Crop Vulnerability Statement – Dates
V2021.1

Summary of key points (1 p. maximum)

The date palm (*Phoenix dactylifera* L.) is the type species for the genus *Phoenix* of the monocotyledonous family Arecaceae (Palmae). There are approximately 14 species of *Phoenix*, mostly in the subtropical and tropical areas of Asia and Africa. They are distinguished from other genera by leaf morphology. *Phoenix* species are dioecious and their fruit is a drupe.

The date palm itself has its center of origin and diversity along rivers and wadis in the arid subtropical areas of North Africa and the Middle East. Date palms are adapted to varied conditions, but they differ from many other plants that are found in shared habitats. The date palm grows well in sand, but it is not arenaceous. It has air spaces in its roots and may grow well where soil water is close to the surface, but it is not aquatic. It grows well in saline conditions, but it is not a true halophyte and does better in higher quality soil and water. Its leaves are adapted to hot, dry conditions, but it is not a xerophyte and requires abundant water.

The date palm was domesticated in two (or possibly more) regions, one in North Africa and one in the Middle East. From these centers of domestication, it spread throughout regions that have climates suitable for its cultivation. Due to its early domestication, until recently it was believed that no “wild” date palms still existed. Recent discoveries suggest that there are a few relict wild stands of date palms. However, genetic erosion has occurred. Even among cultivated date palms, the use of elite varieties and loss of some genotypes due to political events has contributed to genetic erosion.

Date palms are also threatened by various diseases and pests, including notably palm weevils in the genus *Rhynchophorus* and diseases caused by fungi in the genus *Fusarium* and bacteria in the genus *Phytoplasma*. Date palms are adapted to high temperatures, so will be more resistant to climate change than many other crops, as long as water is available. However, the range of cultivated area may change.

Responsibility for the maintenance of date palm germplasm in the United States is charged to the USDA-ARS National Clonal Germplasm Repository for Citrus & Dates (NCGRCD), located on the campus of the University of California at Riverside (UCR). The actual germplasm collection is maintained at the UCR Coachella Valley Agricultural Research Station (CVARS) in Thermal, California (approximately 130 km from Riverside). The collection at this time consists only of field-grown trees and thus is vulnerable. A program has been initiated to back tissue-cultured trees cryogenically at the National Laboratory for Genetic Resource Preservation in Fort Collins, Colorado, but progress has been slow.

The collection includes many traditional and historical cultivars that in some cases are no longer available in their country of origin. Consequently, the collection has become important in genomics studies. Obtaining new genotypes has been difficult in the past due to diplomatic issues (trade sanctions with countries in the area of origin). Some of these issues have been resolved but phytosanitary issues remain. Direct importation of propagative material is prohibited by USDA-APHIS. Recently, tissue-culture-derived plantlets have been permitted in under a Controlled Import Permit, which requires extensive pathogen testing. Identification of useful genotypes to add to the collection is also a challenge.

1. INTRODUCTION TO THE CROP (3 PP. MAXIMUM)

1.1 Biological features

The genus *Phoenix*, which includes the date palm (*Phoenix dactylifera* L.), is the sole member of the tribe *Phoeniceae* of the monocotyledonous family Arecaceae (Palmae) (Bailey and Bailey 1976; Moore 1963). *Phoenix* is widespread in the tropical and subtropical areas of southern Asia and Africa (Figure 1). It does not occur naturally in the New World but is cultivated there. Uses of *Phoenix* species include food for humans and animals, fiber, wood, fuel, and as handsome ornamental plants.

Phoenix species are either single trunked or clumping, with trunks ranging in height from less than 1 m to over 30 m. *Phoenix* species may be distinguished from other palms having feather-type leaves by the modification of the basal leaflets into spines, the presence of a terminal leaflet, and a central fold or ridge on the leaflets, which causes the leaflets to remain erect at all times. *Phoenix* species are dioecious, with the inflorescences arising among the leaves. The small, pale yellowish flowers are borne singly, with the sepals united into a cupule. There are 3 petals. Female flowers have 3 carpels, only one of which matures; male flowers generally have 6 stamens. The fruits of *Phoenix* species are drupes of variable size, depending on the species, with a single grooved seed.

The taxonomy of the genus *Phoenix* has not been well established in the literature until relatively recently. There has been disagreement between various taxonomic treatments and some confusion about species names and validity. *Phoenix* species hybridize readily, which has led to the suggestion that the genus *Phoenix* is monotypic (Wrigley 1995). The ready interspecific hybridization of *Phoenix* species can lead to confusion, especially when several species are present, as may occur in *ex situ* collections. In cultivation, *Phoenix* species are often mislabeled in gardens and in some cases are obvious hybrids or off-types (Hodel 1995).

Although 19 species of *Phoenix* have been named, most taxonomic treatments of *Phoenix* list about 12 - 14 species as accepted, although not necessarily the same species (Table 1). As stated by Uhl and Dransfield (1987), “Despite the economic importance of *Phoenix* and the great ease of recognition of the genus, the species remain poorly known and in much need of a careful revision. The most useful account remains that of Beccari (1890).” Barrow (1998) greatly elucidated the relationships between the various reported species. This treatment, as summarized in Table 2, has become widely accepted and is the system utilized in the USA by the USDA-ARS National Plant Germplasm System (NPGS) https://npgsweb.ars-grin.gov/gringlobal/taxonomygenus.aspx?id=9268. Barrow (1998) noted that prior to her monograph, Beccari (1890) had written the most recent monograph dealing with *Phoenix*, recognizing 10 species, and that since that publication three additional species had been published: *P. caespitosa* Chiov. from Somalia, *P. atlantica* A. Chev. from the Atlantic Islands, and *P. theophrasti* Greuter from Crete. The treatment of Moore (1963) recognized 12 species. Barrow (1998) synonymized Moore’s (1963) *P. abyssinica* with *P. reclinata* and his *P. farinifera* with *P. pusilla*, recognized the recently published *P. caespitosa* and *P. theophrasti*, recognized two varieties of *P. loureiroi*, included a new species *P. andamanensis* from the Andaman Islands, and considered *P. atlantica* to be incompletely known. This resulted in 13 species of *Phoenix* being recognized, with 33 synonyms and 57 nomina nuda (invalid or unpublished names). Two recent publications (Henderson *et al.*, 2006; Pintaud *et al.*, 2013) recognize *P. atalantica* as a valid species, bringing the current number of recognized species to 14.

Phoenix dactylifera, the date palm, is the type species for the genus *Phoenix*. The date palm is the tallest *Phoenix* species, reaching heights of more than 30 m. It has clustering trunks smaller in diameter than *P canariensis*, but larger than other *Phoenix* species. In cultivation, it usually appears as a single trunked tree, as the offshoots are usually removed for propagative purposes. The fruit is the largest of any *Phoenix* species, reaching up to 100 mm × 40 mm. The fruits are very tasty and nutritious and are the reason that the date palm is widely cultivated in areas with suitable climates.

Date palms evolved in a unique manner (Wrigley, 1995). They have characteristics that adapt them to varied conditions, but differ from many other plants that are found in these conditions. The date palm grows well in sand, but it is not arenaceous. It has air spaces in its roots and may grow well where soil water is close to the surface, but it is not aquatic. It grows well in saline conditions, but it is not a true halophyte and does better in higher quality soil and water. Its leaves are adapted to hot, dry conditions, but it is not a xerophyte and requires abundant water.

Characteristics and geographic distributions of *Phoenix* spp. other than *P. dactylifera* are shown in Table 2.

1.2 Ecogeographical distribution

Dates can grow in very hot and dry climates and are relatively tolerant of saline and alkaline soils. Date palms require a long, intensely hot summer with little rain and very low humidity during the period from pollination to harvest, but with abundant underground water near the surface unless irrigated. One old saying describes the date palm as growing with ‘‘its feet in the water and its head in the fire.’’ Such conditions are found in the oases and wadis of the date palm’s center of origin in the Middle East (Figure 2). Date palms can grow from 12.7 to 27.5 °C average temperature, withstanding up to 50 °C and sustaining short periods of frost at temperatures as low as –5 °C. The ideal temperature for the growth of the date palm, during the period from pollination to fruit ripening, ranges from 21 to 27 °C average temperature. Dates are widely grown in the arid regions between 15°N and 35°N, from Morocco in the west to India in the east and in certain areas in the New World (Southwestern United States, Northwestern Mexico, a restricted area in Peru) and Oceania (Australia) having suitable climates (Zaid and de Wet 2002a).

Date is one of the oldest known fruit crops and has been cultivated in North Africa and the Middle East for at least 5000 years (Zohary and Hopf 2000). The earliest record from Iraq (Mesopotamia) shows that date culture was probably established as early as 3000 BCE. Because of the long history of date culture and the wide distribution and exchange of date cultivars, the exact origin of the date is unknown, but it most likely originated from the ancient Mesopotamia area (southern Iraq) or western India (Wrigley 1995). Barrow (1998) notes the existence of feral date palms throughout the range of current date cultivation and Zohary and Hopf (2000) claimed that true wild dates have been identified in “the Near East and very probably also in the north-eastern Sahara, in Arabia, and in Baluchistan” based upon archaeological evidence. Regarding the issue of whether wild date palms might exist, Barrow (1998) stated “[a] paucity of morphological characters makes differentiation of wild from feral plants difficult. Molecular data from a wide range of domesticated, wild and feral date palms may offer new and useful information.” And indeed, Gros-Balthazard *et al.* (2018) have identified wild date palm populations in Oman based on molecular and seed morphological markers.

The traditional view is that date cultivation spread from its center of origin throughout the Arabian Peninsula, North Africa, and the Middle East. Date culture had apparently spread into Egypt by the middle of the second millennium BCE. The spread of date cultivation later accompanied the expansion of Islam and reached southern Spain and Pakistan. The Spanish were the first to introduce date palms outside the Arabian Peninsula, North Africa, and the Middle East/South Asia, carrying them to America (Nixon 1951). More recently, molecular studies have suggested that separate domestication events occurred in the Middle East and North Africa, resulting in distinct Eastern and Western gene pools (Hazzouri *et al*., 2015; Mathew *et al*., 2015; Gros-Balthazard *et al*., 2016, 2017; Flowers *et al*., 2019) and possibly involving additional secondary gene pools (Gros-Balthazard *et al*., 2018).

1.3 Plant breeding and its products

Perennial crops are challenging to breed due to their extended juvenility periods and other factors. There is on file a letter from Dr. Walter Reuther, Director of the University of California Citrus Experiment Station, to Dr. John Carpenter, USDA, stating admiration for the USDA date breeding program due to the “ponderous nature” of date breeding. Consequently, breeding programs for dates are not as common as for other perennial crops.

In 1948, JR Furr and RW Nixon of the US Date and Citrus Station began a comprehensive date improvement program. Other participants over the years included C.L. Ream, H. Barrett, and J.B. Carpenter. The overall aims of the program (Nixon and Furr, 1965; Barrett, 1973; Carpenter and Ream, 1976; Carpenter, 1977) were:

- Production by back-crossing of male palms that approach the female parent in genetic composition.
- Production of new and superior females by use of advanced back-cross males in inter-varietal hybridization.
- Selection of superior male and female seedlings with the potential for commercial development.

The initial phase of this breeding program lasted from 1948 – 1970 and was concerned primarily with production of back-crossed males. Towards the end of this period, inter-varietal hybrids began to be made. The inter-varietal crossing was intensified in the early to mid-1970’s. However, it was during this period that US governmental policy with respect to the Date and Citrus Station changed. Support levels were cut, and the breeding program was terminated. The Station was closed in 1982 and the breeding lines were incorporated into the National Date Palm Germplasm Repository (Carpenter 1979b, Krueger 2001).

There are apparently few date palm breeding programs in other countries, the most notable being Moroccan efforts to produce bayoud-resistant date palms (Boumedjout 2010).

1.4 Primary crop products and their value (farmgate)

In the United States and worldwide, the primary crop product is the fruit. Farmgate values in the United States appear below. Much date production, particularly in the United States, is not actually fresh consumption since the dates are typically consumed in the tamar or rutab stage, which is after physiological maturity (khalal stage). Dates are consumed in the Middle East and North Africa at the khalal stage. Dates are also processed into syrups, jellies, and utilized in baking. There is also a limited use for leaves for basketry, fence building, etc.

1.5 Domestic and international crop production

1.5.1 U.S. (regional geography)

In the United States, dates are a commercial crop only in California and Arizona. Production in California is confined to the Low Desert areas of Riverside, Imperial, and San Diego counties. Riverside is the major date producing county, with a planted area of 3,300 ha, a total production of 18,000 mt, and a farmgate value of USD 50,000,000, mostly in the Coachella Valley with a minor amount in the Palo Verde Valley in 2017 < https://www.rivcoawm.org/Portals/0/PDF/2017-crop-report.pdf>. In Imperial County, dates are grown mostly in the Bard Valley, although there are increasingly date palm plantings in other parts of the county. In 2017, Imperial County produced 8,200 mt of dates on 1,000 ha for a farmgate value of USD 25,000,000 < https://www.co.imperial.ca.us/ag/docs/spc/crop_reports/2017_Imperial_County_Crop_and_Livestock_Report.pdf>. San Diego County has a few small date plantings in the Borrego Valley but these are not separated out in the Annual Report. The Coachella Valley has traditionally produced approximately 70 % 'Deglet Noor' and 30 % 'Medjool' whereas the Bard Valley has traditionally produced exclusively 'Medjool'. There are only small areas of other cultivars. Although newer plantings are tending toward 'Medjool', the overall ratio of 70 % 'Deglet Noor' and 30 % 'Medjool' has persisted (Krueger 2015). In Arizona, dates are produced mostly in Yuma County. Production is said to be worth nearly USD 35,000,000 from 2,000 ha < https://cals.arizona.edu/fps/sites/cals.arizona.edu.fps/files/cotw/Date_Offshoot.pdf>. Most dates grown in the Yuma area are 'Medjool' and most of the planted area is less than 15 years old. Tempe was formerly a commercial date producing area but has been overtaken by urbanization. There is a unique small industry of 'Sphinx' dates grown in urban neighborhoods in the Phoenix metropolitan area.

Date production income is supplemented by the sale of mature trees for ornamental plantings. As urbanization has increased in the Coachella Valley, date producing blocks have been sold for housing or resorts. Mature trees are sold and the planted area has moved southeast of its traditional center near Indio. This has resulted in an increase in planted area from approximately 2,500 ha to its present 3,300 ha. However, most of the recently planted area consists of small trees not yet in full production (Krueger 2015).

1.5.2 International

On a world-wide basis, date production is concentrated in the Middle East and North Africa. This region is the center of origin and domestication for dates, and date consumption is deeply ingrained in its inhabitants. Date culture has spread into other areas with climates suitable for their production. However, most of the surface area of the Middle Eastern and North African countries has climates suitable for date production, whereas only limited areas in other countries producing dates (eg, United States, Australia, Mexico) have suitable climates.

According to FAO < http://www.fao.org/faostat/en/#data/QC>, dates are produced in 41 countries. The countries with the largest planted areas of dates in 2017 were Iraq, Iran, Algeria, Saudi Arabia, and Pakistan and the countries with the highest production were Egypt, Iran, Algeria, Saudi Arabia, and Iraq (Table 3). FAO does not report income from date production in this tool. It should also be noted that not all countries producing dates are shown in the FAO tool (eg, India, Mexico, Australia).

2. Urgency and extent of crop vulnerabilities and threats to food security (4 pp. maximum)

2.1 Genetic uniformity in the "standing crops" and varietal life spans

As revealed by recent studies of date palm global genetic diversity (see sections 1.2 and 3.3), some genetic diversity does exist. Much date production in the Middle East and North Africa remains centered on traditional oasis culture. In these cases, the genetic variability within and between oases must be considered.

Within an oasis, it would be expected that there would be little genetic diversity without external inputs. Clonal propagation of the most desired local cultivars does not increase genetic diversity, and seed propagation would not result in much additional diversity unless the pollen was derived from an outside source. Movement of elite cultivars between oases, which has historically occurred, would be one potential way of increasing genetic diversity within an oasis. Due to the difficulty of transporting offshoots by traditional means (eg, camel), most external introductions would be from relatively close oases. With improved transport (trucks, trains), transport from further away became more feasible. However, at least based upon archival materials, there was not much additional movement between oases using these tools (Krueger 2011).

Recent genomics studies are beginning to clarify the overall amount of genetic diversity and its movement (see sections 1.2 and 3.3). It now appears that there may be up to four centers of domestication and these might be thought of as proxy genepools. Until recently, the existence of truly wild populations of date palms was not verified. The recent report of Gros-Balthazard *et al*. (2018) of wild populations in Oman supplies hope that there may be other wild populations available that represent reservoirs of genes not currently present in domestication.

As far as varietal lifespans, date cultivars associated with local areas have cultural resonance with the local populations and there is little incentive for the introduction of new cultivars in less developed areas. In more developed or urbanized areas, there may be more incentive but until populations become more diverse there will still not be a strong incentive to introduce new cultivars. An exception might be in areas where threats occur, if cultivars that are resistant or adapted to the threats are available.

2.2 Threats of genetic erosion *in situ*

Genetic diversity in the centers of origin is severely threatened by habitat losses caused by deforestation, population pressure, fire, hydroelectric development, clearance for agriculture or other development, tourism, etc. (WWF and IUCN 1994-1995). Traditional oasis culture may be threatened by unstable political climates and other pressures resulting in population losses or abandonment of at least the smaller oases. This could result in a loss of genetic diversity as the traditional date culture is no longer practiced, resulting in the decline and death of the date genotypes growing there. A shift away from traditional oases date culture to industrial culture can also potentially lead to genetic erosion as (1) traditional date culture becomes non-sustainable economically, or (2) currently popular date cultivars displace the traditional cultivars grown in the oases. As with other crops, industrial agriculture can result in a decrease in genetic diversity as popular preferences change.

Brief summaries of the conservation status of other *Phoenix* spp., derived from Johnson (1996) and Barrow (1998), are shown in Table 2.

2.3 Current and emerging biotic, abiotic, production, dietary, and accessibility threats and needs

2.3.1 Biotic (diseases, pests)

Although date palms are attacked by different diseases and arthropod pests throughout their cultivation range, few of these represent existential threats to date palms on a world-wide scale. However, palm weevils are a potentially lethal insect pest, and diseases caused by *Fusarium* spp. fungi and *Candidatus* Phytoplasma spp. bacteria are also potentially lethal.

Palm weevils include the genus *Rhynchophorus* in the subfamily *Dryophthorinae* of the family *Curculionidae*. Palm weevils are large insects whose larvae chew or tunnel into various organs of palm species, causing damage or death due to destruction of the apical meristem (Giblin-Davis and Howard 1988). Of the various insects that bore into palms, the palm-associated members of the *Dryophthorinae* are the most damaging on the global scale (Giblin-Davis 2001). There are approximately nine species of *Rhyncophorus* distributed throughout the world (Wattanapongsiri 1966).

The red palm weevil (RPW), *R. ferrugineus* (Olivier), is considered the most destructive pest of date palm worldwide, also causes economic losses in coconut (*Cocos nucifera* L.), and affects many other species of palms (Malumphy and Moran 2007). *Rhynchophorus ferugineus* is native to Southeastern Asia but beginning in the 1980's began to spread westward into the date producing areas of the Middle East and North Africa, and from thence into the areas of Southern Europe that have climates suitable for cultivation of *Phoenix* species (Giblin-Davis 2001; Malumphy and Moran 2007; Molet *et al*. 2011a; USDA-APHIS 2010). Spread of *R. ferrugineus* is generally believed to be associated with the movement of infested date palm offshoots, and perhaps secondarily through the movement of entire *Phoenix* spp. trees for landscape purposes (Giblin-Davis 2001).

The South American palm weevil (SAPW), also known as the giant palm weevil, *R. palmarum* L., has historically been established in much of South and Central America, the Caribbean, and north into Central Mexico, where it is considered an important pest of palms in general (Molet *et al* 2011b; Hodel *et al*. 2016). Primary palm host species include *Phoenix* spp. as well as *C. nucifera*; there are a number of other palm hosts as well as many secondary hosts (Molet *et al*. 2011b). In addition to direct damage and potential lethality to palms, *R. palmarum* presents a threat to palms by vectoring *Bursaphelenchus cocophilus* (Cobb) Baujard, the red ring nematode (RRN), which causes red ring disease (RRD) (Molet *et al*. 2011b). RRD primarily is an economic disease of coconut due to its geographic distribution but can also affect other palms, including *Phoenix* spp. (Sullivan 2013). RRD is a vascular wilt that may result in death of a palm, particularly when the SAPW is also present and damaging the palm (Sullivan 2013).

Fusarium is a fungal species with sometimes conflicting taxonomies. Of the over 300 published species, the most important plant pathogens are found in only four species complexes: *F. fujikori, F. graminearum, F. solani, and F. oxysporum* (Aoki *et al*. 2014). *Fusarium oxysporum* is unique in that it has a long history of mostly sexual reproduction; it colonizes root xylem tissue, causing wilt diseases; and it displays apparent gene-for-gene relationships with several hosts, resulting in host-specific formae speciales (Michielse and Rep 2009). The formae speciales do not describe formal taxonomic relationships but rather physiological capabilities and host-relationships and are useful because they identify a subset of isolates that affect crops susceptible to vascular wilts (Gordon and Martyn 1997). There are three formae speciales of *F. oxysporum* that cause vascular wilts of date palms: *F. oxysporum* f. sp. *albidensis* (Killian et Maire), Malencon and Gordon; *F. oxysporum* f. sp. *canariensis*; and *F. oxysporum* f. sp. *palmarum*.

The Bayoud disease of date palms in North Africa is caused by *F. oxysporum* f. sp. *albidensis*. This disease was first observed in Morocco prior to 1890 and has since spread to Algeria and Mauritania (Carpenter and Elmer 1978; Djerbi 1983; Abdelmonem and Tasmy 2007). Bayoud is a very destructive disease, and has had particularly devastating effects in Morocco, having destroyed almost 70 % of plantings and taking most of the elite cultivars (Djerbi 1983). The pathogen is soil-borne and spread primarily by water, wind, and diseased offshoots, although aerial transmission to the crown has been reported in a few instances (Carpenter and Elmer 1978; Djerbi 1983; Abdelmonem and Tasmy 2007). *Phoenix canariensis* is also susceptible to *F. oxysporum* f. sp. *albidensis* (Carpenter and Elmer 1978). *Fusarium oxysporum* f. sp. *canariensis*, or Canary Island Date Palm Wilt (CIDPW), was first reported in southern France (Mercier and Louvet 1973) and subsequently in Southern California (Feather *et al*. 1989) and many other areas around the world where *P. canariensis* is cultivated (Downer *et al*. 2009). With the exception of *P. roebelinii*, date palms and other *Phoenix* spp. are also susceptible to CIDPW (Feather *et al*. 1989; Downer *et al*. 2009). Symptomology and transmission are similar to *F. oxysporum* f. sp. *albidensis*, with the important exception that in landscape palms transmission by contaminated tools is also important (Downer *et al*. 2009). CIDPW is endemic in the coastal areas of Southern California, where *P. canariensis* is widely planted as a landscape or ornamental tree. CIDPW is not known or is present at only very low incidences in the date production area. In Florida, a new and novel forma specialis (*F. oxysporum* f. sp. *palmarum*) has been reported on *Syagrus romanzoffiana* and *Washingtonia robusta* (Elliott *et al*. 2010), *P. canariensis* (Elliott 2011), and ×*Butyagrus* *nabonnandii* (Elliott *et al.* 2017). Although *F. oxysporum* f. sp. *palmarum* has apparently not been reported in nor assayed in *P. dactylifera*, its virulence against *P. dactylifera* should be assumed, especially as *F. oxysporum* f. sp. *palmarum* is apparently closely related to *F. oxysporum* f. sp. *albidensis* (Elliott *et al.* 2010).

Fusarium proliferatum Nirenberg is a fungus with a worldwide distribution that is pathogenic to various crops and can also cause keratitis and other medical problems in humans (Sun *et al.* 2018). *Fusarium proliferatum* has been identified as a wilt pathogen of date palms in Saudi Arabia (Abdalla *et al.* 2000; Saleh *et al.* 2017), Spain (Armengol *et al.* 2005), Canary Islands (Hernández-Hernández *et al.* 2010), and has been associated with bunch rots in Iraq (Hameed 2012) and Israel (Cohen *et al.* 2010). *Fusarium solani* (Mart) Sacch 1881 has been associated with wilt of date palms in Saudi Arabia (although less frequently than *F. proliferatum*) (Saleh *et al.* 2017), Oman (Al-Sadi *et al.* 2012), Pakistan (Maitlo *et al.* 2014), Iraq (Al-Yasiri *et al.* 2010), and Iran (Mansoori 2003; Mansoori and Kord 2006).

Phytoplasmas, classified as *Candidatus* Phytoplasma spp., are thus far uncultured bacteria lacking cell walls and having reduced genomes. Phytoplasma taxonomy has historically been based upon 16S ribosomal gene sequences. Phytoplasmas of various taxonomic designations have been associated or shown to cause diseases in a wide range of plant species, both cultivated and wild. In recent years, long-established and newly reported declines or diseases of date palms have been associated with phytoplasmas (Gurr *et al.* 2015). For purposes of discussion, these declines may be divided into Old World and New World problems.

Lethal Yellows (LY) is an often-fatal disease of coconuts that was first reported in Jamaica in 1891 and much later (1972) associated with a phytoplasma (Tsai and Harrison 2003), which was later identified as being in the taxonomic sub-group 16SrIV-A (Harrrison *et al.* 2002b). An epidemic of LY occurred in southern Florida in the 1960's to 1970's (Tsai and Harrison 2003). This epidemic also attacked *Phoenix* spp. planted as ornamentals or present in germplasm collections or botanic gardens, as evidenced by the presence of mycoplasma-like bodies observed in tissues via electron microscopy (Thomas 1974, 1979; Howard *et al.* 1979). *Phoenix dacylifera* was more susceptible to decline than other *Phoenix* spp., being equivalent in this regard to *C. nucifera* (Howard and Barrant 1989), although the symptomology was distinct compared to that in *C. nucifera* (McCoy et al. 1983). The vector of LY was demonstrated to be the leaf hopper *Haplaxius crudus* van Duzee, and this is assumed to be the vector transmitting LY to *Phoenix* spp. as well (Howard *et al.* 1983, 1984).

In the late 1970's, *Phoenix* spp. palms growing in the Lower Rio Grande Valley of south Texas were observed to be declining in a manner similar to *Phoenix* spp. in south Florida associated with phytoplasmas, and it was assumed without proof that phytoplasmas were also the cause of the declines in Texas (Miller *et al.* 1980; McCoy *et al.* 1980 a, b). An additional outbreak of declines of similar symptomology in 2001 was found to be associated with phytoplasmas of the taxonomic sub-group 16SrIV-D and was designated as "Texas Phoenix Decline" (TPD) (Harrison *et al.* 2002a). However, Harrison *et al.* (2002a) stated that it was not clear whether the source of this decline was the previously reported decline in Texas of had been introduced from a different area. The vector of TPD was unknown and was not considered to be *H. crudus* (Elliott and Harrison 2007). In 2007, declining trees with symptoms similar to those of LY and TPD were detected in Florida and found to be associated with the TPD phytoplasma as well as an additional closely related phytoplasma in the sub-group 16SrIV-F (Harrison *et al.* 2008). Although the vector is TPD is still not definitively known, in Florida *H. crudus* has consistently been found in areas with declining palms and associated phytoplasmas; additional potential vectors have also been identified (Halbert *et al.* 2014).

"Al Wijam" is a minor disease of date palms reported in Saudi Arabia at least as early as the 1950's. It is characterized by reduction in size of newly formed leaves, which are marked by a narrow, longitudinal line on the midrib. The leaves become chlorotic and die prematurely. During this time, there is a reduction in growth of the terminal bud, eventually resulting in the death of the bud and the palm (Carpenter and Elmer 1978; Djerbi 1983; Abdelmonem and Tasmy 2007). At the time of the referenced reports, the cause of Al Wijam was unknown. A 16SrIV group phytoplasma was found associated with date palms affected by Al Wijam; however, this was only 87 % homologous with the Lethal Yellows phytoplasma (El-Zayat *et al.* 2000). Later, sequences associated with phytoplasmas in the 16SrI (*C* Phytoplasma asteris) and 16SrII groups were found associated with Al Wijam, the apparent vector being the leafhopper *Cicadulina bipunctata* (Melichar), in which the sequences were also found (Alduhaib *et al.* 2007a, b, c). Also in the Old World, two new declines of date palm associated with phytoplasmas were reported from Sudan in the year 2000. White tip disease (Cronjé *et al.* 2000a) and slow decline (Cronjé *et al.* 2000b) were associated with closely related phytoplasmas that were also similar to Bermuda grass (*Cynodon dactylon* (L.)) white leaf-associated phytoplasmas, but not to LY phytoplasmas. In Kuwait, phytoplasmas were found associated with the "yellowing" disease of date palms (Al-Awadi *et al.* 2002).

2.3.2 Abiotic (environmental extremes, climate change)

Climate change is modelled in various ways with differing assumptions and conclusions. See, for instance, CCSP (2008) and USGCRP (2017). Most likely scenarios project increases in average and extreme temperatures, but the magnitude of these changes varies from slight to large, depending on the model. Conversely, the effect on precipitation is not as well understood, and varies depending on region of the earth.

CCSP (2008) concludes that production of forage and grain crops will be affected less by climate change than will production of "many" horticultural crops. Annual crops and weeds will likely change their geographic range and lifespans of annual crops may be shorter. This report deals mainly with staple agronomic crops with little said regarding perennial crops other than to note that there will likely be fewer chill hours under most models.

Date palms are adapted to high temperatures and low humidities. Temperatures of up to 56 ºC can be endured when abundant water is available and conversely, temperatures below 0 ºC are endured (Zaid and De Wet 2002b). Thus, increases in temperature will likely have less effect on date palms than on most other crops plants. Depending on the scope of temperature increase, areas with suitable climates for date production may change little; more extreme temperature increases could push date production farther north and south. The effect of precipitation changes are not as easy to predict. In traditional oasis production, where date palms grow in standing water, the effect of precipitation my not make much difference if standing water remains available. The same is true for irrigated industrial production if water remains available for irrigation. A caveat here is that precipitation during fruit ripening can cause decreases in fruit quality or cause crop losses.

Shabani *et al*. (2012) used a climate change model to project that some date producing areas in North Africa, Iran, Iraq, and Saudi Arabia may become unsuited to date production in less than 100 years, while some areas in North and South America will become more suitable. In addition, some areas in Spain not currently suitable for date cultivation predicted to become suitable (Shabani *et al*. 2013a). The model with regard to Iran was later modified to include additional parameters such as soil moisture and low temperature (Shabani *et al*. 2014a, b, c). The result was a modification that areas suitable for date palm production in Iran would increase; as some areas become too hot for date production, cooler areas will become suitable. Shabani *et al*. (2013b) also modelled the threat from *F. oxysporum* f. sp. *albidensis* in possible new date producing areas.

2.3.3 Production/demand (inability to meet market and population growth demands)

Since dates are not a staple food, and many countries in the world do not have high per capita consumption of dates, it is unlikely that a shortage of dates will occur on a global scale. However, population growth in the Middle East and North Africa is higher than the global average, and countries in these regions have high per capita date consumption. Therefore, it is possible, but not necessarily probable, that market demand in these areas may not be met. However, production increases may well be possible as would be lesser fruit being exported to Europe.

2.3.4 Dietary (inability to meet key nutritional requirements)

Although dates are a nutritious food (Zaid and De Wet 2002a), they are not a source of a large amount of calories for meeting daily energy requirements. Therefore, an inability to meet key nutritional requirements is not associated with dates.

2.3.5 Accessibility (inability to gain access to needed plant genetic resources because of phytosanitary/quarantine issues, inadequate budgets, management capacities or legal and bureaucratic restrictions)

Acquisition of new date palm germplasm is addressed in section 3.1.3. below.

3. Status of plant genetic resources in the NPGS available for reducing genetic vulnerabilities (5 pp. maximum)

3.1 Germplasm collections and in situ reserves

3.1.1 Holdings

NPGS *Phoenix* holdings are shown in Table 4. Most current holdings are derived directly from Old World elite varieties imported prior to 1930 (Nixon 1947, 1950). These were imported mostly by the USDA to develop the US date industry and were maintained at the US Date Garden (later the US Date and Citrus Station) in Indio, California until Congress ceased appropriations for it in 1983. The Date Station at some point had several hundred cultivars. The "best" were propagated at the Imperial Valley Research Station in Brawley prior to the closing of the Indio Station. As USDA began to phase out of the Brawley Station, the date palm germplasm collection was propagated to the University of California Riverside Coachella Valley Agricultural Research Station (CVARS) beginning in 1992 (Carpenter 1979b, Krueger 2001). The collection also included some cultivars developed in the US (Nixon 1955; Hodel and Johnson 2007) and breeding lines developed in the breeding program described above. More recently, the collection has acquired 19 accessions representing 9 other *Phoenix* spp. There are also seedling accessions from the historic oases in Baja California Sur, Mexico, and from Spain. The most recent acquisitions have been tissue culture-derived cultivars of Saudi Arabia origin, obtained at the request of stake holders.

3.1.2 Genetic coverage and gaps

The collection as it stands represents a broad geographic range of accessions. However, since these accessions were originally imported as industrial types, they represent elite cultivars that may not represent a broad range of genetic diversity. That said, the contribution of the NPGS holdings to recent genomics studies (Mathew *et al.* 2015; Hazzouri *et al*. 2015; Chaluvadi *et al.* 2018; Torres *et al*. 2018) indicates a reasonable range of genetic diversity considering the small size of the collection. The most outstanding gaps are in feral or wild material, such as that recently reported by Gros-Balthazard *et al*. (2018). These types of accessions may be difficult to identify or obtain. Although a range of other *Phoenix* spp. are maintained, they are represented by few accessions, usually only one, and so their genetic base is also probably narrow.

3.1.3 Acquisitions

Acquisition of new date palm germplasm is challenging for several reasons. As with many crops, identifying useful genotypes and persons willing and able to supply them is difficult. This is particularly true in the case of feral or wild date palms, which exist in remote areas without much infrastructure nor technically trained individuals. Countries in the center of origin and diversity in the Middle East and North Africa are where the most desirable genotypes would be expected to exist. However, countries in this region have often been politically unstable and in some cases in opposition to the United States. This is reflected in the fact that for many years, some countries in this region, including but not limited to Iraq and Iran, were sanctioned by the Dept. of Treasury and so were completely off the table as far as communications and exchange. Although Iraq is no longer on the list of sanctioned countries, its infrastructure is not necessarily in good condition and identifying scientists with whom to cooperate is difficult.

USDA-APHIS phytosanitary regulations also make acquisition of new date palm germplasm challenging. Vegetative material for propagation (i.e., offshoots) are prohibited as per 7 CFR 319. This means that any offshoot importations would need to come through via a Plant Controlled Import Permit (PCIP). Quarantine of offshoots is not straight forward due to their size and handling needs. The terms of the permit might require a sanitation step (tissue culture) in addition to pathogen-testing and NCGRCD does not currently have tissue culture expertise. Although seeds are not prohibited, introduction of date palm germplasm as seed is sometimes not the best course of action due to seedling variability. However, even if the resulting seedlings are not "true to type" or genetically identical to the source tree, they can be useful additions to the collection.

As stated in the previous section, NCGRCD has recently acquired some new germplasm as tissue cultured plantlets under a PCIP. The PCIP requires testing for specific pathogens. NCGRCD has implemented the phytoplasma tests. Implementation of the Coconut cadang cadang viroid assay is pending (2021). NCGRCD has also received a PCIP for importation of tissue cultured plantlets from other sources. We are partnering with a private entity with tissue culture expertise to potentially source new genotypes from the Middle East and North Africa. These would be cultured into Stage 1 material in United Arab Emirates and brought into the US in this form. After regeneration of the palms into small, manageable plantlets, they would be tested at NCGRCD according to the conditions of the PCIP.

3.1.4 Maintenance

Date palms in the NPGS collection are currently maintained only in field plantings at CVARS. Previously, the old Brawley planting was maintained and served as a sort of backup. However, budgetary constraints at both the Brawley Station and NCGRCD have prevented maintenance of the Brawley trees and when last observed (2016) the planting was in poor condition and was declining.

Maintenance of the NPGS date palms is done by CVARS personnel, sometimes supplemented by contract labor. Since this is a germplasm collection rather than a production orchard, management is not as intensive. However, at least one tree of each female variety is pollinated each year so that representative fruit can be harvested for educational purposes.

Starting in 2018, an attempt has been made to backup the date palm germplasm under cryogenic conditions at the USDA-ARS National Laboratory for Genetic Resource Preservation (NLGRP) in Fort Collins, CO. Tissue cultured date palms generated by a cooperating private entity are sent to NLGRP for preservation. Currently, the protocols are under development so no tissue cultured date palms have been cryopreserved. Starting in 2019, pollen from male accessions has been sent to NLGRP and cryopreserved.

3 Regeneration

Accessions in the active collection are currently regenerated by planting offshoots. In some cases, offshoots are not available. It may be possible to regenerate accessions not having offshoots available by using tissue culture-derived plantlets but to date this has not been done. This should be considered a future programmatic goal.

3.1.6 Distributions and outreach

Typically, only a few date palm accessions are distributed each year. Over the years, only a very small quantity has been distributed to the industry or private citizens. In recent years, most of the distributions have been made to groups doing genomic studies of date palms. Some of the Old-World genotypes represent cultivars long-established in specific countries or areas that, due to war, civil unrest, etc, are no longer known to be present in their traditional areas. Thus, the preservation of these genotypes in the NPGS collection has played an important part in these genomic studies. To date, seven refereed publications that include contributions from NPGS date palm germplasm have been published (Al-Dous *et al*. 2011; Mathew *et al*. 2015; Hazzouri *et al*. 2015; Chaluvadi *et al*. 2018; Torres *et al*. 2018; Mahamoud *et al*. 2019; Flowers *et al*. 2019b).

3.2 Associated information

3.2.1 Genebank and/or crop-specific web site(s)

NPGS date palm holdings are maintained on the Genetic Resources Information Network (GRIN-Global) and basic information is available to the public at < https://npgsweb.ars-grin.gov/gringlobal/search.aspx>. These records have minimal information and need to be updated. The NCGRCD administrative webpage is available at < https://www.ars.usda.gov/pacific-west-area/riverside-ca/national-clonal-germplasm-repository-for-citrus/>. Other crop-specific websites devoted to date palms are best identified using a search engine.

3.2.2 Passport information

Passport information is available for NPGS date palm accessions. This passport information is not currently available on GRIN-Global for older accessions. Amplified passport data is also available in Nixon (1950, 1955) and its update as Hodel and Johnson (2007).

3.2.3 Genotypic characterization data

Very limited genotypic information has been done on NPGS date palm holdings. Specific accessions were analyzed by AFLP by Cao and Chao (2002) and Devanand and Chao (2003). These studies have some issues, such as finding genetic variation between clonal propagations from mother trees, but still are the only ones currently extant. Some genetic analysis has also been done within larger datasets in the genomic studies cited above, as well as other studies utilizing NPGS germplasm via distributions. However, these contribute little towards understanding the diversity and genetic structure within the collection. A within unit initiative to analyze NPGS date palm accessions using SSR markers was initiated in 2019 but progress has been slow to do pandemic restrictions.

3.2.4 Phenotypic evaluation data

Phenotypic evaluation is lacking for NPGS date palm accessions. Nixon (1950, 1955) and Hodel and Johnson (2007) contain phenotypic data for many of the genotypes maintained by NPGS. Informal observations have verified consistency with the descriptive information, but these have not been formally documented or made available in GRIN-Global. Limited phenotypic information (bloom time, fruit maturity date) is on file at NCGRCD for the CVARS planting and will be documented into GRIN-Global when resources permit.

3.3 Plant genetic resource research associated with the NPGS

Most research associated with NPGS date palm germplasm holdings has involved genetic and genomic relationships. Cao and Chao (2002) used AFLP to assess genetic relationships within the collection, finding that the accessions fell into four main groups based upon geographic origin. Devanand and Chao (2003) used AFLP to determine genetic variability within 'Deglet Noor' and 'Medjool' from NPGS and commercial sources, finding little in 'Deglet Noor' but considerable within 'Medjool', including within clonal propagations. NPGS date palm accessions contributed to the development of SSR markers by various groups (Akkak *et al*. 2009; Johnson *et al*. 209; Zhao *et al*. 2009).

NPGS date palm accessions have been incorporated into genomics studies that also include many genotypes collected worldwide. As stated previously, the NPGS collection includes cultivars that are no longer available in their centers of origin and so are valuable in assess global genomics. NPGS date palm accessions were included in the first published genome (Al-Dous *et al*. 2011). This study identified ~ 380 Mb sequence data, representing ~ 90 % of the genes and ~ 60 % of the genome. > 3.5 million polymorphic sites were identified, a small subset of which could distinguish multiple cultivars. A region of the genome linked to sex was identified and evidence was found that date palm employs and XY system of sex inheritance. Four genes were conserved in males, and two of these that are critical for male flower development were absent in females. This is consistent with a two-mutation model for the evolution of dioecy in *Phoenix* (Torres *et al.* 2018). A recent paper associates specific areas of the genome with fruit quality traits, particularly fruit color and sugar composition (Hazzouri *et al*. 2019).

Use of NPGS date palm accessions, with other globally-derived accessions, has revealed two apparently independent domestication events, one in the Middle East and the other in North Africa (Hazzouri *et al*. 2015; Mathew *et al*, 2015; Chaluvadi *et al*. 2018), with some admixing in Egypt (Hazzouri *et al*. 2015) and some variance in Tunisia (Chaluvadi *et al*. 2018). There also appeared to be some linkage between North African types and South Asian types (Mathew *et al*. 2015). More recently, sequencing of the mitochondrial and chloroplast genomes revealed thee and possibly four original maternal combinations, leading to the model that there might actually be three distinct domestication events (Mohamoud *et al*. 2019).

Although most date palm research within NCGRCD has been associated with genetic and genomic studies, NCGRCD personnel have contributed to physiological and cultural studies of mineral nutrition (Krueger, 2007; Krueger, unpublished data) and irrigation (Montazar *et al*. 2020; Perring and Krueger, unpublished data).

3.3.1 Goals and emphases

The goal of the NCGRD with regard to date palms is to conserve and accurately curate the accessions. Emphasis is on long-term preservation.

3.3.2 Significant accomplishments

Curation and preservation of significant genotypes and contribution to genomics work globally.
Initiation of cryopreservation program.
Initiation of PCIP-supported importation of tissue culture-derived date palm genotypes.

3.4 Curatorial, managerial and research capacities and tools

The curation of NPGS date palm germplasm is handled by the same person responsible for curation of NPGS citrus germplasm. Due to the larger size of the citrus holdings, most of this FTE is devoted to citrus-related responsibilities. Management of the field collection is done by UCR personnel who are experienced in date production, in consultation with the curator. There is currently a lack of genetics expertise in the unit.

3.4.1 Staffing

Current (2021-12) overall staffing of NCGRCD is 6.5 permanent FTE: Research Plant Pathologist/Research Leader (vacant); Horticulturist/Curator; Support Plant Pathologist; Biological Science Technicians (3 FTE, 1 currently vacant: 2 FTE greenhouse-based, 1 FTE laboratory-based); Program Support Assistant; Maintenance Mechanic (0.5 FTE). Approximately 1 FTE part-time student employees supply support. Due to pandemic restrictions, 2 FTE limited term appointment positions are currently covering duties normally associated with permanent USDA employees.

Due to the workload of the citrus-related tasks, most work with date palms is done by the curator. Day-to-day maintenance of the collection is done by UC personnel, sometimes supplemented with contract labor.

3.4.2 Facilities and equipment

The main NCGRCD facility is co-located on the University of California, Riverside campus. Approximately 1 ha of leased land houses approximately 130 m^2 of lab and office space; 185 m^2 of protected plant work area; 560 m^2 of greenhouse space; and 1,500 m^2 of screenhouse space. In addition, approximately 650 m^2 of UCR greenhouse space is rented or utilized. With the exception of small amount of greenhouse space devoted to quarantine of the tissue culture palms held under a PCIP, the greenhouse and screenhouse space are used for maintenance of citrus and supporting activities. The laboratory is used for pathogen testing and elimination and research. Virus-tested potted trees are maintained as the protected collection in the screenhouse. The greenhouses are used for propagation, virus indexing, and maintenance of cold-sensitive materials. A 480 ft^2 office trailer provides office space, a break area, and additional lab space.

The date palm field collection is at CVARS, approximately 140 km from the main facility. The date palms are maintained in CVARS blocks 4A, 4C, and 4D, totaling approximately 12 ha. The date palms are irrigated by mini-sprinklers, with injection of fertilizer possible. CVARS currently has a boom lift available for the work in the date palms.

3.5 Fiscal and operational resources

The NCGRCD budget was static for well over a decade. Salary and other inflation gradually eroded operational financial resources and operations were severely constrained. An FY 2019 increase to base funds increased the total base funds to approximately USD 1.7 million. This should greatly improve NCGRCD function. Since the additional funds were received only a few months before this was written, they have not yet been fully integrated into NCGRCD functioning. Extramural funds also supplement the base funds. However, industry support for research is low compared to citrus and prioritizes pest control.

Most date palm-related activities (maintenance, cultural care) are supported by a Research Support Agreement with the UCR Dept of Agricultural Operations. Date palms are a labor and machinery-intense crop to manage and the cost is substantial at approximately USD 40,000 per annum.

4. Other genetic resource capacities (germplasm collections, in situ reserves, specialized genetic/genomic stocks, associated information, research and managerial capacities and tools, and industry/technical specialists/organizations) (2 pp. maximum)

There are only a few formal date palm genebanks known. Bettencourt *et al.* (1992), an admittedly old reference, lists only 15, the largest of which were found in Algeria, India, Iraq, Nigeria, and the United States. A theoretically more up-to-date resource, Genesys https://www.genesys-pgr.org lists only 310 accessions held by 8 institutions, one which is NCGRCD, holding 117. Some of the date palm germplasm collections are far removed from the center of origin and maintain only a few accessions (Brazil, Dominican Republic, France, Taiwan), while others have been destroyed by natural events (Miami, Florida, USA). Except possibly for the Nigerian collections, most date palm accessions maintained in genebanks appear to be elite cultivars or breeding lines, so the genetic diversity is probably rather low. There are other germplasm collections that are either new since the compilation of Bettencourt *et al.* (1992) or perhaps were simply unknown at the time of that compilation. For instance, a small field genebank was established in UAE at the International Center for Biosaline Studies for salt-tolerant varieties (A Jaradat, personal communication, 2010). Al-Ghamdi (2001) reports a date palm germplasm bank at King Faisal University, Saudi Arabia, having 18 elite cultivars produced by tissue culture in various laboratories around the world. A larger gene bank has reportedly been established at the campus of Al Qasim University in central Saudi Arabia (A Jaradat, personal communication, 2010). Another example is given by a poster presentation (not appearing in the proceedings) at the Third International Date Palm Conference in United Arab Emirates, February 2006, concerned the Wadi Quriyat Date Palm Research Station in Bahla, Sultanate of Oman. Among the activities of this station are germplasm conservation. There is a collection of 167 pistillate cultivars (including 11 important cultivars) and 19 staminate cultivars. Evaluation data is taken on some of the cultivars. There is also the possibility of the development of a germplasm repository of sorts at the Date Palm Development Center in Al-Ain, UAE (A Zaid, personal communication, 2006). There may be other genebanks for date palms that are not widely known.

The low number of date palm genebanks and the emphasis on maintenance of elite cultivars in those that do exist lead to two complementary conclusions: First, it is vital that such genebanks be established, and second, that efforts be made to support and maintain the existing traditional oases and the genetic diversity that they contain. Although the oases have endured in some cases for many hundreds or possibly thousands of years, pressures on them have increased greatly in modern times and it cannot be assumed that they will continue to exist or to contain genetic diversity. An example is found in Iraq. Iraq, formerly one of the major date producers in the world, has experienced a great reduction in date production in recent decades. An unfortunate series of events (the Iran-Iraq War, the Gulf and Iraq Wars, the draining of the southern marshes, a lack of infrastructure development, UN sanctions, an authoritarian regime, and current unrest) has resulted in an unknown but possibly significant portion of the date palms being lost (Walsborn 2008; see also <http://www.usaid.gov/iraq/pdf/AYearInIraq_agriculture.pdf> for one of many webpages dealing with these issues). Undoubtedly, some of the lost trees have contained interesting or useful genes as well as producing fruit for local consumption or export. In addition, the current status of the Iraqi date palm genebank, one of the largest cited by Bettencourt *et al.* (1992) is currently uncertain. A personal communication (R. Walsborn, 2010) indicated that there are still some date palms maintained at the location of the Iraqi genebank but details were not available.

There are apparently no *in situ* reserves of *Phoenix* spp. The report of an existing wild population of *P. dactylifera* in Oman (Gros-Balthazard *et al*. 2017) suggest that this may be important to consider. *In situ* reserves encompassing key traditional oases should also be considered.

5. Prospects and future developments (2 pp. maximum)

The status of the date palm germplasm collection held by NCGRCD should be considered moderately healthy. The accessions are reasonably well documented and verified. A few accessions need to be removed but this is expensive and at this time they remain in place. There are a few areas that need attention:

1. The collection needs back-up. Please refer to section 3.1.4. above. The back-up at NLGRP is still in the research stage and no accessions have successfully been cryopreserved. This area needs emphasis and sufficient resources to successfully achieve a backed-up collection.

2. Some accessions do not have offshoots and so cannot be repropagated conventionally. Although NCGRCD has partnership with a private tissue culture laboratory, in-house expertise needs to be developed. This is not trivial as tissue culture production of date palms is complex and requirements appear to vary depending on genotype. A future position should emphasize tissue culture and other novel propagation methods.

3. Recently, some of the individual trees appear to be declining. Lower leaves exhibit a marginal necrosis, which then becomes more evident in the intermediate leaves. Young leaves do not exhibit necrosis to this point and there has been no shrivel of the fruit. This was first observed in May 2017. Up to the time of writing, the first observed trees have not died, although necrosis of the leaves has increased. Spread of the decline was first observed within a row, suggesting a soil-borne pathogen, but subsequent spread appeared sporadic and random throughout the block.

A team consisting of University, Extension, and Federal personnel have been investigating these declines, so far without definitively identifying a cause. We have evaluated biotic and abiotic factors. Regarding possible pathogens causing the decline, most microbes identified have been saprophytes (*Aspergillus* spp., etc.) that would not be considered pathogenic. However, a potential pathogen, *Fusarium proliferatum*, has been isolated from a number of the trees sampled, and another *Fusarium* species, *F. solani,* from one tree. These *Fusarium* spp. must be regarded as potential causes of the declines we have observed. However, pathogenicity tests with cultures derived from the declining trees have not been successful, despite wounding the base of the trunk (Mauk *et al*. unpublished data). Wounding or some of stress has generally been required to induce pathogenicity from *Fusarium* spp., and this has been true with other Fusarium spp. in palms (Elliot 2018). However, pathogenicity is specifically difficult to induce from *F. proliferatum* (M.L. Elliott, personal communication, 2018).

Another possibility that has been mentioned by observers is potassium deficiency. The pattern of necrosis and development starting with older leaves is characteristic of potassium deficiency as observed in ornamental palms (Broschat and Meerow 2000). However, limited leaf sampling did not show much difference between symptomatic and asymptomatic leaves on the same tree or between leaves from symptomatic and non-symptomatic trees. K levels were similar to or only slightly below those reported in ornamental *Phoenix* spp. (Broschat and Meerow 2000) and similar to those in apparently healthy palms previously sampled (Krueger 2007; and unpublished data).

4. There is a lack of both phenotypic and genetic evaluation data. Please refer to sections 3.2.3. and 3.2.4. above. Although we have initiated an evaluation project using SSR markers, additional methods of analysis (e.g., SNP) should also be utilized. NCGRCD does not currently have a geneticist on staff, so progress in this area may be slow.

5. The documentation in the GRIN-Global system needs to be improved. Passport data, historic descriptive data, and, when available, more current evaluation data needs to be loaded. Vouchers also need to be added to GRIN-Global. Additional of a database specialist with responsibilities of developing these sorts of documentation would be desirable.

6. Expansion of the collection is desirable. Please see sections 3.1.3. and 4 above.

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7. Appendices (number and lengths at the CGC's discretion)

Table 1. Species of *Phoenix* recognized by several investigators.

Species	Martius (1836-1850)	Beccari (1890)	Miller *et al.* (1930)	Chevalier (1952)	Mowry *et al.* (1952)	Moore (1963)	Munier (1973, 1974)	Bailey and Bailey (1976)	Barrow (1998)
abyssinica Drude						+		+	
acaulis Roxb.	+	+	+	+	+	+	+	+	+
andamanensis S. C. Barrow									+
atlantica A. Chev.				+			+		?
caespitosa Chiov.									+
canariensis H. Wildpret		+	+	+	+	+	+	+	+
dactylifera L.	+	+	+	+	+	+	+	+	+
farinifera Roxb.	+	+		+		+	+		
hanceana Naudin ex Hance				+			+		
humilis Royle ex Becc.		+	+	+	+		+		
loureiroi Kunth	+				+	+		+	+
ouseleyana Griff.	+								
paludosa Roxb.	+	+	+	+	+	+	+	+	+
pumila hort.			+						

pusilla Gaertn.	+	+	+		+	+		+	+
reclinata Jacq.	+	+	+	+	+	+	+	+	+
roebelenii O'Brien			+	+		+	+	+	+
rupicola T. Anderson		+	+	+	+	+	+	+	+
spinosa Schumach.	+								
sylvestris (L.) Roxb.	+	+	+	+	+	+	+	+	+
theophrasti Greuter									+
zeylanica Trimen			+		+			+	

Table 2. The genus *Phoenix*: a summary (after Barrow (1998) and Johnson (1996).

Species	Common name	Distribution	Notes	**Synonyms**
P. acaulis	--	N India, Myanmar	stemless; fruit edible; sometimes confused with *P. loureiroi*; conservation status uncertain; local populations possibly threatened by development.	--
P. andamanensis	--	Bay of Bengal	single trunk; semi-dwarf; species status somewhat questionable; rare, may be considered threatened.	--
P. atalantica	--	Cape Verde Islands	multiple trunk; limited distribution; may be population of feral *P. dactylifera*.	--
P. caespitosa	--	Somalia, Arabian peninsula	habitat: wadis; stemless; fruit edible; species status somewhat questionable; restricted area, may be considered threatened.	*P. arabica*
P. canariensis	Canary (Island) date palm	Canary Islands	wide range of habitats within distribution; single trunk; fruit edible; widely cultivated as ornamental; genetic erosion from hybridization threatens genetic integrity.	*P. cycadiflora, P. jubae*, *P. tenuis*
P. dactylifera	Date palm	Middle East to W India, N Africa	habitat: wadis, oases; widely cultivated in suitable climates for fruit; many other plant parts utilized.	*P. atlantica*

P. loureiroi	--	India, China, Indochina, Philippines	dwarf; fruit edible; other plant parts utilized; taxonomy somewhat confused: 2 varieties (*loureiroi*, *humilis*); development threatens local populations but overall not threatened.	*P. formosana, P. hanceana, P. humilis*, *P. ousleyana*
P. paludosa	--	Bay of Bengal, Indochina, Malaysia	habitat mangrove swamps and estuaries; semi-dwarf; not considered threatened as a species but specific populations might be threatened.	*P. siamensis*
P. pusilla	--	S India, Sri Lanka	fruits edible; other plant parts utilized; conservation status unclear.	*P. farinifera, P. zeylanica*
P. reclinata	Senegal date palm	tropical & subtropical Africa, Madagascar, Comoro Islands	habitat and morphology variable; fruit edible; other plant parts utilized; widely cultivated as ornamental; not considered threatened.	*P. abyssinica,* *P. baoulensis,* *P. comorensis,* *P. madagascariensis*, *P. senegalensis*, *P. spinosa*, *P. zanzibarensis,* etc.
P. roebelenii	Pygmy date palm	Laos, Vietnam, S China	rheophytic; dwarf; widely cultivated as ornamental; conservation status unclear, use as ornamental may result in removal of native populations.	--
P. rupicola	Cliff date palm	N India	single trunk; semi-dwarf; fruits eaten by animals but not humans; conservation status unclear.	--

P. sylvestris	Indian date palm	India & Pakistan	wide range of habitats; utilized for sugar, fruit; not threatened.	--
P. theophrasti	Cretan date palm	Crete, Turkey	habitat: coastal areas; species status questionable; restricted growing area, threatened by population pressure.	--

Table 3. World Date Production 2017 (Source: FAO)

Country	Area Harvested (ha)	Yield (hg/ha)	Total production (tonnes)
Albania	480	270,464	12,978
Algeria	167,663	63,136	1,058,559
Bahrain	3,600	29,169	10,501
Benin	579	24,277	14,06
Cameroon	162	37,394	605
Chad	10,576	18,920	20,011
China	13,814	117,304	162,041
China, mainland	13,814	117,304	162,041
Colombia	8	40,499	33
Egypt	49,522	321,155	1,590,414
Eswatini	99	31,793	314
Iran (Islamic Republic of)	169,793	69,801	1,185,165
Iraq	365,908	16,912	618,818
Israel	4,314	101,917	43,967

Jordan	3,223	78,256	25,222
Kenya	471	22,833	1,076
Kuwait	3,031	288,324	87,391
Libya	32,620	53,520	174,583
Mali	60	128,662	772
Mauritania	9,296	23,696	22,029
Mexico	1,377	59,661	8,215
Morocco	58,316	22,217	129,562
Namibia	142	25,261	359
Niger	6,777	28,310	19,186
Palestine	2,657	13,215	3,512
Oman	24,617	146,613	360,917
Pakistan	98,023	53,461	524,041
Peru	85	26,353	224
Qatar	2,458	119,639	29,404
Saudi Arabia	108,133	69,799	754,761
Somalia	2,682	50,644	13,583
Spain	492	37,561	1,848

Sudan	37,139	118,299	439,355
Syrian Arab Republic	453	95,162	4,309
Tunisia	64,398	40,374	260,000
Turkey	2,604	148,006	38,535
United Arab Emirates	65,021	73,097	475,286
United States of America	5,420	72,509	39,300
Yemen	13,960	34,108	47,615

Table 4. NPGS *Phoenix* holdings as of 2019.

		ACCESSIONS
Total		169
P. dactylifera		150
	Named Old World female cv	49
	Named New World female cv	9
	Superior male selections	5
	Backcrossed male accessions	30
	Hybrid “Breeding Lines”	17
	Baja California Sur seedlings	13
	Spanish seedlings	7
	Miscellaneous unverified	19
	Australian	1
P. acaulis		1
P. canariensis OPS	seed source	1
P. hanceana OPS	seed source	2
P. loureiroi	seed source	1
P. loureiroi var. *loureiroi*	seed source	1

P. paludosa OPS	seed source	1
P. reclinata	1 clonal, 1 seed source	2
P. roebelenii		3
P. sylvestris		7

Figure 1. Distribution of *Phoenix* spp. throughout the world (Munier 1973).

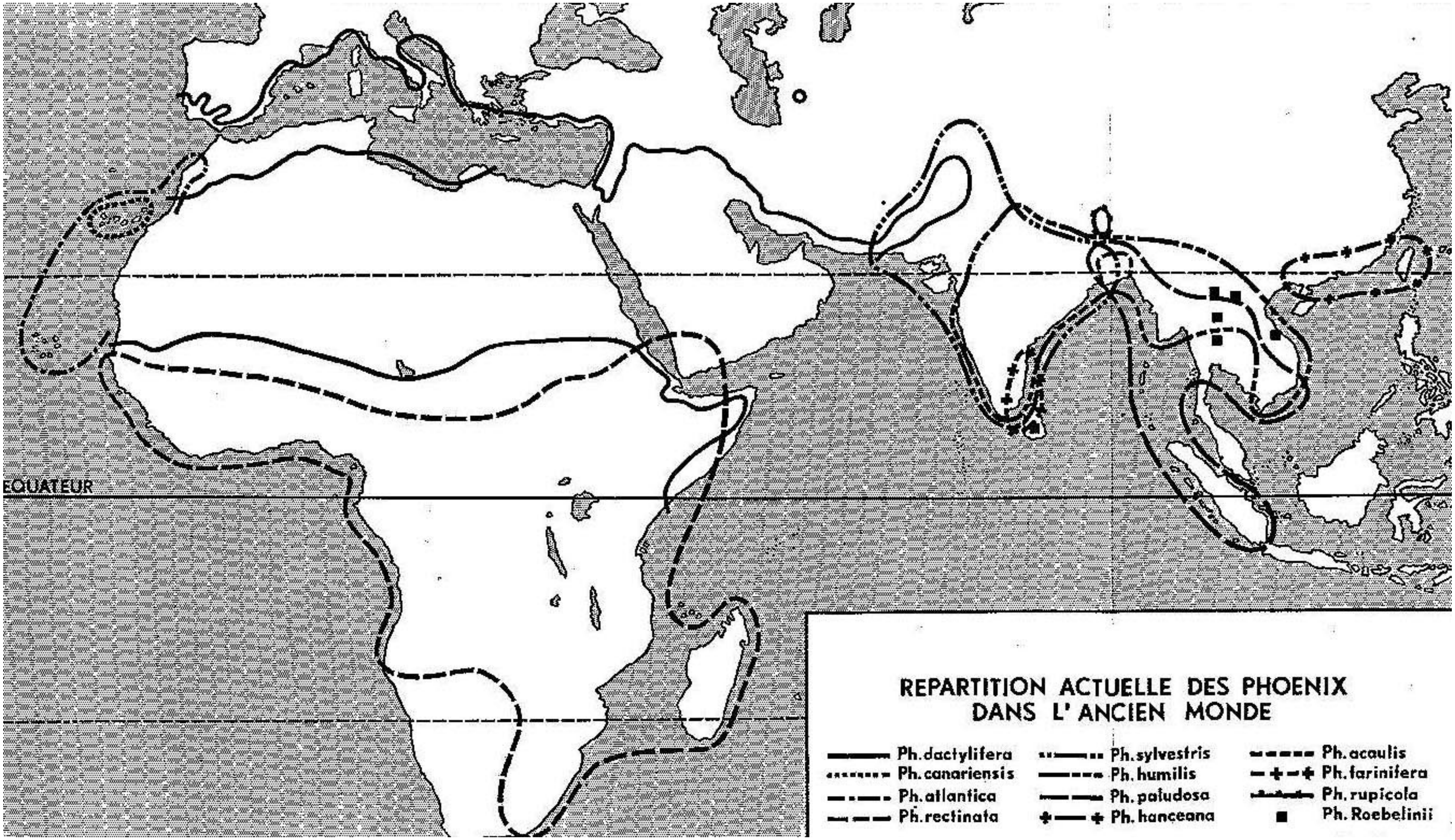

Figure 2. Spread of the date palm throughout the Old World (Munier 1973).