selection and clonal propagation of date palms, in the oasis agro-ecosystems, greatly altered their original genetic structure. Nevertheless, these cultivars stand at the centre of a complex agro-ecological, economic and social structure, and for millennia, they functioned as a multi-purpose genetic resource. Due to biotic and abiotic stresses, economic, and social factors, the diversity of date palm orchards in many parts of MENA is declining and the composition of these orchards as to the number of cultivars witnessed a sharp decline in recent years. A complex of interacting factors of climate change, desertification, and salinity stress, in addition to consumer preferences and market forces, are impacting the diversity and varietal composition of date palm orchards in the vulnerable oasis agro-ecosystems.

According to recent reports, the number of date palm cultivars in the world range from 1,500 to approximately 5,000. Each cultivar is derived from a unique single seed, cloned and multiplied by offshoots. More recently, however, an increasing number of date palm cultivars are being propagated through tissue culture. Cultivated date palm is closely related to a variable aggregate of wild and feral palms distributed over the southern, warm and dry Middle East as well as the north-eastern Saharan and north Arabian deserts. These spontaneous dates show close morphological similarities and parallel climatic requirements with the cultivated clones. In addition, they are inter-fertile with the cultivars and are interconnected with them through occasional hybridization.

Reports are conflicting as to the number of date palm trees and cultivars in each of the major date-producing countries in MENA. According to recently published accounts, there are approximately 120 million trees producing ~ 7 million tons of dates; these are almost equally divided between the Middle Eastern and North African countries with Egypt and Saudi Arabia as the leading countries in date production. The 10-top date producing countries (in alphabetic order), presumably cultivating the largest number of trees, but not necessarily the largest number of cultivars are: Algerian oases harbour ~800 date palm cultivars, the largest number reported from North Africa and contribute ~ 6% of world production. There are ~12 million date palm trees and ~255 cultivars, 55 of which are commercially produced in Egypt which the largest date producing country in MENA. Egypt contributes 17% of world production from plantations along the Nile, in the Nile Delta and from several oases (e.g., Siwa, Farafrah, Dakhlah, Khargah, and Bahriah) in the western and southern deserts, and in the northern and southern parts of Sinai. Iran, the second largest date producing country in MENA, contributes 13% of world production with ~ 400 date palm cultivars mostly in the southern part of the country. Prior to the 1980s, Iraq was the major date producer in the world with ~ 30 million date palm trees and ~ 700 cultivars, most of which is found in the southern part of the country along the Tigris-Euphrates Rivers and Shatt Al-Arab waterway. During the past ~30 years, the country witnessed a huge loss (~ 20 million) in number of trees and date production (6% of world production), some, if not most of the lost trees represented unique clones and valuable genetic resources. Morocco has ~5 million date palm trees and approximately 250 date palm cultivars and contributes ~1% of world production. Oman contributes 3.5% of the world production from ~12 million date palm trees, 7.3 million of which are fruit-bearing, and 230 date palm cultivars, 20 of which are grown commercially in a number of mountain and valley oases. Pakistan is one of the largest date producers, contributing ~ 10% to the world production and has ~300 cultivars. A total of 450 date palm cultivars were reported in Saudi Arabia contributing 12% of the world production; whereas, the Medina date market alone contains about 150 cultivars, the most popular and most expensive of which is Anbarah. Date palm agriculture in Sudan is mainly concentrated in the northern part of the country along the Nile; however, there are few oases scattered in northern Kordofan and northern Darfur. There are approximately 5-6 million date palm trees and about 400 cultivars of date palm in Sudan. Tunisia contributes 2% of the world production from more than 4 millions date palm trees and about 250 cultivars. Almost 55% of the recently developed plantations in Tunisia are dominated by the elite variety Deglet Nour at the expense of other traditional, albeit less desirable commercial cultivars. The United Arab Emirates contributes 11% of world production and is considered as a leading country in date production; it has ~40 million date palm trees and a minimum of 200 cultivars, 68 of which are the most important commercially.

Traditional date palm farmers in these and other countries practice *de facto* conservation of genetic resources and genetic diversity by maintaining traditional cultivars, especially in traditional oases. Farmers also engage in management practices, including the conscious selection of clones for various characteristics and selecting elite male cultivars for hand pollination. Such practices may have far reaching effects on the status of date palm genetic resources and their diversity. These practices also go beyond pure conservation by improving and developing new and improved genetic resources. Farmers engaged in these types of efforts typically have limited financial resources. However, these practices generally are not well documented, their effectiveness in maintaining or creating new genetic combinations, are not well known or documented. Usually, the choice of which cultivars or clones to grow is subject to each farmer's decision at each planting and the factors influencing farmer's choices are complex and not well understood. In addition to traditional conservation practices, there are about 15 documented date palm field genebanks (*ex situ*) in the world engaged in the conservation of date palm genetic resources.

Although most date palm germplasm diversity and genetic resources exist within the centre of origin of date palm, a sizable portion can be found in the wider centre of diversity of the species. However, the latter is most probably composed of elite cultivars or breeding lines; therefore, the number of unique cultivars and level of genetic diversity are probably rather low. This situation calls for more field genebanks to be established throughout the centre of diversity of date palm, and for more concerted efforts to enhance the genetic diversity available in traditional oases, some of which endured for thousands of years and are now threatened by adverse anthropogenic and climatic factors. Even with an increased number of *ex situ* collections of date palm germplasm, these collections will be fewer and smaller than for most other crops, due to the relatively limited geographic area in which cultivation of date palm is feasible, the nature of the palm tree, and the relatively narrow genetic base. In addition to conserving germplasm, *ex situ* collections also increase the efficiency of its utilization. These *ex situ* collections allow for proper conservation of the genetic purity of specific genotypes, reduce the incidence of biotic stresses, allow for precise documentation of characterization and evaluation data, and furnish enough germplasm for genetic and management experimentation to be carried out.

5.6. Dynamic Conservation of Date Palm Genetic Resources

During the last ~50 years, significant changes have occurred in most MENA countries in date palm management and in date harvesting, packing, processing and marketing. Some of these practices inevitably contributed positively; whereas, others contributed negatively to conserving date palm genetic resource. However, despite the decreasing importance of the date as a staple food due to socio-economic changes in oil-rich MENA countries, the highly traditional nature and close relationship of the date palm growers to their crops helped tremendously in the dynamic conservation of date palm genetic resources and prevented a decline in date production. Dynamic conservation of date palm genetic resources has become an important issue regarding the development of date palm production and the food security of resource-poor farmers in desert and semi desert parts of several MENA countries. Therefore, the evaluation of the genetic diversity of existing date palm cultivars and the worldwide preservation of the date palm germplasm are imperative, especially where the genetic diversity has not been previously identified, characterized and evaluated.

Traditional oases predominantly have been established in remote areas within MENA countries; their inhabitants often lack financial resources and rely on inadequate infrastructural support in managing their date palm orchards. These oases continue to play a vital role in the maintenance and enrichment of date palm genetic resources and their genetic diversity through multiple processes and dynamic conservation practices. Modern plantations, which are competing with traditional oases and are based on a few elite cultivars, may adversely affect the dynamic conservation of these genetic resources and their diversity. Therefore, support for the role of traditional oases must balance the need for preservation of their positive aspects with improvement of some of their less desirable characteristics.

Long before modern transportation became available, oases in close proximity were more likely to have exchanged desirable cultivars than they would with more distant oases. Consequently, we find (e.g., in North Africa) that some elite cultivars of dates are associated with certain oases; whereas, most recently, we find others widely distributed in several oases and modern plantations within and among countries (e.g., cv. Khalas in Saudi Arabia, Qatar, UAE and Oman). This indicates that some clonally-propagated superior cultivars tend to be exchanged more often than inferior cultivars. The latter usually develop from seedlings that are left to grow and generally provide lower quality dates and remain local. The exchange of offshoots between farmers and between oases may have resulted in heterozygous and heterogeneous populations; whereas, the introduction of seedlings, after fruit consumption, may have resulted in generating more diversity within and among oases. However, consumer demands for fruit of specific elite cultivars led to their dominance in some countries (e.g., Deglet Nour in Tunisia) and the loss of genetic diversity due to the disappearance of many cultivars with medium and low fruit quality.

The dynamic conservation of the within-species diversity of the date palm is necessarily set within the context of the oasis agro-ecosystem and its management. A preliminary consideration for the implementation of a dynamic conservation program of genetic resource of date palm is what genotypes to incorporate in a field genebank? If the objective is to supply germplasm for propagation (e.g., using tissue culture) for a local industry, such field genebank would have limited range of genotypes than a field genebank that has the objective of general genetic resource conservation and utilization. The latter might incorporate diverse genetic resources with much larger genetic diversity and would contribute to widening the genetic base of new date palm plantations.

5.7. Sustainable Utilization of Date Palm Genetic Resources

A biodiversity-based paradigm for sustainable agriculture in oasis agro-ecosystems is potentially the most cost-effective and durable solution for the problems associated with or emanating from anthropogenic, biotic, and abiotic stresses. Due to the unique, and often fragile, oasis agro-ecosystem, it is imperative to understand the combined social and ecological functions of its biodiversity, determine its contribution to ecosystem services and aesthetic value to society, and evaluate options for sustainable utilization of this biodiversity with the date palm as its central component. Rational and sustainable utilization of date palm genetic resources requires extensive characterization, evaluation and documentation of the germplasm available at a local or regional level. "Characterization" is defined as "assessment of the presence, absence, or degree of specific traits that are little influenced in their expression by varying environmental conditions"; whereas, "evaluation" is defined as " assessment of plants for potentially useful genetic traits, many of which may be environmentally variable (e.g., pest or disease resistance, fruit quality, flavour).

The productivity of some oasis agro-ecosystems (e.g., in northern Oman) has been sustained for millennia with only moderate build-up of salinity. This sustainability could be attributed to a low ratio of crop:palm orchards area, which indicates the existence of water-rich oasis or oasis with stable water flows; whereas, those oases with a higher ratio of crop:palm orchards area, indicating a large inter-annual variability of water resources, were less sustainable. Horticultural practices have direct effect on yield, fruit quality, and ultimately on the sustainable utilization of date palm genetic diversity. Traditional practices may adversely affect yield and its quality. These include: narrow row spacing, minimal inputs of fertilizers and irrigation water, inadequate pollination, and fruit thinning and protection from biotic and abiotic threats. In addition, little information is available on the effects and interaction with saline water on these horticultural practices. Researchers and farmers realized that high organic carbon is an important factor in sustaining long-term productivity, especially under intensive agro-ecosystems. It is more so in sustaining productivity of the more fragile oasis agro-ecosystem. Organic carbon, unlike carbon derived from chemical fertilizers, contributes to improving physical and chemical soil properties through aggregate stability; it reduces the effects of salinity on plant growth and development, and supplies plant nutrients. Under traditional management, regular manure application is a key factor in maintaining high organic carbon levels; however, easy access to and the availability of inexpensive chemical fertilizers may lead to a long-term decline of soil organic carbon. This trend will lead to build-up of salts in the soil profile and may lead to the deterioration of the physical soil structure and hamper drainage, a critical factor in the long-term sustainability of oasis agro-ecosystem.

Public awareness may help create a conducive environment for the conservation and sustainable utilization of date palm genetic diversity. This objective can be achieved, for example, by organizing date fares, where the public, including policymakers and producers, can experience the diversity of dates and date products and begin to appreciate the importance of making use of more and diverse date cultivars. However, two research and development questions remain to be answered. What are the prospects of developing new fruit-, or tree-based products to enhance the sustainable utilization of date palm genetic diversity? How to promote sustainable utilization of traditional and new products through the standardization of quality traits, opening new markets, and public engagement?

6. Threats to Biodiversity of the Date Palm

The process of genetic erosion and loss of biodiversity in date palm have been more difficult to document than initially imagined because time-series data are not generally available for the species in its centre of origin or centre of diversity. Inter-linked factors of ecological and socio-economic nature are affecting the delicate equilibrium of oasis agro-ecosystems. Ecological factors include land degradation, genetic erosion, inappropriate agronomic practices, frequent droughts, aquifer depletion, sand encroachment, and the introduction of exotic plant species. In addition, date palm biodiversity and production potential are threatened by a number of biotic and abiotic stresses. Date palm orchards in North Africa are aging; almost one-third of productive date palm trees in Algeria are beyond the limits of their productive years, and almost half of the Tunisian productive date palms are more than 50 years old.

The status of genetic vulnerability is not well established for most *Phoenix* species. Although many of the species are cultivated as ornamentals, there are probably few "pure" *Phoenix* in ornamental plantings due to the readiness of the species to hybridize. However, due to its extensive cultivation (in oases and, most recently, in modern plantations) *P. dactylifera* as a species may not be considered threatened; whereas, wild date palm germplasm may be lost due to habitat destruction. Nevertheless, the genetic diversity that does exist in the cultivated date palm can be lost due to these factors if they result in the loss of local cultivars having specific genetic structure. For example, molecular evidence of hybridization between the "wild" endemic and cultivated date palm (e.g., *Phoenix canariences* and the widespread *Phoenix dactylifera*), highlighted the need for and provided the means to select target populations and implement strategies for *in situ* conservation of the endemic species. In this and similar situations (e.g., *P. atlantica* in Morocco, and *P. sylvestris*, in Pakistan), the introduction of *Phoenix dactylifera* may pose important threats for the genetic integrity and conservation of the endemic species; the latter may become at risk from genetic assimilation or from out-breeding depression. In spite of individual cases where date cultivation has diminished or even vanished, overall date production worldwide has increased over time. However, threats to genetic diversity increased during the last ~30 years partly due to the introduction of improved propagation methods such as tissue culture.

6.1. Biotic and Abiotic Threats

Biotic and abiotic threats to the millions of date palms in MENA have been highlighted recently in a number of reports and workshops. Specifically, the red palm weevil [(*Rhynchophorus ferrugineus* (Olivier)] and *Bayoud*, caused by *Fusarium oxysporum f.sp. albedinis*, are threatening the regions multimillion dollar date industry and the very survival of the date palm trees. The red palm weevil is causing severe damage in date palm orchards in eastern Arabia, Iraq, and Egypt. Also, it is considered as a major threat to *P. theophrasti*, the native palm species in Crete, Greece. The pest was first known in India in the early 1900s; however, it wasnt until 1918 that the weevil presented a serious threat to the date palm industry in Iraq. It could have been introduced to the UAE during the 1980s from India or Pakistan. Unfortunately, the only effective control measure is to cut down the infected trees and destroy them at an early stage to prevent the weevil from spreading over large areas. On the other hand, the high incidence and severity of *Bayoud* in North African date palm orchards could be due to the susceptibility of genetically uniform and widespread date palm cultivars. It is estimated that *Bayoud* already destroyed more than 13 million trees in Algeria and Morocco during the last century. Molecular markers have been recently identified in date palm as potential markers of resistance to this disease.

Soil and water salinity, caused by the presence of excessive amounts of mainly soluble sodium chloride salts that hinder or affect the normal function of plant growth, is increasingly becoming a serious threat to the expanding data palm industry in several MENA countries (e.g., Tunisia, UAE). Also, drought, due to lengthy rainless periods and drying-up of many water wells, may lead to increased water and soil salinity. Salinity problems develop in oasis agro-ecosystems due to mismanagement of water and soil resources under high evapo-transpiration demand of hyper-arid environments. Although some farmers are learning how to manage their date palm orchards under increasingly saline conditions, the need for a holistic solution to the salinity problem is greater than ever. Date palm is one of the most salt-tolerant fruit trees; however, large varietal differences have been documented in the species. Research results indicated that salt tolerance depends on growth stage, edaphic, and management conditions. Recent results of RAPD analysis revealed that certain DNA fragments may characterize genes coding for salinity and drought. The amplified DNA fragments, which proved to be specific for the relatively high salinity tolerant cv. "Bugal White", the moderately salinity tolerant cv. "Khashkhar" and the drought tolerant cv. "Khalas," may serve as markers for early evaluation and screening for salinity and drought tolerance in date palm.

6.2. Anthropogenic Factors

The within-species diversity of the date palm is being reduced by pressures for higher productivity and concentration of the market on a few high-quality cultivars due to consumer demand. Furthermore, and in response to biotic stresses (diseases and insects), selecting an even smaller number of resistant cultivars is a further threat to the diversity of the species. This may be even more damaging if the resistance proved to be short-lived because of changing climatic conditions or through a change in the virulence of the pathogen. Economic and social factors also impact the diversity of date palm orchards. As a result, the composition of these orchards as to the number of cultivars witnessed a sharp decline in recent years. Among the socio-economic factors which influence peoples livelihoods and the oasis agro-ecosystems are the marginalization of indigenous communities and the fast erosion of local cultures and indigenous knowledge. For example, Deglet Nour, an elite variety of high demand, constitutes 45 and 60% of all Algerian and Tunisian date palm orchards, respectively. Furthermore, traditional propagation using offshoots of elite cultivars having desirable fruit quality traits resulted, even in the centre of origin, in genetic erosion and in the confinement of cultivars with distinctive fruit types to certain oases. This process has been exacerbated by the massive propagation of elite date palm cultivars using tissue culture at the expense of less popular cultivars.

6.3. Climate Change

Climate change and human activities (i.e., anthropogenic climate change) play different, but equally important roles in oasis evolution on different temporal scales. The impact of climate change on oasis evolution is continuous and is manifested over large areas; whereas, the impact of human activities is local and disconnected. Oasification (i.e., the evolution or development of a more sustainable and productive oasis) and desertification are largely related to the abundance or shortage of water resources in the oasis. Changes in spatiotemporal water resources in the oasis are key determinants of the process of oasis evolution; whereas, the effect of human activities on oasis evolution is manifested through the direct and indirect impact on water resources. Modelling results suggest that dry and hyper-arid regions could become hotter and drier. If climate change increases the frequency and/or intensity of droughts, it would lead to more desertification and the loss of sustainable and productive oases. Recent examples from the Sahara Desert highlight the adverse effect of climate change on fragile oasis agro-ecosystems. Ten oases in southern Morocco have lost ~40% of their vegetation due to the combined effects of drought, depletion of groundwater, high temperature, and sand encroachment; whereas, date palm orchards disappeared altogether from *Wadi al-Ajal* in Libya due to the depletion of desert aquifers.

These and similar consequences of climate change may point to the inability to timely and adequately quantify and value oasis agro-ecosystem services before they reach a "tipping point." Furthermore, the accelerated degradation of oases and the loss of their biodiversity pose the question: to what extent does the inherent buffering capacity provided by oasis agro-ecosystems enhance societal ability to adapt to and mitigate anthropogenic climate change? Therefore, it is necessary to ensure that the oasis agro-ecosystems are sustainable by being resilient to future changes in global climate, markets, and other social and economic pressures. The genetic diversity of the date palm (and of other crops in the oasis) is an important component of that resilience and needs to be enhanced by ensuring that the wide range of existing cultivars is not further reduced. Also, it is important not to allow the market forces to dominate or dictate the selection of the cultivars grown or favoured in the future.

7. Indigenous Knowledge

The oasis represents the climax of rigorous management of scarce water and land resources in alliance with the date palm. Human interactions that shaped oasis agro-ecosystems and enabled them to provide multiple ecological and socio-economic services to meet the needs of local populations have always been a key to oases sustainability. Plant species and crop cultivars have been carefully selected from natural ecosystems or human-made introductions over centuries of experimentations. This diversity and its associated indigenous knowledge (IK) are fundamental assets for the inhabitants of the oases and constitute a strategic portfolio of livelihood options. Unfortunately, the IK associated with the oasis agro-ecosystems, in general, and with date palm (bio)diversity and its management, in particular, is being gradually lost and need to be maintained to ensure the sustainable life in the oases.

The traditional social water management system has been largely replaced by modern governing bodies with little or no coordination in some oases (e.g., Morocco, Tunisia), while it persisted for millennia in others (e.g., Oman). In the latter, IK in managing crop, water, and land resources in a "model" oasis agro-ecosystem is evident in maintaining high quality irrigation water, the elaborately built soil structure of terraces, a system of water distribution designed to match crop needs during their different growth stages, adequate drainage, and the lack of salinization in ancient mountain oases. However, it remains to be seen if this IK can help manage these *aflaj*-based systems to withstand the challenges posed by anthropogenic climate. As water becomes increasingly scarce, diversity is lost, cropping systems change, and social institutions are weakened; therefore, the need for documenting indigenous knowledge and values associated with life in the oases has become urgent. The process should include systematic and comprehensive documentation of local and traditional knowledge on date palm bio(diversity) and proper functioning of the oasis agro-ecosystem, cultivar identification, water and soil resources, and land-use options. A fundamental question is how to gather, document, and use this knowledge for the improvement of living conditions in the oases?

8. Biodiversity of Date Palm and Ecosystem Services

The date palm represents a powerful example of integrating sustainable use of renewable material resources. Practically, all parts of the date palm, except perhaps its roots, are used for a purpose best suited to them. The date palm not only provides a concentrated energy food, it also creates a more amenable habitat, and provides shade and protection from the desert wind and heat. In addition, the date palm yields a variety of products for use in agricultural production and or domestic utensils. It is said that there are as many uses for dates as there are days in the year. The reproductive phenological cycle varies greatly for various cultivars planted in the same or different oases. This allows for extended harvest season with dates suitable for fresh consumption, storage, and processing. A small number of elite cultivars usually dominate in some oases because of their high fruit quality or, because of their early or late maturity; they fill a special market niche. For example, of some 180 cultivars producing over 230,000 MT annually, only 10 cultivars produce 80% of dates in Oman.

Changes in biodiversity that alter the oasis agro-ecosystem function have economic impacts through the provisioning of goods and services to society. Large levels of diversity within the oasis agro-ecosystem can be expected, on average, to give rise to ecosystem stability; however, diversity is not the driver of this relationship; rather, ecosystem stability depends on the ability of the oasis to contain different species, or functional groups (e.g., different cultivars of date palm, different species and cultivars of fruit trees, forage crops, annual grain crops, vegetable crops, semi-domesticated crops, weedy relatives of crops, etc.) that are capable of differential responses to biotic and abiotic stresses and to different management practices. Oasis diversity at the species level has functional consequences because the number and kinds of species, besides *P. dactylifera*, present in an oasis determine the traits that influence a multitude of processes within, and services provided by, the oasis agro-ecosystem.

It is increasingly recognized that poor management has caused some oasis agro-ecosystems to pass ecological thresholds, leading, in a few, well-documented instances (e.g., *Sijilmasa* in the oasis of Tafilelt, southern Morocco, and *Timbuktu* in Mali) to irreversible changes in the ecosystem and the loss of its goods and services. Rehabilitation of such oasis agro-ecosystems is likely to be costly, if possible at all. The changes leading to the collapse of such oases can occur suddenly, although they often represent the cumulative outcome of a slow decline in biodiversity and reduced ecological resilience of the oasis. The impact of modern irrigation techniques for human settlement in hyper-arid regions, for example, is demonstrated by the large quantitative and qualitative changes in vegetation cover that have occurred in several MENA oases over the past fifty years. The impact of this technology on natural vegetation is demonstrated by the disappearance of date palm orchards due to the depletion of desert aquifers (e.g., *Wadi al-Ajal* in Libya) or to seawater intrusion (e.g., coastal regions of *Ras al Khaimah* in UAE). Nevertheless, in-depth assessment of the genetic vulnerability of date palm to many threats (e.g., climate change, desertification and salinity stress) requires knowledge of the extent and distribution of its genetic diversity, both of which depend on the species evolution and unique breeding system; past genetic bottlenecks; and ecological, geographical and anthropogenic factors.

9. The Future of Date Palm

The bulk of future research on date palm will be carried out in MENA countries where dates are an important economic commodity and the date palm is a culturally significant fruit tree. Improving date quality is a major breeding and selection objective; it depends on access to improved cultivars adapted to local climate conditions, and on the skill and dedication of scientists and date producers. However, for a successful date palm industry, accurate estimates of genetic diversity and its partitioning, especially for fruit quality traits, tolerance to biotic and abiotic stresses within and among gene pools in its centre of origin and centre of diversity are important considerations. Increased global trade and germplasm exchange present a number of challenges to date production whether in traditional oases or in large-scale plantations. Such challenges stem from increased pressure on water supplies, salinity, and biotic stresses caused by traditional, invasive or emerging pests and diseases. Genes or gene complexes of potential use in meeting these future challenges may well be present in non-elite date palm cultivars found in traditional oases but their presence is largely unknown. Therefore, traditional farmers should be encouraged to replant orchards with locally produced, highly heterozygous and heterogeneous offshoots or seedlings. Replacement of old or dead date palm trees with only elite and foreign cultivars will diminish genetic diversity and hasten genetic erosion of locally-adapted cultivars.

Opportunities exist for date palm improvement through biotechnological research to identify and quantify genetic diversity components in the species, identify and clone genes and gene complexes for biotic and abiotic stresses, and utilize the generated information for future research and development. The assessment of inter-specific hybridization and introgression between species or subspecies is important for the implementation of appropriate genetic conservation strategies and for the assessment of overall biodiversity. Efficient management of wild relatives of date palm needs to identify and conserve the remaining unique populations and to evaluate the extent to which they are endangered by the introduction of the cultivated species. Efficient genetic transformation methods can be utilized to incorporate desired traits in newly developed cultivars. The new technology of genetic manipulations allows the transfer of selected gene(s) to a specific genotype in only a single generation that would not be possible by conventional breeding.

Although clonal propagation using offshoots and tissue culture maintains heterozygosity and genetic purity of female cultivars, it promotes genetic uniformity, may accelerate genetic erosion or enhance vulnerability of the date palm to environmental stresses. Therefore, the maintenance of genetic variation within and among oases remains a central question in the study of evolutionary biology and the production of genetically-diverse populations of date palm. Strongly selected traits, especially through mass propagation using tissue culture, are expected to have low levels of genetic variance and lower heritability; whereas, traits that are closely associated with fitness likely will have higher levels of genetic variance but lower heritability than weakly-selected traits. Future advances in developing elite date palm cultivars will depend on the identification or development of molecular (and phenotypic) markers that may assist in identifying economically and agronomically important traits and cultivars. Detailed analyses of date palm populations originating from different geographic locations will help in understanding their genetic structures and will reveal the extent of geneflow between populations and its impact on population structure and fruit quality.

The future of date palm, as a dioecious monocot fruit tree largely depends on (1) developing advanced knowledge and information about the dynamics, management, and sustainability of the oasis agro-ecosystem, and (2) in-depth understanding of the genetic diversity of the species and its wild relatives using analytical and predictive powers of quantitative trait loci, somatic cell hybridization, and genomics to overcome some of the genetic research limitations. While it is not too difficult to define the conditions for achieving a sustainable and resilient oasis agro-ecosystem, managing such a system requires understanding of ecosystem functions in changing environmental, social, and economic conditions. Crucial aspects of those ecosystem functions may depend on certain components that have not previously been studied in sufficient detail. It is necessary to ensure that the oasis agro-ecosystems are sustainable by being resilient to future changes in global climate, markets, and other social and economic pressures. The genetic diversity of the date palm (and other perennial, annual, and forage crops, and their wild and weedy relatives in the oasis) is an important component of that resilience and needs to be enhanced by ensuring that the wide range of existing species and cultivars is not further reduced, especially due to market pressure.

Research and development questions with significant impact on the future of date palm biodiversity include: (1) What are the functions and services the date palm can provide within, and contribute to the survival of, oasis agro-ecosystems? (2) How can the date palm impact and interact with other components of the biodiversity complex within oasis agro-ecosystems, and what are the practical implications of these interactions? (3) How is the genetic diversity partitioned within and among populations and within and among traditional oasis and modern plantations? (4) What are the scientific and practical implications for the conservation of this genetic diversity? (5) What are the pros and cons of mass vegetative reproduction of date palm through tissue culture, and what are the consequences of this technology on total diversity and vulnerability of the species?, and (6) Where are the "hot-spots" for key tree traits for biotic and abiotic stress tolerance, and for fruit quality traits, and how to utilize these efficiently?

There is a need for capacity building and strengthening of existing research centres and the establishment of regional and national date palm field genebanks in MENA. Collectively, these would enhance research on current and future problems important to local production, both in traditional oases and large-scale plantations. Building relational databases on wild and domesticated species, tree and fruit phenotypic and biotechnological attributes of populations and cultivars, and the development of a "Digital Atlas" will help document and provide on-line information for research, conservation and sustainable utilization of date palm genetic resources. Finally, the development of alternative markets for date palm by-products will create incentives to grow more and diverse date palm cultivars, encourage the development of a wide range of products based on phenotypic and fruit traits, and enhance the role of date palm as a functional genetic resource.

10. Conclusion

Cultivated date palm is closely related to a variable aggregate of wild and feral palms distributed over the southern, warm and dry Middle East as well as the north-eastern Saharan and north Arabian deserts. The wild and feral palms show close morphological similarities and parallel climatic requirements with the cultivated date palm. In addition, they are inter-fertile with the cultivars and are interconnected with them through occasional hybridization. The date palm is composed of genetically discrete clones representing highly heterozygous cultivars without the benefits of a dynamic mutation-recombination system. Domestication of the date palm has led to the increase in fruit size and pulp quality and to a shift from sexual to vegetative propagation; the latter resulted in the immediate fixation of desirable tree and fruit traits in highly heterozygous female cultivars. The strong artificial selection and vegetative propagation of date palms in oasis agro-ecosystems greatly altered their original genetic structure. The date palm is the dominant component upon which the oasis agro-ecosystem is based. The tremendous advantage of the date palm tree is its resilience, its long term productivity, and its multipurpose attributes. However, some of its unique characteristics (i.e., slow growth, dioecy, the slow offshoot-based propagation system and the difficulty of predicting adult characteristics of the seedlings) have severely restricted its improvement. Vegetative propagation by offshoots is the only method to maintain genetic integrity of date palm cultivars. Man-made selection resulted in increased yield, fruit size and palatability, reduced branching (offshoots), and facilitated its propagation. Traditional oases continue to play a vital role in the maintenance and enrichment of date palm genetic resources and their genetic diversity through multiple processes and dynamic conservation practices. Date palm (bio)diversity and its link to the properties of the oasis agro-ecosystem have cultural, intellectual, aesthetic and spiritual values that are important to the general public. A biodiversity-based paradigm for sustainable agriculture in oasis agro-ecosystems is potentially the most cost-effective and durable solution for the problems associated with or emanating from anthropogenic, biotic, and abiotic stresses. Due to the unique, and often fragile, oasis agro-ecosystem, it is imperative to understand the combined social and ecological functions of its biodiversity, determine its contribution to ecosystem services and aesthetic value to society, and evaluate options for sustainable utilization of this biodiversity. The within-species diversity of the date palm is being reduced by pressures for higher productivity and concentration of the market on a few high-quality cultivars due to consumer demand. Furthermore, the accelerated degradation of oases and the loss of their biodiversity pose the question: to what extent does the inherent buffering capacity provided by oasis agro-ecosystems enhance societal ability to adapt to and mitigate anthropogenic climate change? Therefore, it is necessary to ensure that the oasis agro-ecosystems are sustainable by being resilient to future changes in global climate, markets, and other social and economic pressures. The genetic diversity of the date palm (and of other crops in the oasis) is an important component of that resilience and needs to be enhanced by ensuring that the wide range of existing cultivars is not further reduced. The future of date palm largely depends on developing advanced knowledge and information about the dynamics, management, and sustainability of the oasis agro-ecosystem, and in-depth understanding of the genetic diversity of the species and its wild relatives. It is necessary to ensure that the oasis agro-ecosystems are sustainable by being resilient to future changes in global climate, markets, and other social and economic pressures. The genetic diversity of the date palm is an important component of that resilience and needs to be enhanced by ensuring that the wide range of existing species and cultivars is not further reduced, especially due to market pressure.

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Glossary

Accession : An entry in a (field) genebank. A sample, cultivated variety, strain, or population maintained at a genetic resources centre.

Allozyme	**:** An isozyme which differs from other variants of the enzyme as a result of an allelic difference.
Arid land	**:** Barren, desert or semi-desert that is typically dry with less than 200 mm of annual rainfall.
Arecaceae	**:** The palm family.
Biodiversity	**:** Refers to variation within the species.
Breeding system	**:** The system by which species reproduce.
Carpel	**:** The female reproductive organ of a flowering plant.
Centre of diversity	**:** The area believed to be that in which a particular crop species was first cultivated or collected for human use.
Centre of origin	**:** The area in which a species or taxon first arose.
Clone	**:** A group of organisms (or cells), descended by mitosis from one common ancestor, that are genetically identical except in so far as mutations occur amongst them.
Conservation	**:** The management, preservation and use of known genetic resources so that they may yield the greatest sustainable benefit to the present generation, while maintaining their potential to meet the needs and aspiration of generations to come.
Conservation (*ex situ*)	**:** The conservation of species under other than natural habitat conditions.
Conservation (*in situ*)	**:** The conservation of species under natural habitats.
Cultivar	**:** A cultivated variety.
Cytology	**:** The branch of biology dealing with the structure, function and life history of the cell.
Dioecious	**:** Describes a species in which the male and female gametes are formed on different plants. It results in obligatory out-crossing in these species.
Dioecy	**:** The state of being dioecious.
Domestication	**:** Is the process whereby a population (of plants), through the process of selection, becomes accustomed to human provision and control.
Drupe	**:** A stone fruit, which is indehiscent, usually fleshy, with one (or more) seeds.
Ecological niche	**:** The sum of physical, chemical, and biological factors which an organism, population, or species needs in order to survive.
Ecosystem	**:** The complex of an ecological community, together with the non-living components of the environment, which function together as a stable system and in which exchange of material follows circular path.
Edaphic	**:** Pertaining to the physical and chemical conditions of the soil, especially with respect to their influence on organisms living in or on that soil.
Evolution	**:** The transformation of the form and mode of existence of an organism in such as a way that the descendents differ from their predecessors due to the effect of external environmental variation,

mutation, genetic recombination, isolation, and chance variation.

Field gene-bank **:** A collection of genotypes of a species, kept as plants in the field.

Gene complex **:** A group of genes which combine to determine the development of a particular character.

Gene pool **:** All the genetic information encoded in the total gene composition of a population of sexually reproducing organisms, at a given time. It generally refers to a group of phylogenetically related species that constitute a genus.

Genetic diversity **:** The range of a genepool; the amount of genetic variation present in a population or species as a consequence of its evolutionary pathway. For date palm, genetic diversity represents the heritable variation that can be found within and between oases, populations, and cultivars of the date palm throughout its distributional range

Genetic erosion **:** The loss of genetic material (genes and genotypes) from individuals or populations.

Genetic resources **:** Germplasm of plants containing useful characters of actual or potential value. In a domesticated species, it is the sum of all genetic combinations produced in the process of evolution.

Germplasm (1) **:** The genetic material which forms the physical basis of heredity and which is transmitted from one generation to the next by means of the germ cells.

Germplasm (2) **:** An individual or clone representing a type, species, or culture that may be held in a repository for agronomic, historic, or other reasons.

Hermaphrodite **:** An organism having the sex organs of both sexes. In botany : A plant having both male and female reproductive organs in the same flower.

Inbreeding depression **:** The loss of vigour and fitness as a result of inbreeding in species which are normally out-crossing and do not tolerate homozygosity (revealing deleterious recessive alleles); the breakup of a favourable balanced polygenic series.

Inflorescence **:** A cluster of flowers borne on the same stalk.

Inheritance **:** The transmission of genetic information from parents to progeny.

Karyotype **:** The entire somatic chromosome complement of an individual or species.

Lamina **:** The blade of a leaf or petal.

Male sterility **:** A condition in which pollen is absent or non-functional.

Marker **:** A gene of known function and location; a group or molecule that is linked chemically to another molecule for purpose of identification.

Mating system **:** The system whereby individuals of opposite sexual type are paired to produce progeny.

Maternal effect **:** Any non-lasting environmental effect or influence of the maternal genotype or phenotype on the immediate offspring.

Micropropagation **:** The in vitro culture, or vegetative propagation of an organism.

Monoecious : Having staminate and pistillate flowers on one plant, or having hermaphrodite flowers.

Oasis : Greek word for watered green fertile land in the desert.

Organogensis : The initiation and growth of an organ (shoot, root, stem, leaf, etc.) from cells or tissue. Organs may from on the surface of explants or on an intervening callus phase.

Palmeae : The palm family.

Pedicel : The stalk of a single flower.

Peduncle : The stalk of an inflorescence.

Perennial : A plant that lives for more than two years, often for a number of years; many flower annually.

Phenotype : The observable characters of an organism due to the interaction between genotype and environment; a group of organisms with similar, expressed characters.

Population : A group of individuals who share a common genepool and have the potential to inbreed.

Qualitative trait : A trait which occurs in a number of sharply distinct and discrete descriptive classes which show discontinuous variation.

Quantitative trait : A trait which is manifested over a range of forms that may be distinguished from each other by differences of degree, rather than by differences in their qualities, i.e., it shows continuous variation.

Sex chromosome : A chromosome which determines the sex of an eukaryotic species with two sexes, and which is represented differently in the male and female sexes.

Sexual reproduction : Reproduction involving the union of gametes that are typically haploid and of two kinds (male and female). It allows genetic recombination and increases the genetic variation in populations.

Somaclone : A plant regenerated from a tissue culture of somatic cells.

Species : A group of actually or potentially inbreeding natural populations which are reproductively isolated from other such groups.

Tissue culture : A cellular mass grown and maintained in vitro on solid medium or supported and nurtured by a liquid medium.

Variation : Differences in form or function between individuals or populations or species.

Vegetative propagation : The production of a new individual plant by detachment of some part of the parent plant.

Xenia : A phenotypically evident effect of the pollen genotype on the character of the endosperm or embryo.

Xerophyte : A plant that is adapted to dry habitats and is resistant to drought.

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Biographical Sketch

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