Chapter 3
Date Palm Status and Perspective in Saudi Arabia

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Abstract Date palm is a major crop significantly contributing to the agroecosystems in Saudi Arabia. There has been vast support and development in the agricultural sector in general and the date palm sector in particular during the last decades in Saudi Arabia. However, there are several challenges facing date cultivation, processing, and marketing. Such difficulties relate to water scarcity and salinity, soil erosion and desertification, insect pest infestations and disease, insufficient processing and packaging facilities and technologies, as well as a decline in date fruit demand. There is an enhancement in investment in world-class facilities and operations by leading date producers in Saudi Arabia. Large farms are prevalent in Saudi Arabia, and they are making substantial investments in new or replacement trees not in production signifying a further increase in production capacity; however, cultivar selection is generally not based on technical analyses such as yield, disease resistance, or water and fertilizers requirements. The aim of this chapter is to provide an overview of major recent aspects of the date palm in Saudi Arabia, a hot and arid region. Subjects discussed include fruit production, propagation, molecular and genetics descriptions, field management practices, entomology and pathology, postharvest handling, value-added products, commercial value, and nutrition and health benefits. Also presented are ways of minimizing the usage of nonrenewable natural resources as well as recent findings from research and development activities.

Keywords Cultivation • Dates • Germplasm • Marketing • Molecular identification • Processing • Propagation • Research • Tissue culture

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3.1 Introduction

3.1.1 Importance to Saudi Arabia Agriculture

Date palm (*Phoenix dactylifera* L.) is a unisexual fruit tree native to the hot arid regions of the world, mainly grown in the Middle East and North Africa. Since ancient time, this majestic plant has been recognized as the *tree of life* because of its integration into human settlement, well-being, and food security in hot regions of the world, where only a few plant species can flourish (Al-Khayri 2007). Saudi Arabia has a land area of 2,250,000 km^2, of which less than 0.2 % is presently under cultivation. The country is characterized by an arid and semiarid climate. The cultivated land is estimated at 525,000 ha. However, three to four times as much land is arable but not yet put to use. The significant feature of Saudi agriculture lies in the scarcity of water, with rainfall averaging about 100 mm per year in most regions except the southwest, which averages 250 mm or more (Abo-Hassan 1981). Temperatures are generally high, reaching 50 °C at times in some places in summer, when the relative humidity is also high in the eastern Saudi Arabia. Soils are fragile and subject to erosion by wind and water, as well as degradation through salinization. Over 95 % of the total land area in the Arabian Peninsula suffers from some form of desertification, of which 44 % is severe to very severe; wind and water erosion account for over 60 % of the desertification (Erskine et al. 2004).

The number of named date palm cultivars distributed all over the world was reported to be approximately 5,000 (Bashah 1996). Different date cultivars taste different from place to place, and even within one date grove, there is a range of qualities in the same cultivar.

Date palm is the most widely grown fruit tree in areas with long dry summers and mild winters, such as the predominating climate of Saudi Arabia. It thrives in desert and oasis where temperatures are high but with groundwater table that is close to the soil surface. Date fruit production is dependent on the availability of certain heat requirements, according to cultivar. Most dry fruit cultivars are found in the dry areas, whereas soft and semidry cultivars are confined to the humid and semidry areas. Date palms in Saudi Arabia can grow in different types of soil, but the best productions are recorded in light deep soils. It can tolerate high levels of salinity, i.e., some cultivars can survive salinity levels up to 22,000 ppm, but their growth and fruit productivity would be affected (Erskine et al. 2004). Salinity stress exerts negative influence on date palm growth and chlorophyll content (Al-Abdoulhadi et al. 2012).

Saudi Arabia occupies the first rank in the world in terms of average per capita consumption of dates, reaching 34.8 kg/year in 2003 (Al-Shreed et al. 2012).

3.1.2 Production Statistics and Economics

World date palm cultivation has expanded rapidly in recent years. The global production of date was estimated at 7.75 million mt, worth USD 3.82 billion in 2010. Saudi Arabia is ranked as the second largest date producer in the world after Egypt

Table 3.1 Estimated area and production of dates by region in Saudi Arabia in 2011

Region	Production (mt)	Area (ha)
Riyadh	248,327	42,208
Qassim	187,561	39,301
Eastern	147,305	13,625
Madinah	139,924	18,502
Hail	109,229	16,187
Jouf	46,898	5,471
Makkah	44,882	8,068
Tabuk	20,679	2,966
Asir	20,119	4,297
Najran	19,526	3,070
Baha	6,618	1,095
Jazan	326	288
Northern	152	40
Total	991,546	155,118

Source: Ministry of Agriculture (2011)

(FAOSTAT 2012). In 2011, date production in Saudi Arabia reached 991,546 mt, from 3.7 million trees which covered an area of 155,118 ha (Ministry of Agriculture 2011). Table 3.1 shows estimated area and production of dates by region in Saudi Arabia. The date palm orchards are distributed in various regions. Riyadh in the Central Region is considered the highest producer of dates (25.04 %) followed by Qassim region and Eastern region (Al-Hassa and Qatif) which represent 18.91 % and 14.85 %, respectively. While there are about 400 date cultivars grown in four main regions in the Kingdom, only about 50–60 cvs. are commercial (Mikki 1998).

Because of surplus date production in Saudi Arabia, domestic marketing of the product needs to be enhanced; moreover, exports have not reached the expected level. Also, the per capita consumption of dates in Saudi Arabia has significantly declined over the years, due to competition from other fresh fruits and sweets, in addition to changes in family size and eating habits, while the production has increased. This has impacted date production negatively, in spite of support from the government. The Kingdom currently has 64 date processing factories (Al-Shuaiby and Ismael 2007; Anonymous 2006, 2009).

3.1.3 Current Agricultural Problems

Presently, date palm development in Saudi Arabia is of great governmental concern, while project implementation concerns the private sector. After the ambitious expansion of developing programs for new date palm plantation, the overall picture is now a series of continuous new endeavors aimed at improving the date growing areas through the introduction of labor-saving methods in cultivation and modern irrigation systems, improved packaging, industrialization of fruit processing, and product diversification, for example, a better utilization of lignocellulosic residues of the date palm tree (Mikki 1998). However, there are constraints facing the development of date palm in Saudi Arabia. Date palm cultivation in the country has a long history, yet the efforts exerted on research and development, although significant, are still insufficient and fall below expectations. In general, product quality is still low, field and postharvest losses are high, and date product and by-product utilization needs improvement. To address these constraints, the Saudi Arabian government ranked date palm as having the highest research priority in setting priorities for agricultural research (Erskine et al. 2004).

3.2 Cultivation Practices

3.2.1 Current Cultivation Practices

Date palm cultivation practices in Saudi Arabia can be summarized in the following steps: fertilization, irrigation, pollination, fruit thinning, bending and bagging of bunches, pesticide control, and harvesting. Most date farmers practice manual pollination techniques and are generally reluctant to adopt innovative pollination techniques. Proper training programs for the use of mechanical fertilization methods need to be implemented. The three highest expenses of date farmers in Saudi Arabia are labor, chemicals, and energy to pump water. Brown (1983) showed that among cultural operations, harvesting, pollination, and pruning are the most labor-intensive work, accounting for more than 80 % of the total production costs. Most of palm trees in the old historic date palm orchards in Saudi Arabia such as Al-Hassa, Kharj, and Madinah have been planted densely with only 2–5 m between trees, which represents an impediment to mechanization.

In Saudi Arabia, flood irrigation is primarily practiced in Madinah and Al-Hassa. However, most date palm farms have adapted modern irrigation techniques such as drip and sprinkler irrigations. However, some old farms still practice flood irrigation. Farmers do not keep records of water consumption; date palms are typically overwatered, resulting in a waste of critical water resources. Al-Amoud et al. (2000) studied the effect of different irrigation methods on date palm tree yields in Saudi Arabia. The results demonstrated that the maximum average yield was obtained for trees irrigated with trickle methods, followed by basin-irrigated trees. An annual water volume of 108 m^3 per tree (1.08 m/ha) would be sufficient to produce the highest water use efficiency. The trickle irrigation method has been shown to be the best for water use efficiency, followed by the basin and then the bubbler methods (Al-Amoud et al. 2000).

Timing between applications of fertilizers varies considerably among growers in Saudi Arabia, ranging from every year to 3 years. Fertilizers are often applied without soil sampling, with limited use of chemical fertilizers in some regions such as Al-Hassa and Madinah. In Saudi Arabia, responses to fertilization are inconsistent and probably depend upon cultivar, soil type, and other factors. Manure has traditionally been used in date production, but in many instances inorganic fertilizers are used. Many producers, even in industrialized production, consider manure to be superior to inorganic fertilizer. Cover crops are also often grown in date groves (Abdul-Baki et al. 2002). In a study by (Almadini and Al-Gosaibi 2007), evaluating the effect of the use of organic fertilizer for palm trees on soil properties and fertility, the results indicate that applying organic amendments led to improved physical and chemical characteristics of the soil and greater soil fertility, indicating the importance of adding organic fertilizers to enhance soil quality and sustain the productive capacity of fruit quantity and quality. Al-Kahtani and Soliman (2012) reported that agricultural waste plus 40 % sheep manure gave the highest initial fruit set and retained fruit, bunch weight, yield fruit weight, flesh weight, flesh thickness, fruit volume, fruit dimensions, total soluble solids, nonreducing sugars, and total sugars, as compared with the other treatments over two seasons.

Soil testing can be a useful tool to assess the fertilizer needs of date palms. Of the 17 essential elements, N, P, and K are commonly deficient in soils. Therefore, field fertilizer trials predominantly involve these three elements. There is a direct relationship between soil test values and date palm yield, justifying the need to improve fertilizer. Elprince and Alsaeedi (2007) estimated fertilizer requirements of date palm from site variables including soil testing, water, and leaf analysis. The results warrant the establishment of an extension service for fertilizer recommendations in the Al-Hassa region. Presently, there is a tremendous opportunity to increase tree yield and fruit quality simply through the adoption of improved cultivation practices.

3.2.2 Pollination and Fruit Quality

3.2.2.1 Pollination

In most date palm growing countries, including Saudi Arabia, seedling males are used for pollination. These seedling males are highly variable and differ greatly in their growth, vigor, spathe characteristics, and pollen quality (Al-Baker 1972). In some date cultivars better fruit set results from pollen of some males than others, apparently due to compatibility of male and female cultivars (Nixon 1969). The principal characteristics desired in a male palm are fertility, flowering early in season, and a large quantity of flowers. At room temperature, pollen will retain its viability for 2–3 months. Soliman and Al-Obaid (2013) reported significant differences in pollen grain morphology among 11 Saudi date palm males.

Al-Ghamdi et al. (1988) evaluated eight date palm males and their effects on fruit character of three female cultivars grown in Al-Hassa. They observed that males varied considerably with respect to vegetative and reproductive characters. Fruit characteristics such as total weight, pulp weight, moisture content, length, and width were significantly affected to a degree, influenced by the genotype of both male and female trees. In general, the male designated M1 appeared to be superior to the other males tested based on the fruit characteristics evaluated.

3.2.2.2 Fruit Quality

Quality profile of dates involves an evaluation of four aspects: (a) color, shape, size, taste, texture, pit/flesh ratio, and uniformity in color and size of the fruit; (b) moisture, sugar, and fiber content; (c) defects of the fruits, which may include discoloration, broken skin, sunburn, blemishes, and shrivel deformity; and (d) presence of insect infestation, foreign matter, pesticide residues, mold, and decay (Saleem 2005). Horticultural practices, in particular, have direct effect on yield, on fruit quality, and ultimately on the sustainable utilization of all resources within the oasis agroecosystem, including date palm cultivars (Siebert et al. 2007). Some traditional horticultural practices may adversely impact date yield and quality. These include narrow spacing between trees, minimal fertilizer inputs, and inadequate irrigation due to limited resources, in addition to inadequate pollination, fruit thinning, and protection from biotic and abiotic stress as well as inefficient pest and disease control (Jaradat 2013). Hand pollination and fruit thinning guarantee adequate fruit set and optimal fruit quality (Mukhtar et al. 2011).

3.2.3 Pest and Disease Control

The most important pests and diseases affecting date palm in Saudi Arabia are the red palm weevil (RPW), *Rhynchophorus ferrugineus* (Olivier), and Al-Wijam disease. A phytoplasma pathogen is suspected to cause Al-Wijam; its main symptoms are leaf stunting, yellow streaking, and a marked reduction in fruit and stalk size, which leads to failure in fruit production at harvest (Alhudaib et al. 2007). The RPW has been identified by FAO as a *category-1* insect pest of date palm in the Arabian Gulf region and is a key pest in Saudi Arabia. Close spacing of palms and open flood irrigation favor increased attack by RPW, probably due to higher relative humidity in the plantations resulting from these practices (Sallam et al. 2012). In Saudi Arabia, RPW was reported in Qatif in the Eastern Province then spread throughout the country, mainly through transport of infested planting material (Al-Abdulmohsin 1987). In Saudi Arabia, the annual loss due to eradication of severely infested palms is put at 1–5 %, with estimated value to range from USD 1.74–8.69 million, respectively, at a fixed eradication level of 20 % of infested palms (El-Sabea et al. 2009).

Early detection of infestation is the key to the success of RPW management in the field. Infested palms, if not detected early and treated, usually die after harboring several overlapping generations. However, palms in an early stage of attack respond to insecticide treatment by stem injection (Faleiro 2006). Recently El-Shafie et al. (2011) assessed the efficacy of trap-free *attract and kill* pheromone technology for managing RPW in date plantations, while Faleiro et al. (2010) developed models to validate area-wide RPW-IPM programs in the date plantations of Saudi Arabia.

Stored dates are attacked by insects, birds, rodents, mites, and microorganisms including fungi. Fumigation is the most commonly important alternative to pest control of stored dates (see Sect. 3.7.4.1 for more details).

Treatment of dates on the bunch during April to June will effectively control the lesser date moth, date stone beetle, and greater date moth. This will affect positively the control of other ripe fruit moths and beetles, particularly the sap beetle during August to late October. Management of date pests during this time of the cropping season will guarantee clean undamaged and uninfected dates in the storehouse.

Precautions have to be taken to prevent reinfestation after storage and immigration of insects from outside the storage facilities. International CODEX food safety standards for dates list the absence of live insects and insect eggs and mites as an important index for quality. Therefore, to reduce the quantitative and qualitative losses due to insect pests, and to meet the international marketing standards, an integrated stored product management program (ISPM) for dates should be established and strictly applied (Abo-El-Saad and Elshafie 2013).

3.2.4 Cultivation Challenges and Limitations

The date palm is a drought-resistant and salt-tolerant plant. The annual water requirement of a mature date palm ranges between 115 and 306 cubic meters (1.15–3.06 mt/ha) (Al-Baker 1972). Scarcity of water in Saudi Arabia contributes significantly to reducing date palm productivity and even to the death of the trees (El-Juhany 2010). Date palm cultivation requires plenty of water, and if the current trend of palm expansion in Saudi Arabia continues, a considerable amount of additional irrigation water will be required. However, due to the limited availability of water resources, the increase in using water conservation measures, such as modern irrigation systems (trickle and bubbler), is necessary (Al-Amoud et al. 2000). Moreover, there are several constraints facing the development of date palm in Saudi Arabia, such as: (a) the presence of low-quality cultivars; (b) poor farm management; (c) pests and diseases, and inadequate IPM control; (d) deficiencies in harvesting, processing, and marketing practices; (5) shortage of qualified and national trained staff and laborers; and (e) insufficient research and development activities (Erskine et al. 2004). Although the cultivation of date palms has developed considerably, and great attention has been given by the Government of Saudi Arabia; nonetheless, the level of date productivity is low compared with other date-producing countries (Al-Obaid 1996). The main causes of low date productivity are the increase in the large number of the older trees, the existence of many low-quality and undesirable cultivars, lack of sufficient offshoots to establish new orchards or even renew the old ones, and the increase in cost of offshoots of good-quality cultivars (Al-Sakran and Muneer 2006).

3.3 Genetic Resources and Conservation

Date palm genetic diversity is the foundation of an effective crop improvement program to develop new cultivars resistance to current abiotic and biotic limitations. This highlights the importance to preserve date palm germplasm by utilizing all available means. In Saudi Arabia, limited research was encountered related to date palm in vitro cryopreservation. General conservation efforts are evident from the establishment of two field germplasm banks to conserve national and international cultivars, discussed below. Moreover, to protect germplasm against degradation threats due to the spread of pests, the authorities have implemented quarantine regulations on date palm international exchange and transport within the country.

3.3.1 Threats and Degradation

Date palm germplasm biodiversity and productivity in Saudi Arabia is threatened by a number of factors common to most date palm growing countries. In addition to urbanization, desertification, salinization, and genetic erosion, date palm is threatened by numerous diseases and insects as well as environmental stress factors including drought, salinity, and temperature extremes that may be exacerbated as a result by global climate change.

In Saudi Arabia, red palm weevil (RPW) (El-Sabea et al. 2009) and Al-Wijam disease (Alhudaib et al. 2007) are the most serious pests for date palm cultivation. Lack of efficient integrated pest management (IPM) has resulted in the spread of pests and diseases in different regions of the country (El-Juhany 2010). It is reported to attack mostly young date palm less than 20 years old. Reports indicated that 99 % of the infested date palms are less than 20 years old with 75 % being in the age group of 6–15 years which is the most vulnerable age of infestation (Anonymous 1998).

There are several factors that contribute to genetic erosion that also threaten date palm diversity and productivity. Krueger (2011) stated that modernization of traditional oasis culture can contribute to genetic erosion of date palms due to the importation of more profitable elite cultivars to replace old or dead date palms with elite foreign cultivars. Lately, it is noticeable that some Saudi framers are interested in the cultivation of certain foreign elite cultivars such as Medjool. Also, certain elite local cultivars comprise most of the cultivation areas in each growing regions, marking the decline of genetic diversity.

Water scarcity and salinity of water and soil, aggravated by typical lengthy rainless periods and drying of many water wells, restrict expanding date palm cultivation in most parts of the Arabian Peninsula, including Saudi Arabia (Jaradat and Zaid 2004).

Another important threat is the shortage of skilled labor to maintain date palm cultivation, which requires attention. Enhanced income through the opportunities presented by modern technologies has led the majority of the small farmers to abandon their date palm groves (El-Juhany 2010). Neglecting these aspects can cause the degradation of date palm germplasm and limit cultivation. It is important to strengthen research and conservation efforts to keep these factors in check in order to conserve date palm germplasm resources and sustain productivity.

In an effort to manipulate growth of date palm and examine the potential effects on various physiological parameters, several studies were conducted involving magnetic fields (Dhawi and Al-Khayri 2008a, b; 2009a, b, c; Dhawi et al. 2009) as well as x-ray irradiation (Al-Enezi and Al-Khayri 2012a, b; Al-Enezi et al. 2012). These studies involved exposing seeds collected from cv. Khalas in Al-Hassa, germinated and grown under greenhouse conditions, and chemical analyses based on seedling tissue. Changes were observed in germination and seedling growth as well as physiological responses including proline accumulation, ions concentration, DNA content, and photosynthetic pigments distribution. These studies provide guidelines for future studies aimed at inducing growth manipulation and possibly mutations that may contribute to enhancing the available genetic resources and expanding the genome of the date palm (Dhawi and Al-Khayri 2011).

3.3.2 Cryopreservation

Cryopreservation is currently considered an effective method for long-term conservation of date palm germplasm. Several studies to examine these factors include the effect of different components of cryoprotectant solution. In Saudi Arabia, the only relevant study encountered was reported by Al-Bahrany and Al-Khayri (2012a), which showed that the revived cell samples treated with 10 % DMSO in combination with 0.75 M sucrose showed the most colony formation, greatest callus growth, and highest embryo numbers. Accumulating fundamental knowledge of cryopreservation requirements may be utilized to develop a germplasm bank for the long-term conservation of date palm germplasm. This is of tremendous importance, especially under current predictions of global climate change and the potential abiotic and biotic threats that may challenge date palm cultivation in different regions of the world.

3.3.3 Germplasm Banks

3.3.3.1 Date Palm Germplasm Bank at King Faisal University

A date palm germplasm bank was established in 1982 at King Faisal University, Date Palm Research Center of Excellence, located at the Agricultural and Veterinary Experimental Station in southeastern Al-Hassa (25°15′36″ N lat.; 49°43′30″ E long., elev. 145 m). This collection contains national and international date palm cultivars as well as a section for trees produced by tissue culture. The national

Fig. 3.1 Views of the date palm germplasm bank at the Ministry of Agriculture, Date Palm Research Center, Al-Hassa, Saudi Arabia (Photo by: Kabeel M. Ghawas)

collection comprises 510 palms representing 31 Saudi cultivars collected from 7 major growing regions (Al-Hassa, Qatif, Madinah, Besha, Najran, Jouf, and Qassim). The international collection comprises 615 date palm trees representing 26 cultivars imported as offshoots from California, USA, and Iraq. In addition, 282 tissue culture-derived date palm trees representing 15 cultivars are obtained from the USA, England, France, and Saudi Arabia (Al-Ghamdi 2001).

This germplasm collection encountered adverse conditions which led to the decline of numerous trees. Degradation was mainly due to the decline of groundwater quality resulting in increased soil salinity, low soil fertility, and shallow soil depth, as well as the location of the germplasm field over an underground salt belt within the experimental station, high water table, and increased exchangeable sodium percentage. Consequently, a decision was made in 2010 to transfer some of the surviving trees to the Ministry of Agriculture Date Palm Germplasm Bank. Currently the relocation of the date palm germplasm bank to a more suitable site where soil conditions are more favorable is being considered.

3.3.3.2 Date Palm Germplasm Bank at the Ministry of Agriculture

The Ministry of Agriculture, Date Palm Research Center, located in northern Al-Hassa (25°27′ N lat.; 49° 33′ E long.), established a date palm germplasm bank in 2000 (Fig. 3.1). This was implemented through the technical cooperation between the Ministry of Agriculture and FAO to conserve elite cultivars. Subsequently, the collection was augmented with seedling date palms through collaboration with the Arab Center for Studies of Arid Zones and Dry Lands (ACSAD). The collection consists of 89 cultivars collected from major growing regions of Saudi Arabia and 5 cultivars from international sources. In addition, there are14 date palm seedling cultivars from the Zulfi region of central Saudi Arabia (26°18′ N lat.; 44°48′ E long.) and 2 seedling cultivars from the Al-Hassa region. Moreover, the collection contains elite male date palms collected from various regions of Saudi Arabia.

The main objectives of establishing this date palm germplasm bank were: (a) conserve genetic diversity, (b) study the morphological and physical characteristics of cultivars, (c) develop a germplasm repository for plant breeding and molecular work, and (d) study the reaction of the cultivars to major abiotic and biotic stresses.

3.3.4 Quarantine Regulations

Due to the threats posed by biotic factors on agriculture, numerous countries have imposed certain actions to minimize the phytosanitary risk associated with the inadvertent introduction and spread of pests and diseases. Saudi Arabia has approved implementation of Quarantine Law of the Gulf Cooperation Council of the Arab Gulf States through Royal Decree No. M/9 dated 8 March 2005 (Experts 2005). The aim of this law is to prevent the entry and spread of agricultural pests, protection of environmental and plant resources, and the facilitation of trade. Implementation of the Regulations of the Quarantine Law, Article 6 of Chapter II, prohibits import of consignments of plants or plant products or any other material of any palm species and their derivatives. Fruits of date palm and fiber-stripped coconuts are exempted (Ministry of Agriculture 2005).

Measures were taken in the early 1990s by the Ministry of Agriculture to restrict the spread of pests, especially red palm weevil (Committee 1993). These acts included (a) prohibiting transportation of date palm offshoots within Saudi Arabia among date palm growing regions, (b) obtaining official permits to transport any date palm offshoots within the Kingdom, and (c) strengthening extension services to increase farmers' awareness of the danger and prevention methods, as well as providing on-field technical assistance to deal with infested trees.

The transport of offshoots is restricted within the country mainly because of the lack of a protocol ensuring the phytosanitary condition of the plants. Recently, Al-Shawaf et al. (2013) developed an insecticide-based protocol that kills larval stages of RPW feeding inside date palm offshoots. This would allow transport of treated offshoots to a different growth region without the danger of spreading this devastating insect. The protocol involves dipping offshoots in 0.004 % fipronil 3.5 % (ThripGuard 35 SCTM) for 30 min.

3.4 Plant Tissue Culture

3.4.1 Importance and History

Propagation by offshoots, axillary buds growing from the base of the tree, is the preferred method as compared to seed propagation which normally produces off-type progeny. Although seeds are a rich resource of germplasm useful for genetic improvement (Johnson et al. 2013), seed propagation is not suitable for the multiplication of known date palm cultivars because genetic traits including fruit traits are not maintained. Offshoots are produced only in the early life of the date palm, the first 10–15 years, in very limited number, although this number varies among cultivars.

Offshoots must remain attached to the parent tree for 2–3 years to develop an adequate growth and their separation from the parent tree is often difficult and expensive, and a large number of offshoots do not survive, making this method inefficient particularly at commercial scale. Alternatively, micropropagation is gaining increased interest as it provides a relatively rapid means for mass clonal propagation (Al-Khayri 2005, 2007).

In the early 1980s, research on in vitro plant regeneration of date palm began in Saudi Arabia, mostly at the Date Palm Research Center, King Faisal University, (Abo El-Nil 1989a, b; Abo El-Nil and Al-Ghamdi 1989; Khalil et al. 1983; Khan et al. 1983) and continued to build in the 1990s (Al-Khayri et al. 1996; Al-Maarri and Al-Ghamdi 1995, 1997). This early work demonstrated successful micropropagation of a number of important Saudi date palm cultivars. Subsequently, research was focused optimizing in vitro factors (Al-Khayri 2013) and the utilization of tissue culture for physiological and genetic improvement studies including tolerance to drought (Al-Khayri 2002) and salinity (Al-Bahrany and Al-Khayri 2012b; Al-Khayri and Al-Bahrany 2004a), the most important stress factors limiting cultivation in this region.

3.4.2 Research and Development

Various research institutions which are actively engaged in date tissue culture include the Ministry of Agriculture, King Abdulaziz City for Science and Technology, King Saud University, and King Faisal University. Relevant research by Saudi scientists is chronologically presented in Table 3.2. This table reflects the studied factors to optimize somatic embryogenesis and organogenesis in various cultivars.

3.4.3 Scale-up Commercial Micropropagation

Two commercial tissue culture labs currently are involved in date palm micropropagation: SAPAD Tissue Culture Date Palm Co. (http://sapad.com.sa/en) in Dammam, Eastern Province, and Al-Rajhi Tissue Culture Laboratory (http://www.clonebiotech.com/) located in Riyadh, Central Province. They provide venues for local purchase as well as international export. Different sizes of in vitro plants are shipped depending on customers' specifications.

3.4.4 Micropropagation Protocol

A micropropagation protocol effectively used for date palm regeneration via somatic embryogenesis is fully described by Al-Khayri (2005, 2007). Briefly it involves culturing explants (sectioned lateral and apical buds of offshoots) on MS medium

Table 3.2 Major findings of research on date palm tissue culture in Saudi Arabia

Cultivar	Results	Reference
Helali	Callus and roots formed from various seed zones but no plant redifferentiation was observed	Khalil et al. (1983)
Not specified	NAA-containing medium resulted in highest callus formation in all explants. Plantlets were obtained by reculturing explants on a medium containing 1 mg L^{-1} NAA with 0.1 mg L^{-1} kinetin	Khan et al. (1983)
Not specified	SH and B5 media induced best callus induction, while MS medium supported best regeneration by organogenesis. Embryogenesis was best on ER and SH media. Best level of AC was 1.5–2 g L^{-1}	Abo El-Nil (1989a)
Khalas	Callus growth was enhanced by the inclusion of 0.5 mg L^{-1} thiamine and 2 mg L^{-1} biotin. This treatment also gave the highest number of embryos. Embryo elongation was greatest at 0.5 or 2 mg L^{-1} thiamine combined with 1 mg L^{-1} biotin	Al-Khayri (2001)
Barhi	The number of embryos increased in response to increasing $AgNO_3$ concentration in the absence of 2iP, but in the presence of 2iP, the opposite trend was observed. The number of resultant embryos was the highest on 25 μM $AgNO_3$ in the presence of 0.5 μM 2iP	Al-Khayri and Al-Bahrany (2001)
Khalas	The highest percentage of somatic embryos formed complete plantlets (86 %) occurred on half-strength MS containing 0.2–0.4 mg L^{-1} IBA	Al-Khayri (2003)
Barhi, Naboot Saif, Ruzeiz, Hilali, Khesab	Optimum callus growth occurred at 50 μM $AgNO_3$ in Barhi, Naboot Saif, and Ruzeiz, whereas Hilali grew best at 62.5 μM. Khesab maximum growth occurred at 62.5 μM. Best $AgNO_3$ concentrations for somatic embryogenesis were 62.5, 50, and 37.5 μM for Barhi, Hilali, and Ruzeiz, respectively; whereas 12.5 μM was best for Naboot Saif and Khesab	Al-Khayri and Al-Bahrany (2004b)
Sukury	The highest numbers of buds, number shoots, and shoot length were obtained on MS medium containing (in mg L^{-1}) 0.05 kinetin + 0.25 2ip + 0.025 BAP + 0.025 IAA + 0.025 NOA + 0.025 NAA	Al-Khateeb (2006a)
Sukkari	The results indicated that sucrose at a high level of 60 g improved production of embryos. The production of embryos was greatly enhanced by the addition of 5 % PEG combined with 60 g L^{-1} sucrose	Al-Khateeb (2006b)
Sukkari	Addition of 60 g L^{-1} sucrose produced the highest number of somatic embryos and longest shoot equal to that produced by 6 % date syrup. At 10 %, the syrup caused severe reduction in somatic embryogenesis	Al-Khateeb (2008a)
Khenaizy	Using 5 % of date syrup successfully induced buds and shoots formation; however, higher concentrations (10–20 %) resulted in browning and dryness of plant materials	Al-Khateeb (2008b)
Khenaizy	At 30 and 60 g L^{-1} of sugar, optimal shoot growth was obtained but abnormal growth was observed at 90 and 120 g L^{-1}. Fructose gave the highest dry weight. Rooting was enhanced by 60 g L^{-1} and higher sugar	Al-Khateeb (2008c)

(continued)

Table 3.2 (continued)

Cultivar	Results	Reference
Khesab, Naboot Saif	Callus weight and numbers of somatic embryos were directly proportional to CW concentration reaching optimum at 10 and 15 % CW for Khesab and Naboot Saif, respectively	Al-Khayri (2010)
Khesab, Barni, Barhi	The best callus growth was achieved in Khesab using W and WPM media, Barni using SH and NN medium, and Barhi using SH, W, and MS media. The highest regeneration percentage in Barni occurred on WPM, Khesab on W, and Barhi on W and WPM media	Al-Khayri (2011a)
Naboot Saif	Callus growth was best with 1 g L^{-1} of YE or CH. The best somatic embryo formation was seen on 1 g L^{-1} YE or 0.5 g L^{-1} CH	Al-Khayri (2011b)
Barhi	The growth pattern characterizing the exponential phase of cell suspensions commenced 4 weeks after initiation. The highest plating efficiency, 14.6 %, was obtained at cell density of 10,000 cells ml^{-1}	Al-Khayri (2012)
Naboot Saif	Increasing PEG concentration increased total somatic embryo numbers reaching a maximum at 10 % PEG. The highest percentage of medium-size embryos, 52 %, was obtained at 10 μM ABA, whereas the highest percentage of small embryos was obtained at 50–100 μM ABA	Al-Khayri and Al-Bahrany (2012)

Abbreviations: *2,4-D* 2,4-dichlorophenoxyacetic acid, *2iP* 2-isopentenyladenine, *ABA* abscisic acid, *AC* activated charcoal, *AgNO3* silver nitrate, *B5* Gamborg medium, *BAP* 6-benzylaminopurine, *CH* casein hydrolysate, *CW* coconut water, *ER* Eriksson medium, *HE* Heller medium (Heller Basal Salt Mixture), *IAA* indole-3-acetic acid, *IBA* indole-3-butyric acid, *kinetin* furfurylamino purine, *MS* Murashige and Skoog medium, *NAA* 1-naphthylacetic acid, *NOA* 2-naphthyloxyacetic acid, *PEG* polyethylene glycol, *SH* Schenk and Hildebrandt medium, *WH* white medium (White's basal nutrient medium), *YE* yeast extract

Table 3.3 Culture stages requirements for date palm micropropagation

	Hormones (mg L^{-1})				
Culture stage	2,4-D	2iP	NAA	Light*	Stage duration (weeks)
Initiation	100	3	–	Dark	9
Callus	–	30	10	Dark	3
Embryogenic callus	–	6	10	Light*	9
Callus multiplication	–	1.5	10	Dark	12
Embryogenesis	–	–	–	Light*	12
Rooting	–	–	0.2	Light*	6

*Light is provided at 16-h photoperiods of 50 $\mu mol.m^{-2}.s^{-1}$

(Murashige and Skoog 1962) supplemented with (in mg L^{-1}) $NaH_2PO_4 \cdot 2H_2O$ (170) glutamine (200), thiamine (5), nicotinic acid (1), and pyridoxine (1) in addition to 3 % sucrose and 0.7 % agar. Activated charcoal (1.5 g L^{-1}) is added to the medium during the first three culture stages. Hormonal and light requirements as well as the duration of culture stages are shown in Table 3.3 and some of the process is shown in Fig. 3.2.

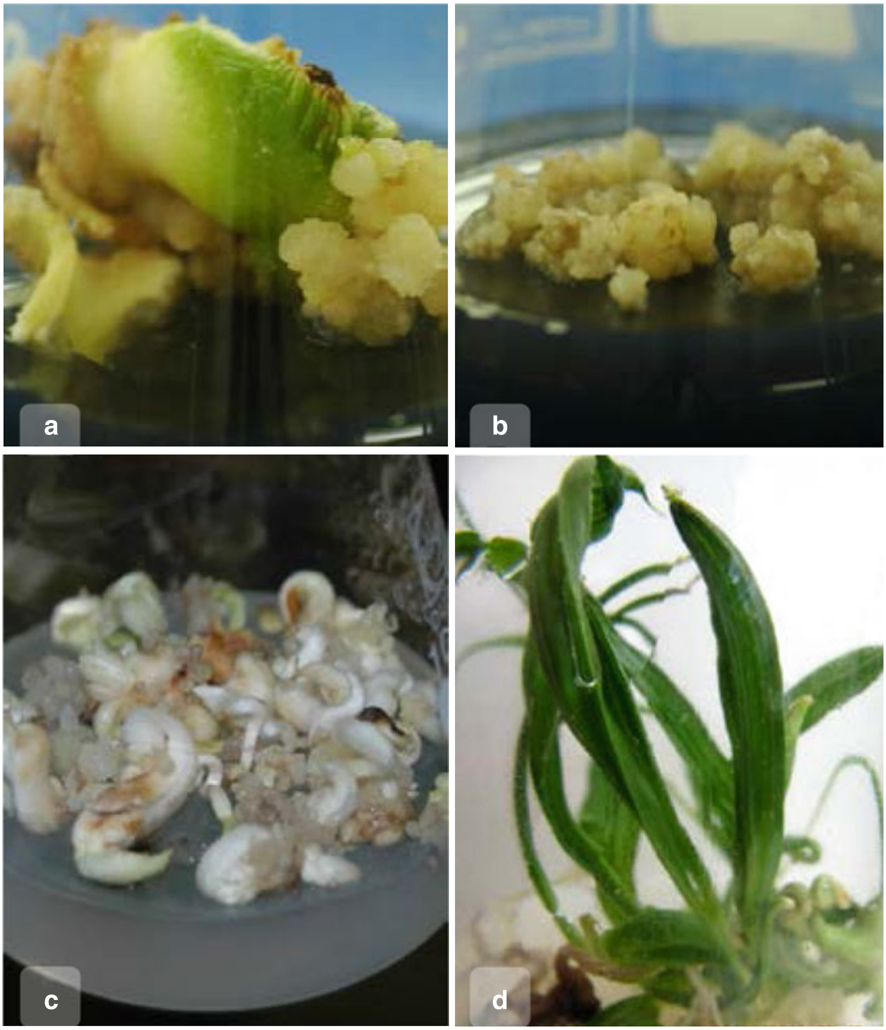

Fig. 3.2 Date palm in vitro regeneration. (**a**) Callus induction from shoot tip explants, (**b**) multiplication of embryogenic callus, (**c**) development of somatic embryos, (**d**) in vitro plantlets

3.5 Cultivars Identification

3.5.1 Role and Importance

A reliable methodology for cultivar identification is important to assure the genetic identity and conservation of date palm germplasm. Local cultivar names may not necessarily be accurate because name duplication exists among date palm cultivars grown in various regions. Morphological characteristics of date palm are traditionally utilized to identify cultivars mainly based on fruit traits and vegetative parts; however, these traits can be influenced by environmental factors. Identification and evaluation of genetic diversity based on morphological markers of reproductive parts are difficult and restricted to after the onset of fruiting (El Hadrami and Al-Khayri 2012; El Hadrami et al. 2011).

The tools of morphological identification of date palm cultivars are being consistently refined. For example, Hamza et al. (2009) developed a new approach for cultivar identification based on six stable vegetative characters unaffected by cultivation conditions. They are the percentage of spined midrib part, apical divergence angle, maximal pinnae width of the top leaf, percentage of solitary spines, spine length at the middle, and maximal spine angle.

Alternatively, biochemical markers based on isozymes analysis have been adapted for cultivar identification, but they provide limited information for detecting genomic variations. Currently, molecular markers based on DNA analysis are the most reliable and accurate method for genomic studies including cultivar identification, evaluation of phylogenetic relationship, and analysis of genetic control of agronomic traits.

This section highlights the results of studies conducted in Saudi Arabia in relation to the utilization of these identification approaches in date palm, including morphological descriptors as well as molecular markers based on isozyme and nucleic acid analyses. It also provides an update of date palm genomic studies.

3.5.2 Morphological Descriptors

3.5.2.1 Cultivar Identification

Asif et al. (1989) studied popular date palm cultivars grown in Al-Hassa, which were classified into groups based on morphological characteristics of vegetative parts (leaf length, leaflet length and width) as well as fruit traits (color, weight, length and diameter of fruit, pulp weight, and seed weight) and season of production. Their classification consisted of three categories to which cultivars were assigned.

Al-Doss et al. (2001) documented variation among Saudi date palm cultivars based upon 21 vegetative traits, 13 flowering and yield characters, and 11 fruit properties at different stages of fruit development. They concluded that the principal component analysis can be effectively used for identification and description of date palm cultivars based upon morphological characteristics of leaves and fruits.

Using morphological characters of dates, Al-Khalifah et al. (2012) characterized 14 elite cultivars of date palm popularly cultivated in Saudi Arabia. They found that fruit morphological data demonstrated a high level of diversity in shape of the fruit, color variation during ripening, length-width ratio, percentage of area covered by the fruit cap, and fruit-base shape (Table 3.4). Fruit cap size and percentage of the fruit base covered by the cap are important morphological markers to distinguish cultivars where variation ranged at 25–90 % among cultivars.

Table 3.4 Morphological characteristics of fruit and ripening season of some Saudi date palm cultivars

Cultivar	Shape	Color variation during ripening			Length/width ratio	Fruit cap (%)	Base	Ripening
		Beser (late khalal)	Rutab	Tamar				
Barhi	Ovoid	Yellow	Apricot yellow	Light brown	1.21	40	Truncate	Mid-season
Deglet Noor	Ovoid elongated	Light red	Light brown	Light brown	2.62	90	Truncate	Late-season
Hilali	Ovoid	Yellow	Yellowish brown	Brown	1.1	90	Truncate	Late-season
Hulwa	Ovoid elongated	Red	Dark red	Dark	1.5	50	Shallowly cordate	Mid-season
Khalas	Ovoid elongated	Apricot yellow	Yellowish brown	Brown	1.46	30	Oblique	Mid-season
Maktoumi	Cylindrical	Yellow	Apricot yellow	Brown	1.46	60	Shallowly cordate	Mid-season
Moneifi	Ovoid elongated	Yellow	Apricot brown	Light brown	1.51	50	Truncate	Late-season
Nabtat Ali	Ovoid elongated	Yellow	Maroon	Maroon	1.44	25	Shallowly cordate	Mid-season
Um Khashab	Ovoid elongated	Light red	Maroon	Maroon	1.84	60	Truncate	Mid-season
Ruthana	Ovoid	Yellow	Yellowish brown	Yellowish brown	1.4	30	Deeply cordate	Early season
Sabaka	Ovoid elongated	Yellow	Golden brown	Light brown	1.5	50	Shallowly cordate	Mid-season
Shaqra	Ovoid elongated	Red	Dark red	Dark brown	1.32	33	Cordate	Mid-season
Sukkari	Ovoid elongated	Yellow	Yellowish brown	Brown	1.43	60	Cordate	Mid-season
Wannana	Ovoid elongated	Reddish yellow	Brown	Dark brown	1.44	30	Oblique	Mid-season

Source: Al-Fuhaid et al. (2011) and Al-Khalifah et al. (2012)

Two book resources providing fruit descriptors of Saudi date palm cultivars illustrated with high-quality photos were published by Al-Fuhaid et al. (2011) and Al-Khalifah et al. (2013). The latter reference also provides molecular identifiers.

3.5.2.2 Male Identification

In an effort to improve date palm production and fruits quality, research to identify superior pollinizers is essential. Most of date palm males available for pollinating different female cultivars are from seed propagation, resulting in many different local males that represent a source of genetic diversity (Soliman et al. 2013). Studying pollen grain characteristics is important for understanding distinguishing features, comparative morphology, ontogeny, as well as aspects of breeding systems and hybridization (Soliman and Al-Obeed 2013). Identifying national male date palms exhibiting superior quality including pollen viability, fertility, and compatibility is considered the first step towards establishing germplasm banks for conservation superior pollen compatible with local cultivars (Al-Ghamdi et al. 1988).

In order to identify highly potent male palms to propagate standard male cultivars, several studies were conducted. Nasr et al. (1989) evaluated 600 males grown in the Central Region of Saudi Arabia based on morphological characteristics relevant to time of flowering, spathe, strands, and weight of pollen grain per spathe. The researchers found significant differences in these parameters among various males and were successful in identifying superior pollinizers based on these characteristics.

Al-Ghamdi et al. (1988) studied date palm males cultivated on Al-Hassa farms and classified them on the basis of morphological characteristics of vegetative growth including number of leaves, leaf length, number of leaflets per leaf, length of leaflet, width of leaflet, length of spines, width of spines, as well as flowering characteristics relevant to spathe number, length, width, and fresh weight as well as pollen viability.

Similarly, Soliman et al. (2013) evaluated 10-year-old seedling date palm males which originated from various popular cultivars at the Research and Agriculture Experiment Station, Dirab, King Saud University, Riyadh. The evaluation was based upon leaf morphological characters (palm crown, pinnae color, pinnae distribution, pinnae end, pinnae bent, and leaf basal color), spathe properties (length, diameter, strand length and weight, strands number/spathe, flowers number/strand and total number flowers) and pollen traits (pollen grain weight and germinate percentage). Their results indicated that as compared with other males, Sukkari cv. exhibited the greatest leaf length, pinnae number, pinnae length, spine numbers, spathe length, strand length, and pollen grains weight, whereas Khalas and Sukkari male cvs. recorded the highest total number of flowers. In contrast, Sefri male cv. followed by Sukkari, Meneifi, and Sari male cvs. germinated at the highest rate.

To investigate pollen morphological traits as a tool to facilitate the identification of date palm males, Soliman and Al-Obeed (2013) examined morphological difference among males based on scanning electron microscopy (SEM) images reflecting surface properties of pollen. Significant variations were detected in terms of shape, pore frequency, and exine patterns of pollen grains proved.

3.5.3 Biochemical Descriptors Based on Isozyme Analysis

In the late 1980s, a study involving cultivar identification was conducted by Al-Helal (1988) using sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE), which separated amylase isoenzymes for fruit extracts of 13 date palm cultivars. He found two bands representing α-amylase and β-amylase activities and concluded that the amylase protein patterns appeared to be cultivar specific. Subsequently, Al-Helal (1992) demonstrated that date palm pollen isoenzyme patterns may be useful to investigate genetic variation among date palm males. He based his observation on electrophoretic patterns of soluble protein, nonspecific esterase (EST), glutamate-oxaloacetate transaminase (GOT), and glutamate dehydrogenase (GDH) of extracts of pollen grains from different date palm males. Qualitative variations were observed based on EST and GOT isoenzymes among males; whereas, three isoenzymes of GDH were present in the pollen extracts but showed no electrophoretic variation.

Early sex determination of seedlings is important for expediting breeding processes and conserve resources required to maintain trees until fruiting stage at which sex can be determined based on flowering morphology. Al-Fredan (2013) investigated the potential use of isozymes to differentiate males and female date palm trees. The genotypes showed specific reliable mobility values for three tested peroxidase isozymes. Results revealed different leaf isozyme patterns for the two female date palm cvs. Ghur and Khenaizy. Moreover, the presence or absence of peroxidase (PRO I) was identified as a reliable marker which distinguished between date palm genders. The most anodal loci PRO I was heterozygous present only in males and PRO II only in females whereas PRO III was found in both genders.

To determine variations within a cultivar, Al-Issa (2013) assessed different trees of cv. Khalas, grown at ten locations within the Al-Hassa oasis, using SDS-PAGE to analyze leaf extracts. Dendrogram analysis revealed three clusters comprising different locations: Cluster 1 occupies a distinct place in the dendrogram composed of Oyuni, Omran, Taraf, and Shoa'bah location samples reflecting monomorphism; cluster 2 included Aqair and Ain Merjan location samples that distinguished each by a unique band; and cluster 3 included Battalia, Gurain, Ulaijalah, and Mutairfi. Consequently, Al-Issa (2014) reported polymorphisms in isoenzyme patterns among cv. Khalas trees growing in the preceding locations with two to seven bands of nonspecific esterase (EST) and two to four bands of glutamate-oxaloacetate transaminase (GOT).

3.5.4 Molecular Descriptors Based on DNA Analysis

Molecular work involving date palm in Saudi Arabia began in the early 2000s (Al-Mssallem et al. 2004). Currently various research institutions are involved in molecular identification and phylogenetic and genomic studies on date palm.

3.5.4.1 Cultivar Identification and Phylogeny

Several studies have focused on molecular analysis of the genetic diversity among Saudi date cultivars. Most of these studies used random amplified polymorphic DNA (RAPD), but other techniques were also used like inter-simple sequence repeat linked simple single repeat (ISSR) for cultivar identification and unweighted paired group method of arithmetic mean (UPGMA) for cluster analysis of various cultivars (Table 3.5). Recently, Al-Khalifah et al. (2013) published a book presenting RAPD markers for the identification of 100 cultivars of date palm grown in Saudi Arabia.

3.5.4.2 Genome Mapping

King Abdulaziz City for Science and Technology (KACST) and Beijing Institute of Genomics, Chinese Academy of Science (BIG/CAS), cooperatively initiated a Date Palm Genome Project (DPGP) in 2008, with research conducted at KACST, Riyadh. The DPGP project is a comprehensive genome research project aimed at sequencing the date palm genome including organelles (chloroplast and mitochondria) as well as the nuclear genome (Zhang et al. 2011).

Table 3.5 Molecular markers research for the analysis of genetic diversity among Saudi date cultivars

Method	Results	Reference
RAPD	Found two clusters: (A) cvs. Shahal, Um Kbar, Ajwa, Um Hamam, and Bareem with 0.59–0.89 Nei and Li's similarity coefficient and (B) cvs. Rabeeha, Shaishi, Nabtat Saif, Segae, Sukkari Asfar, Sukkari Hamra, and Nabtat Sultan with a 0.66–0.85 coefficient	Al-Khalifah and Askari (2003)
RAPD	Found two clusters: (A) cvs. Barhi and Ajwa and (B) cvs. Nabtat Ali, Ruthana, and Sukkari	Al-Moshileh et al. (2004)
RAPD	Found two clusters: (A) cvs. Mouakil and Khalas with 0.73 Nei and Li's similarity coefficient and (B) cvs. Maktoumi and Nabtat Ali with 0.70 Nei and Li's similarity coefficient (Fig. 3.3)	Al-Khalifah (2006)
RAPD	Found high level of genetic similarity (96.3 %) between Sefri and Makfazi, followed by (92.3 %) between Khalas and Maktoumi. The similarity between Sefri, Makfazi, and Khalas and Maktoumi was 90 %, while Sukkari similarity to the other cvs. was the lowest (85 %)	El-Tarras et al. (2007)
RAPD	Found two clusters: (A) red Sukkari and yellow Sukkari with 0.81–0.87 similarity coefficient and (B) naptet Sukkari with 1.0 coefficient	El-Rayes (2009)
RAPD, ISSR	Found two clusters: (A) Sukkari with Nei and Li's coefficient equal to 0.55 and (B) cvs. Medjool, Segae, and Khalas with 0.66–0.85 similarity	Abdulla and Gamal (2010)
RAPD	Analysis of the morphological fruits and RAPD markers of 14 cvs. revealed similarity correlation. In addition, it was shown that fruit shape is most influenced by genetic variation (Fig. 3.4)	Al-Khalifah et al. (2012)

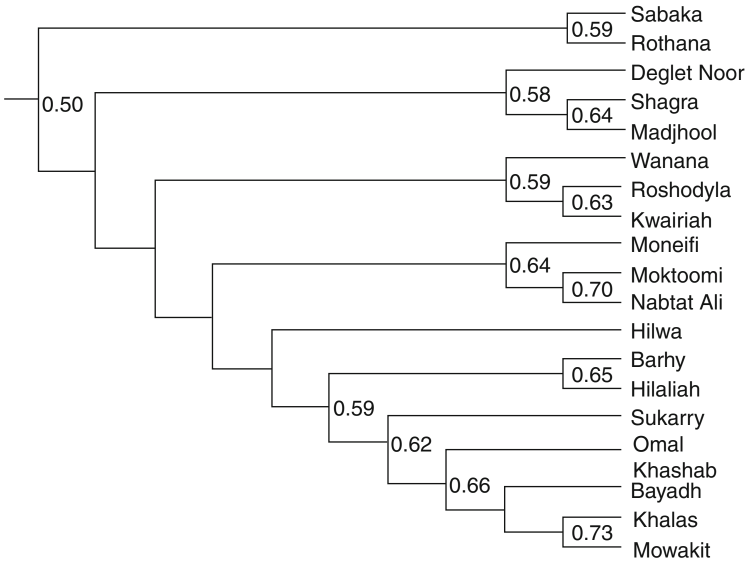

Fig. 3.3 Dendrogram of phylogenetic relationship among 19 date palm cultivars based on RAPD analysis (*Source*: Al-Khalifah et al. (2012))

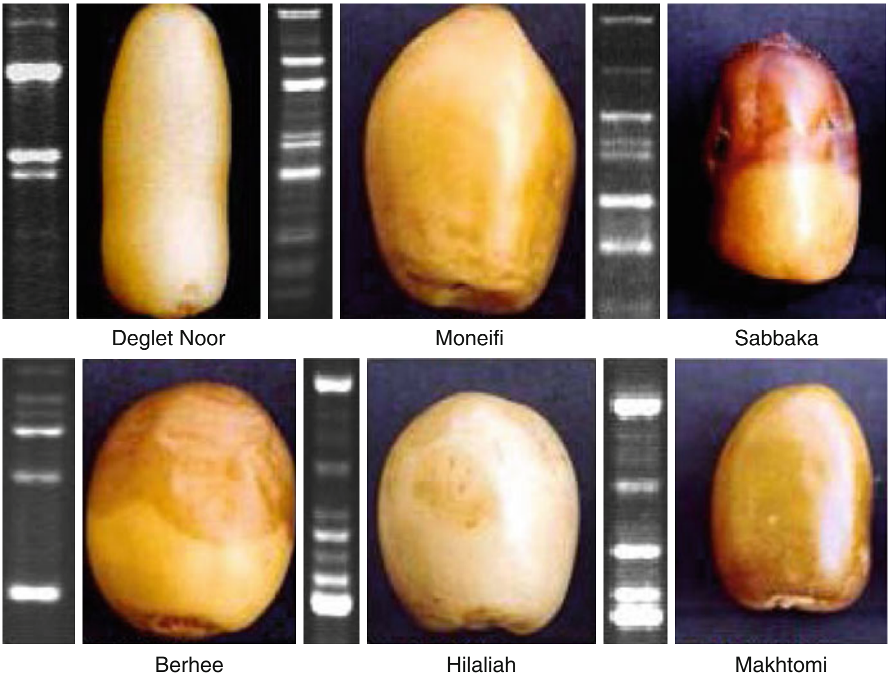

Fig. 3.4 Fruit morphology and DNA profiles of some date palm cultivars produced by A-06 primer (OPERON Tech) (*Source*: Al-Khalifah et al. (2012))

Sequencing and assembling of the date palm chloroplast genome using the pyrosequencing technology was recently achieved by Yang et al. (2010). The chloroplast genome was found to consist of a 158,462 bp double-stranded circular DNA molecule, with a typical quadripartite structure of the large (LSC, 86,198 bp) and small single-copy (SSC, 17,712 bp) regions separated by a pair of inverted repeats (IRs, 27,276 bp). Fang et al. (2012) assembled the mitochondrial genome of date palm, cv. Khalas, by combining data from two next-generation sequence platforms, pyrosequencing (Roche GS FLX) and ligation-based sequencing (Life Technologies SOLiD). They found that the mitochondrial genome of date palm consists of a circular molecule of DNA consisting of 715,001 bp of which 6.5 % (46,770 bp) encodes for 38 proteins, 30 tRNAs, and 3 ribosomal RNAs and the remaining 93.5 % comprises non-coding sequences. Based om the transcriptomic data of the mitochondrial genes expression levels in male flower, root, bud, and female flower, as compared to tissues of seed, fruit, and leaf. In addition, they identified 120 of single nucleotide polymorphisms (SNPs) among cvs. Khalas, Fahal, and Sukkari in which 7 SNPs were found in the coding sequences.

To further understand gene expression during various developmental states of date palm fruit, Yin et al. (2012) conducted a study, using Roche/454 GS FLX instrument, to determine sequencing-based gene profiling of eight stages according to the number of days after pollination. Stages studied included early and late stages of kimri, khalal, and beser (late khalal) as well as rutab and tamar stages. This study identified 7.6 million sequence tags from various fruit developmental stages, excluding tamar stage. Based on gene ontology categorization and pathway analysis, 10 core cell division genes, 18 ripening-related genes, and 7 starch metabolic enzymes were identified. It was concluded that most genes are highly expressed in early stages of development, whereas late stages are critical for expression of fruit ripening and metabolism-associated genes.

The most significant finding related to date palm genomic studies in Saudi Arabia was reported by Al-Mssallem et al. (2013) who successfully sequenced the nuclear genome (cv. Khalas) using pyrosequencing reads. Their results revealed that the gnomic size is 605.4 Mb which covers 90 % of the genome (approx. 671 Mb) and 96 % of its genes (approx. 41,660 genes).

Recent work by Sabir et al. (2014) resulted in sequencing of the mitochondrial and chloroplast genome, using Illumina HiSeq 2000 platform, of nine Saudi cultivars. Based on SNP analysis, this study revealed heteroplasmy and close phylogenetic relationships among cultivars.

3.6 Cultivars Description

3.6.1 Growth Requirements

While different cultivars of dates vary somewhat in their growing seasons, the primary date season in Saudi Arabia runs from March, when the green buds first appear, to the middle of October, when the mature fruits are ready for harvest. Saudi

Fig. 3.5 Saudi Arabia map illustrating 13 geographical regions growing different cultivars of date palm (see Table 3.6) (*Source*: www.google.com)

Arabia is located in southwest Asia between 16 and 32 N lat. and 35–65 E long. Most of the regions are within the dry tropical zone. The climate is characterized by hot, dry, long summers where temperatures in certain areas can reach 50 °C during the months of June to August. Generally the average temperature during summer is around 35 °C; but in the winter season falls during the months of December, January, and February in certain areas to below zero (Ministry of Agriculture 2011). This vast range in temperature between winter and summer affords an optimum climate for date palm cultivars in Saudi Arabia. Each region has its own land race cultivars adapted to its agroecosystem.

3.6.2 Cultivar Distribution and Production

Saudi Arabia has an estimated 24 million date palms spread over the 13 different provinces of the Kingdom (Fig. 3.5). Each province is characterized by certain date palm cultivars. Table 3.6 shows the most famous date cultivars grown in each region of Saudi Arabia (Ministry of Agriculture 2006).

The total area under date palm cultivation reached 155,118 ha in the 2011 growing season. There was a marginal increase in the area under date cultivation attributed to incentives provided by the government to small farmers in terms of subsidies such as fertilizers, short-term loans, pesticides, fixed prices, and market facilities.

Table 3.6 Famous data palm cultivars by region in Saudi Arabia

Region	Famous cultivars
Asir	Sefri, Barni, Shakl, Sari, Bidaira, Ruthana, Khodry, Sullaj, Sagae
Baha	Sefri
Eastern Region	Khalas, Ruzeiz, Shaishi, Shebedi, Khenaizy, Wesaili, Ghur, Hatmi, Tayyar, Hilali, Shahal, Um Raheem, Khesab, Barhi, Bakkeria, Maktoumi
Hail	Hulwa, Kasba, Rikhairni, Majhoola, Hamra, Deglet Hamood, Deglet Shewayish, Miskani, Deglet Moftah, Fankha, Swiria, Hijria, Kdhiria, Dubia, Safran, Balga, Saddrah, Qurain, Khodhreya
Jazan	Sefri, Khodry
Jouf	Hulwa, Bewayda, Kathmaa, Hessaineya
Madinah	Ajwa, Anbara, Safawi, Ruthana, Rabeaa, Shabli, Hulwa, Barni Al Madina, Barni Al Ulaa, Beid, Barni Al Ais, Ruthana Alsharg, Sukkarat Alsharg, Hulya, Barhi, Suwaida Al Mashouk, Mutaban, Wannana, Sabah, Sukkarat Albeid, Al Arous, Looat Musaed, Gawj, Khoshaimi, Jaffari, Khodry, Shaqri, Qatara, Um Khashab, Lubana, Jebaili, Huiwat Beida, Sukkarat Al Madina, Maktoumi
Makkah	Moshwaq, Mutalbia, Alluban, Alhamri, Rabeaa, Khodry, Zafran
Najran	Bayad, Sieqat, Rutab, Barni, Mouakeel, Safraa, Hamraa, Ulooq, Khodair
Northern Boarders	Hulwa, Sukkari, Fankha, Safra, Khalas, Segae, Deglet, Kasba, Um Khashab, Sullaj, Nabtat Saif, Nebtat Sultan, Maktomi
Qassim	Sukkari, Asfar, Barhi, Shaqra, Um Hamam, Sukkaria Ahmar, Khalas, Nabtat Ali, Ruthana, Hulwa, Um Khashab, Nabtat Rasheed, Wannana, Rushodia, Maktoumi, Aseela, Lahrnia, Segae, Nabtat Saif, Um Kabar, Berairni, Hushara, Muneifi Ahmer, Muneifi Asfar, Hulwa Wasit, Khodry, Fankba, Motwah, Quatarah, Salmia
Riyadh	Sullaj, Meneifi, Nabtat Saif, Nabtat Sultan, Khodry, Makfazi, Miskani, Dekhaini, Sari, Sefri, Khalas, Barhi, Segae, Sukkari,Hilali, Rezeiz, Shaishee, Maktomi, Aseela, Ghur, Nabtat Ali, Ruthana, Um Hamam, Haqaqi, Um Raheem, Halawa, Shabal, Sabaka, Rushodia, Um Kbar, Barni, Khesab, Sukkaria Hamra, Khashram, Um Kouz, Degl, Hhawar, Um Aldbur
Tabuk	Hulwa, Barni

Source: Al-Fuhaid et al. (2011)

Total date production reached 991,546 mt in the 2011 growing season. The modest increase in total date fruit production could be due to the slight increase in total area brought under date palm cultivation (Alshuaibi 2011).

Growing citrus with dates, quantity sold, and the price received were significant variables in the econometric analyses of date production cost. Date production and its prices are related to cultivar, cost of production, and intercropping in the orchards, as well as optimal scale of operations, all of which influence the economic efficiency (Alseleem 1998). Osman and Al-Besher (1989) reported that labor was the most important input in date production. Many of the seasonal workers are hired and may not be under the farmer's control. Part-time recruitment necessities throughout the harvest season represent a key challenge for date farmers. The Ministry of Agriculture advises the labor office to issue foreign work visas at a ratio of one laborer per 300 palms.

3.6.3 Description of Date Cultivars

Genotype identification of date palm is commonly based on morphological characters. Female cultivars are recognized by their fruit traits like size, shape, color, and taste, along with vegetative morphology of the tree. Date fruits pass through four distinct stages of maturity, i.e., kimri, beser (also referred to as khalal at early stage), rutab, and tamar (Al-Ghamdi 1996). Young green fruits are termed kimri. The beginning of ripening marks the beser stage, the half-ripened stage is called rutab, and the fully ripened, soft-textured stage is called tamar. Descriptions of Saudi date cultivars are shown in Table 3.4. There is a wide variation among date palm cultivars in terms of fruits maturation in early, mid, or late season. Some cultivars are consumed only in beser or in tamar stage, whereas others are can be consumed in both beser and tamar stages. Fruit appearance for some Saudi cultivars is shown at rutab stage (Fig. 3.6) and at tamar stage (Fig. 3.7).

3.6.4 Nutritional Aspects and Health Benefits of Dates

The contribution of dates to the daily intake of energy and other nutrients in Saudi Arabia is declining. This might be due to the decrease in per capita consumption because of the competition with chocolate and candy. There should be more attention called to the presence of value-added products from dates so that consumers can eat dates in an indirect manner. Applied research culminating in feasibility studies is needed to promote new products fortified with dates, such as extruded baby foods, breakfast cereals, and snacks for youth, to market with the help of food industry in Saudi Arabia. Advertising programs endorsing dates as a healthy nutritional food need to be launched by the government. Certain studies show that the Kingdom occupies the first rank in the world in terms of average per capita consumption of dates per year, which reached 34.8 kg/year in 2003.

Dates are composed of water (10–22 %), invert sugar (62–75 %), protein (2.2–2.7 %), fat (0.4–0.7 %), ash (3.5–4.2 %), total acidity (0.06–0.2 %), and ascorbic acid (30–50 mg/100 g) on dry weight basis (FAO 1992). Total dietary fiber content of dates fluctuates from 6.26 to 8.44 g/100 g, of which 84–94 % is insoluble fiber and 278–301 kcal/100 g as energy expressed on a fresh weight basis, due to the high carbohydrate content (Al-Farsi et al. 2007). Dates are rich in potassium and low in less favorable components like fats, cholesterol, and sodium.

Dates are a good source of antioxidants. Studies on antioxidant activity and phenolic content of various date fruits demonstrated a linear relationship between antioxidant activity and the total phenolic content of date fruit extract (Alliath and Abdalla 2005). Fruits of different cultivars have different total phenolics content and antioxidant activity (Al-Farsi et al. 2007; Al-Turki et al. 2010). The antioxidant properties of date fruits vary depending on their phenolic components and vitamins C and E, carotenoids, and flavonoids (Al-Farsi et al. 2007; Mansouri

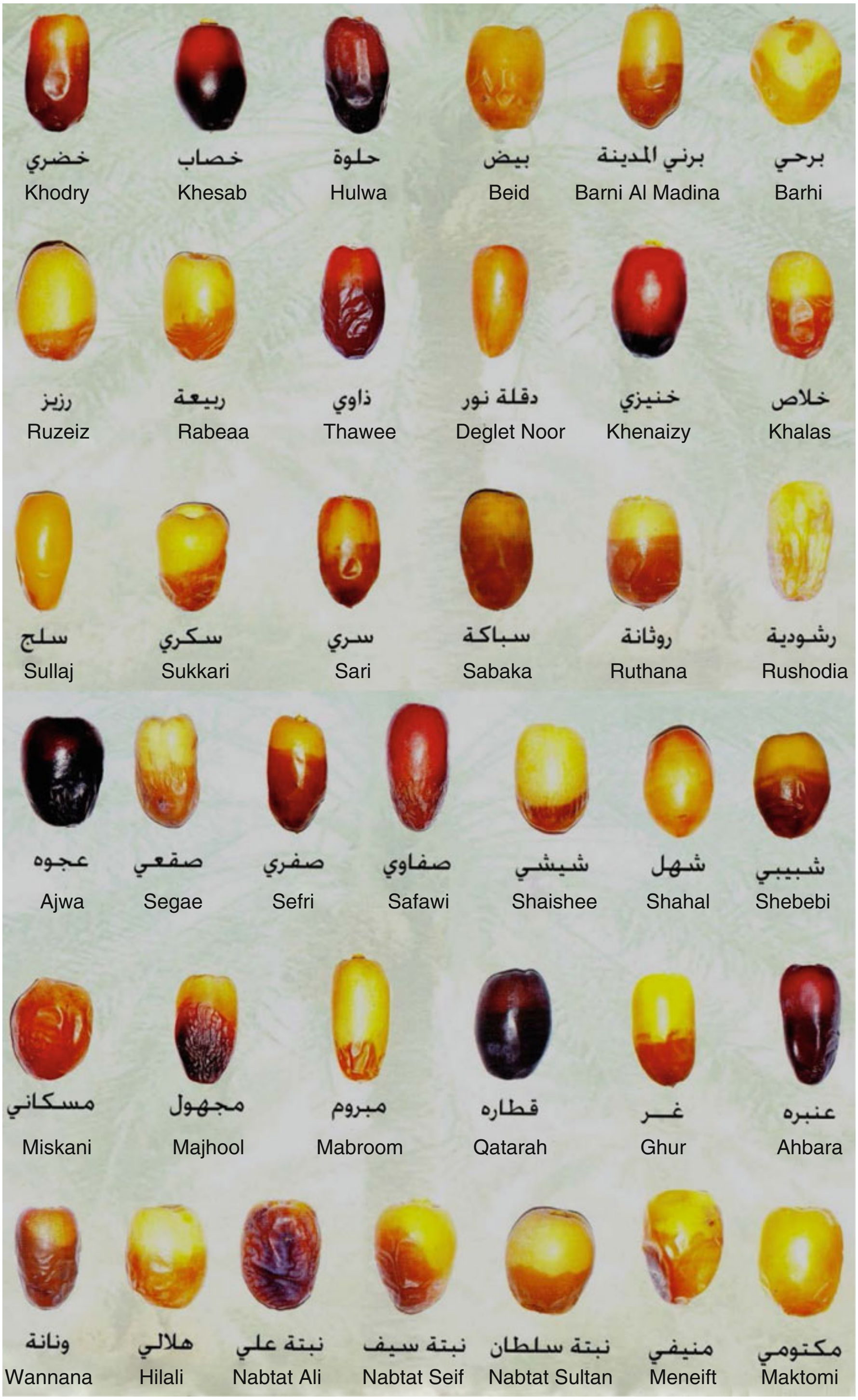

Fig. 3.6 Morphology of some Saudi date cultivars at rutab stage (*Source*: Al-Fuhaid et al. (2011))

Fig. 3.7 Morphology of some Saudi date cultivars at tamar stage (*Source*: Al-Khateeb and Dinar (2002))

et al. 2005). All date cultivars are a good source of natural antioxidants and could potentially be considered as a functional food or functional food ingredient (Al-Farsi et al. 2007).

3.7 Dates Production and Marketing

There is a vast diversity in date palm cultivars in Saudi Arabia; the most notable are Khalas, Sukkari, Ajwa, Anbara, Ruthana, Segae, Barhi, and Ruzeiz. Although the cultivation of date palms has developed considerably and great attention has been given to date production in Saudi Arabia, nonetheless, the level of productivity is low compared with other producing countries (Al-Obaid 1996). The main causes for this decrease in date productivity are the increase in the number of the overage trees, the existence of many low-quality and undesirable cultivars, the lack of sufficient offshoots to establish new orchards or renew old ones, and the increase in cost of offshoots of good-quality cultivars (Al-Sakran and Muneer 2006; Bashah 1999). In date production and marketing, primary consideration should be given to quality. Consumer perception of date quality is mainly based on value attributes, which include date cultivar, taste, texture, size, color, crust cohesion, freshness, no skin fracture, and free of insects. Recently, there are increasing consumer concerns about date quality in the Saudi market. Accordingly, product differentiation strategies are increasingly used in date markets to attract the interest of consumers for various date characteristics. Differentiation is achieved through their distinct attributes and communicated through labeling (Aleid et al. 2014; Al-Kahtani et al. 2011).

Competitiveness of Saudi dates requires an evaluation of consumers' desired attributes. The recognized value may originate from product characteristics as well as from conditions of production. These values can be measured by examining consumer behavior in existing markets or by consumer interviews to assess perceptions of price and product quality (Carlsson et al. 2005).

3.7.1 Practical Approaches

Most dates are harvested at the fully ripe tamar stage when the fruits exhibit a deeper color, the sugar content is high, and moisture and tannin contents are low. Typical production in the primary cultivation regions does not exceed 20–40 kg/palm per year, although production inputs (i.e., fertilizers, pesticides) are low and generally the palms are too closely spaced. However, in well-organized date plantations, yields may reach over 100 kg/palm per year under favorable growth conditions. At 30 years of age, date palms reach their high-yield period. In general, an average well-managed palm can produce about 60–70 kg of fresh dates per year (Organic 2002). The decline in date yields in Saudi Arabia is attributed to inadequate cultural practices coupled with outbreaks of pests and diseases. Pollination and fruit thinning are critical processes in date palm production. Pollen origin in dates affects fruit quality, yield, and annual productivity. Different pollen sources affect fruit size, flesh and seed development, and time to fruit maturation (Al-Ghamdi et al. 1988).

3.7.2 Optimization of Yield

Date palms require regular fertilization for high stable yield (Al-Rawi 1998). El-Shurafa (1984) reported that date palm soils lose considerable amounts of macro- and micronutrient elements through leaf pruning and fruit harvest; therefore, fertilization is necessary. Al-Dekaili and Al-Dejaili (1989) affirmed the need for fertilizers, especially nitrogen to obtain high numbers of leaves with long green pinnae and high yield. Moreover, appropriate fruit thinning gives the remaining fruits a better chance to develop to a larger size and a better quality by reducing compaction among fruits on the bunch. It also helps to promote good flowering in the following year (Marzouk et al. 2007). Such results could be attained either by reducing the number or fruits per bunch or by reducing the number of bunches per palm. Al-Obeed et al. (2005) found that the 15 % shortening of strands at pollination time led to a reasonable yield with fruit quality. Soliman and Harhash (2012) reported that Sukkari cv. was thinned by removing 15 and 30 % of the total number of strands from the center of each bunch, while the control strands were used as reference. Although thinning caused significant decrease in yield (based on both bunch and palm weight), significant improvement in fruit quality was observed. Thinning 30 % at 4 weeks after pollination will lead to optimum fruit quality.

3.7.3 Harvest Mechanization

Harvesting is labor intensive because dates are handpicked. On large date plantations, platforms may be used to raise the workers to harvest fruit. But in most cases, workers must climb the palms to reach and pick the fruit (Organic 2002). There are two methods of date palm cultural operations, traditional and mechanical; the latter is still not a common practice in Saudi Arabia. The most difficult part of the traditional date palm cultural operations involves workers ascending to the crown of the tree; if the trees are very tall, the worker risks falling and injury or even death. Using the tree trunk leaf bases to climb the tree in Saudi Arabia is typical of cultural operations (Nixon 1969). Al-Kiady (2000) reported that skilled specialized laborers were becoming rare and more expensive causing a serious problem in the date production industry.

Mechanized cultivation methods can improve date quality and is essential to optimize this industry (Albozahar 2003). Al-Suhaibani et al. (1988) made a date service machine in Saudi Arabia which was designed at Silsoe College, UK. They carried out a survey on 19 orchards in Saudi Arabia and measured certain physical properties such as tree spacing, height, trunk circumference, bunch spacing, and ground profile to consider in their design. Shamsi (1990) designed a sprocket-type climbing machine to harvest dates, and he later designed and developed a tree-climbing date harvesting test rig at the same college (Shamsi 1998). This machine climbs up the tree trunk with a worker to reach the fruit bunches. Nicklin (1993) designed a tree-climbing rig to lift a man up into the palm.

Fadel (2005) developed a tractor-mounted machine for date palm service based on physical properties. The machine had the capability to lift a worker and required tools to the crown zone as high as 4.5 m. Mazloumzadeh and Shamsi (2007) designed and developed a light tractor-mounted date palm service machine that could reach to a maximum height of 10 m with payload up to 130 kg.

Attempts to mechanically harvest date fruits have not been successful due to inadequate efficiency and the availability of a low cost labor in Saudi Arabia. Date fruits have to be firm enough and resistant to mechanical damage. The developed mechanical harvesting system needs to compensate for the differences in soil compactness taking into account the characteristics of the date palm tree. Moreover, the machine must be manufactured at a commercial scale and made available to farmers at a reasonable cost. Similarly, mechanization of fruit sorting and sizing systems also requires further development.

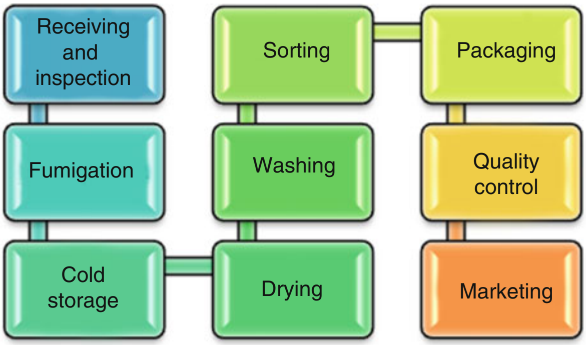

Fig. 3.8 A flowchart of common processes for dates processing

3.7.4 Postharvest Operations

Hygienically processed and properly packed dates harvested in Saudi Arabia have substantial potential in both domestic and international markets. Processing involves fumigating, washing, sorting, grading, glazing, weighing, and packaging (Sindh 2010). A flowchart of date processing steps in Saudi factories is shown in Fig. 3.8.

3.7.4.1 Fumigation

Fumigation is the first step after harvesting to protect fruits from infestation. The date industry suffers substantial losses from the ravages of insects. Infestations of dates with moths (almond moths, meal moths), fig moth *Ephestia cautella*, Indian meal moth *Plodia interpunctella*, beetles (sap beetles, saw-toothed grain beetles, flour beetles), rats, mice, and ants result in contamination and loss of volume (Glasner et al. 2002). Methyl bromide is highly effective for controlling insects in stored products. However, methyl bromide emissions have been found to have deleterious effects on the atmosphere and present a hazard to human health. Therefore, in accordance with the Montreal Protocol, its production and use will be eliminated by the end of 2015 worldwide (Council 1985). Alternatives to methyl bromide include the following: (a) phosphine, the principal alternative; (b) a controlled atmosphere high in carbon dioxide; and (c) physical control methods such as heating or cooling regimes, active oxygen (ozone or hydrogen peroxide), and irradiation. However, some of these methods are very costly. In organic date palm production, carbon dioxide is used instead of methyl bromide (Glasner et al. 2002). Heat treatment is a common alternative for date disinfestation replacing fumigation (Belarbi et al. 2001).

3.7.4.2 Cold Storage

Dates in Saudi Arabia may need to be stored for long periods, as much as 10–12 months. Temperature is the most single important environmental factor affecting shelf life and quality of fresh dates. FAO has developed several approaches to prolonging date storage using refrigeration or freezing. The process is mainly based on slowing down fruit maturation. Most dates are harvested at full maturity (tamar stage) when the color and sugar content characteristic of the cultivar has fully developed. Also, tamar stage fruit has the longest potential storage life (many months) compared to rutab or khalal (several days to weeks maximum). Fresh dates harvested at tamar stage and stored at −18 °C provide for maximum economical extension of shelf life and preserve edible product quality (FAO 2008).

3.7.4.3 Sorting

Sorting of dates is done manually. A chain conveyor for sorting dates is usually used. During this step, workers sort and remove dates with any indication of infestation as well as other particles and damaged dates (Organic 2002).

3.7.4.4 Washing

Date processors generally rely on wash-water sanitizers to reduce microbial counts to maintain quality and extend shelf life (Gil et al. 2009). Dates are typically washed in a circular washer with sprinklers and dried using a hot air blower system in a hygienic environment (Sindh 2010). Washing with sanitizers is important to remove dirt and debris and for water disinfection to avoid cross-contamination between clean and contaminated products. Most sanitizing solutions achieve higher microbial reductions immediately after washing compared to water washing; however, after storage, epiphytic microorganisms grow rapidly, reaching similar levels. Chlorine-based sanitizers are among the most effective and efficient sanitizers when appropriate doses are used (Gil et al. 2009).

3.7.4.5 Drying

Air-drying is designed to result in fruit moisture content of 20 % or below to prevent growth of molds and yeasts (Organic 2002). Temperatures of 55–65 °C for drying of soft dates are generally used (Barreveld 1993). The hot air blast removes excess water and the dates are then loose- or press-packed, sealed, wrapped, and placed in cold storage (Mikki et al. 1989).

3.7.4.6 Packaging

Fancy dates are usually packaged at the processing plants in Saudi Arabia. This involves vacuum packaging of compressed or non-compressed whole dates in flexible sealed plastic coverings (Alhamdan and Hassan 1999) or polyethylene-polyamide (PE-PA) bags. Vacuum packaging is a useful technique for reducing darkening of dates during lengthy storage Mohsen et al. (2003). Mutlak and Mann (1984) reported that both enzymatic and nonenzymatic browning occurred in dates, increasing with higher moisture content and higher temperatures, and inhibited at low oxygen potentials. However, for packing loose dates, cleaned and graded dates are weighed and packaged in cardboard boxes. Generally, the weight of these packages may be 1–20 kg, depending on domestic or international customer requirements.

3.7.5 Survey of Commercial Producers and Major Farms

Date palms in Saudi Arabia are grown primarily in groves, such as found in Riyadh, Qatif, Qassim, Madinah, Bishah, and Al-Hassa, the latter the world's largest oasis, in the Eastern Province. Al-Hassa's famous springs and the extensive irrigation network they feed make it an ideal area for date growing. As far back as 4000 B.C., there is evidence of date cultivation in what is now the Eastern Province of Saudi Arabia (http://www.saudiembassy.net). The government supports establishing modern and well-managed date farms, enhancing date production efficiency, and optimizing use of natural resources such as land and water. Table 3.7 highlights business domains and marketing practices for some active modern date palm farms in Saudi Arabia.

3.7.6 Current Export and Import

In view of the increasing cultivation and surplus date production in the Kingdom, there is an emphasis on exports (Al-Abbad et al. 2011). Saudi Arabia exports dates to France, Germany, and India; Tunisia and Algeria are the potential competitors (Al-Shreed et al. 2012). Saudi Arabia exports only 48.8 mt of dates annually valued at a unit price of USD 0.83 per kg. In general, the potential strengths of exporting Saudi dates into international market can be summarized in the following: (a) existence of modern date palm plantations that can control the quality of dates at the upstream and traceability, (b) existence of cultivars with low demand in the Saudi market that meet international market requirements, (c) possibility to upgrade the exporting packing house to be more competitive with customer needs, (d) capacity of companies to launch new products (value addition) on the international market (e.g., frozen dates and pastries from dates), and (e) spiritual benefits of Saudi dates within the Muslim populations worldwide (Al-Shreed et al. 2012).

There are several technical aspects to be considered for exported dates. For example, for exporting packed Saudi dates to the USA, exporters should consider the following: (a) types of dates to be exported, (b) specification (sugar and moisture content) as well as physical properties, (c) date packaging (size and weight of the carton), (d) number of cartons and their weight to fill a 6 m long container of approximately 8.6 m^3, (e) requirements and specifications for exporting dates from Saudi Arabia to USA, and (f) export mechanism. Some date cultivars have export potential, due to their physical and chemical properties, as well as their abundant availability, including cvs. Sukkari, Khodry, Sefri, Ruzeiz, and Khalas.

Table 3.7 Some major date palm farms in Saudi Arabia

Farm	Business identity	Marketing practices
Al-Aseel Dates	250,000 palms with annual production of 3,000 mt. Has the largest research and development center in private sector to promote dates framing according to international standards	Retail marketing and distribution outlets. Existence in international markets
Al-Rajhi Endowments (Awqaf)	Al-Baten (200,000 palms) and the Darmaa (50,000 palms). Guinness record as largest palm plantation worldwide (2005). ECCOCERT certificated organic (2007). Farm returns are donated to charities	Part of production sold while fruits on the heads of palms. Another part is marketed in sorting and packaging stores. The rest is marketed through direct sales in local date markets. Fancy organic dates are marketed in international markets
Kingdom Dates	Multifarms in various places in Saudi Arabia cultivating more than 300 varieties. Supplying market needs through two integrated and equipped factories, with washing, processing, and packing devises for dates in Qassim	Kingdom Dates is a wholesaler, retailer, and exporter maintaining national and international standards having more than 100 branches
Al-Butain Agricultural Cooperative Association	Nonprofit organization in Qassim with a cold storage complex, financed by Saudi Agricultural Development Fund, with a capacity of 10,000 mt. Equipped with lines to sort, refine, fumigate (ultralow oxygen system), and pack	International marketing. Care of producer and manufacturer of dates in Qassim region
Dohayan Dates	Farms are based in Qassim. Provides a large selection of dates from all regions of Saudi Arabia	Supplies market's needs and delivers a variety of sweets that are derived from dates as raw material
Bin Zaid Dates	Farms and processing plant is located in Al-Hassa Oasis, an area classified as the most productive of high-quality dates in the northeast of Saudi Arabia	Supplying local and international markets with fresh fancy dates, dates stuffed with almonds and cashew nuts, as well as date paste and date syrup
Zadna Trading Company	Providing in the vicinity of consumers a good-quality of dates around the year with reasonable packed quantity	Supplying local and international markets with fresh dates, paste, and syrup. Ma'moul (shortbread pastries filled with date paste covered with chocolate). Dates stuffed with nut (almonds, cashew nuts, and walnuts)
Al-Mohamadia Dates	Farm and dates processing plant located in Kharj. The farm with an area of 18 km^2. HACCP certified 2004	Supplying local and international markets with a variety of date products. Considered one of the major producers of date paste
Yogi and Yousef Dates	Dates produced and packaged	Distribute dates to end retail, such as luxury food stores, organic shops, and boutique hotels in European and American markets

Source: Saudi Dates (2013)

3.8 Processing and Novel Products

3.8.1 Industrial Processing Activities

The date industry in Saudi Arabia is highly supported by government industrial programs. The support for well-established date processing facilities is the initiative of the Agricultural Development Fund through interest-free long-term loans which have advanced the spread of date processing facilities. The most important cultivars used for manufacturing processing in Saudi Arabia are Khalas (16 %), Ruzeiz (21 %), Khodry (15 %), Sukkari (10 %), and others (38 %). About 90 % of manufacturing activities in Saudi Arabia focus on the packaging process, instead of producing value-added manufactured date products. About 56 % of date processing factories produce value-added date products such as paste, jam, syrup, and vinegar. There are many sources of dates as raw material in Saudi Arabia. The best source for quality dates is at wholesale directly from farmers or through intermediate traders. Average and low-quality dates usually go to wholesale markets. About 70 % of dates delivered to processing factories comes from farmers, 25 % from traders, and 5 % from wholesale markets (Aleid 2013a, b; Elsabea and Aleid 2012). Two important products, date paste and date syrup, currently represent the date industry in Saudi Arabia.

3.8.1.1 Date Paste

Date paste typically is used as a filling in pastries and biscuits in the baking industry in Saudi Arabia, as well as a sugar substitute in cereals, puddings, breads, cakes, cookies, ice cream, and confectionaries. Modern industrial processing lines were installed within some large date processing facilities in Saudi Arabia. In date paste production, dates are steamed, seeded, macerated, and converted to a semisolid paste (Alhamdan and Hassan 1999). The extruded date paste is usually packed in high- or low-density polyethylene or polypropylene packaging. Yousif et al. (1991a, b) reported that date paste storage involves many challenges, including hardening, microbial spoilage, and darkening in color. Most date sugars are invert sugars, which increase the softness of bread and cookies (Mikki et al. 1983). Aleid (2009) found that the incorporation of date paste (Khalas cv.) into an Arabic bread as a source of 20 % of the sugar in the recipe was recommended.

3.8.1.2 Ma’moul

Ma’moul is a Middle Eastern pastry usually filled with dates and walnuts. Recipes for ma’moul are geographical and cultural dependent (Fig. 3.9). The two major components of ma’moul are dough and date filling. Major ingredients of the dough are semolina, flour, butter, sugar, yeast, and water; often, rosewater is substituted for

Fig. 3.9 Ma'moul filled with date paste (Prepared by Maryam M. Aleid, photographed by Nasreen N. Alsarra)

part of the water. The filling usually is made of date paste, fine pieces of walnuts, and butter. A specific amount of the filling usually is placed inside a piece of dough and then shaped using a specific type of wooden molding tool. The dough is then baked and cooled and may be dusted with fine sugar.

3.8.1.3 Date Syrup

Consumption of date syrup is very popular in Saudi Arabia, as a sweetener for a number of traditional food dishes. Low-quality dates can be used as raw material for producing date syrup, which is a good source of glucose and fructose (Aleid 2012). Date syrup is rich in sodium, potassium, calcium, magnesium, and iron and has a low sodium-to-potassium ratio (1:8.3). This may be of dietetic importance, particularly for those with restricted sodium intake (Aleid et al. 1999). Moisture content strongly impacts storage stability of syrups, since it directly affects the likelihood of undesirable fermentation (Aleid et al. 2007). Date syrup also has antioxidant activity related to total phenolic content.

Several date processing premises in Saudi Arabia have an automated date syrup production line on a commercial scale. In date syrup extraction, the dates are placed in a vessel and the required amount of water is added. The temperature of the mixture is adjusted and it is mixed for a given time period (El-Shaarawy et al. 1989). The mixture of the sugar solution and date fibers is filtered to separate the solid materials and obtain a clear solution. The dilute solution obtained has a Brix of 12–15. This solution can be heated under vacuum and concentrated to a Brix of 70, which is appropriate for long shelf life. Evaporation is normally carried out at 55–60 °C to prevent burning of the sugars. From 1 kg of dates, approximately 600 g of date syrup with a Brix of 70 can be obtained. Date syrup can also be produced as an incidental by-product when bagged humid dates are heaped for several months and syrup oozes out by the force of their own weight (FAO 1996).

Aleid et al. (2007) utilized second-grade dates of the Ruzeiz cv. to extract syrup through high hydraulic pressure at room temperature. The sugar content of the syrup obtained was 70–85 % dry weight; most of the sugars were reduced sugars. This process gave a yield of 40–50 %. The color of the syrup was light brown compared with syrup from a heat extraction experiment (85–95 °C) which had a dark color and a caramelized flavor due to a high extraction temperature. However, the extraction time for the heat extraction process was relatively short, with a higher yield than the cold extraction process (Aleid et al. 2007). Efficient clarification of date syrup has been achieved using an ultrafiltration membrane with a molecular weight of 20,000 to obtain clear syrup that can be used as a flavoring agent for processed foods. Aleid (1998) reported on the incorporation of date syrup into bread dough recipes as a sugar substitute. Breads with 6 and 9 % date syrup, at 85 and 95 % extraction, exhibited a high total bread score compared with no sugar or 4 % sucrose treatments. Replacement of sugar with date syrup up to 6 % was strongly recommended.

3.8.2 Commercial Dates Processers and Packaging Plants

Date processing factories are licensed in six areas of Saudi Arabia, namely, Riyadh, Madinah, Qassim, Eastern region, Mecca, and Asir. This industry is characterized by geographical concentration. Labor and invested capitals are the most important factors determining the economic feasibility of date factories (Al-Tamimi 2005). In general, date processing factories depend mainly on packing activity and packing for others (farmers and private citizens) for a charge of about USD 0.5 per kg. Table 3.8 represents some major date packaging factories and their activities. One of the most important dates processing factories is the government factory in Al-Hassa. The government established this factory with annual capacity of 25,000 mt to support farmers and to ensure a minimum limit for date prices. It packs dates and donates them to international food programs (Elsabea and Aleid 2012; Mikki 1998).

3.8.3 Baker's Yeast from Dates

Baker's yeast could be produced from dates in Saudi Arabia and such an undertaking could be highly feasible for several reasons. There is a daily need for baker's yeast but no commercial domestic production as yet. Such a value-added product will benefit the date sector in general and thus reduce price volatility. Baker's yeast production is a clean process not harmful to the environment. All fresh yeast consumed in Saudi Arabia is imported. Local dates of low quality available at low

Table 3.8 Some major date processing plants in Saudi Arabia

Region	Processing plant name	Processing activity
Al-Hassa	Al-Hassa Company for Food Industry Date Processing Plant	Packing, paste, syrup, sweets
	Al-Jawharia Dates Factory	Packing, paste, syrup
	Al-Jazirah Dates and Food Factory	Packing
Riyadh	Amal Al-Khair Dates Packing and Packaging Factory	Packing, syrup
	Bateel Sweets and Chocolates Factory	Packing, syrup
	Nakhail Al-Watan Dates Factory	Packing
Kharj	Al-Babtain Factory for Dates Filling and Packing	Packing
	Al-Faisaliah Dates Factory	Packing
	Al-Mohamadia Dates Company	Packing, paste, syrup
	Al-Rajhia Dates Factory	Packing
	Al-Yamamah Dates Packing Factory	Packing
	Kharj Dates Factory	Packing
	Madaen Star Dates Factory	Packing
Qassim	Al-Salehaiah Dates Factory	Packing, syrup, sweets
	Kingdom Dates Factory	Packing, syrup, sweets
	Nadheed Dates Factory	Packing, paste, syrup
	Qassim Agricultural Company Dates Packaging Factory	Packing, syrup
Madinah	Al-Ahli Ideal Dates Packing Factory	Packing
	Al-Ansar Factory for Dates Packing and Wrapping	Packing
	Barakat Al-Madinah Dates and Sweets Factory	Packing
	Madinah Al-Munawarah Dates Company	Packing, stuffed, chocolate coat
	Quba Dates Factory	Packing
	Taiba Dates Packing Factory	Packing

Source: Saudi Industrial Development Fund (2010)

prices are a potential raw material for baker's yeast production. Research projects for the production of baker's yeast are important despite the high cost of the equipment required. Most countries in the world which produce bread yeast use molasses as a raw material.

The use of dates has several advantages over molasses, the traditional raw material. These advantages include saving the cost of some minerals and vitamins not existing in molasses but are naturally present in dates and giving the dates a comparative advantage for the production of baker's yeast. The search for yeasts prefix of high quality is the decisive element in the production process. The production of baker's yeast will increase the economic returns from dates and absorb part of the surplus dates which helps to maintain the balance between production and consumption, which in turn helps to stabilize prices for both producers and consumers (Aleid 2011).

Extensive research on baker's yeast production from dates has been carried out at King Faisal University in Saudi Arabia, leading to awarding of a patent on the process registered at the US Patent Office (US Patent No. 8,323,717B2 dated Dec 4, 2012). This patent has been one of the few pioneering works focusing on development of a fermentation process suitable for the production of baker's yeast from date substrates. The know-how obtained from this study could be applied to commercial production. All calculated financial and economic criteria indicate the feasibility of production of dry yeast, providing that this could be a productive activity as an extension line to an existing date processing factory and not as a stand-alone project. Almost all of the baker's yeast is produced from molasses using *Saccharomyces cerevisiae* (Barnett et al. 2000). The sugars in dates are mainly glucose and fructose, which are easily assimilated by most microorganisms (Sawaya 1986). Substrates from pure date syrup and pure molasses for the propagation of the baker's yeast strain *S. cerevisiae* were examined (Aleid 2009). They found that the overall biomass yield from pure date syrup substrate was significantly lower than that from pure molasses. Despite the fact that lower biomass yield using date syrup was obtained compared to molasses as a substrate, the use of dates as a substrate for baker's yeast production in Saudi Arabia as an alternative to the traditional substrate of molasses imported from external markets will help in finding new profitable ways for the utilization of this important, locally produced food crop and to reduce dependency on imported foods.

3.8.4 Bioenergy

The Saudi Arabian Basic Industries Corporation (SABIC) exclusively exports synthetic ethanol produced from petrochemical feedstocks. The product is exported in crude form, mostly to the USA and South Korea. In Saudi Arabia, ethanol is mainly used for the production of perfumes, cosmetics, medicines, cleaners, paints, and vinegar (Capital 2004). Ethanol derived from biomass has the potential to be a substitute of fossil fuel which is renewable, nontoxic, biodegradable, and more eco-friendly. The three major classes of feedstocks for ethanol production are sugars, starches, and lignocelluloses (Gupta and Kushwaha 2011). Raw biological materials that can be used as feedstock for ethanol production are numerous. The Date Palm Research Center of Excellence, King Faisal University, is currently studying date fruits, by-products, and tree wastes as raw materials for the production of ethanol.

3.9 Conclusions and Recommendations

Agricultural production in Saudi Arabia depends mainly on irrigation from groundwater and, to a lesser extent, on rainfall during the winter season (November to February). Date palm plantations are constrained by severe biotic and abiotic stresses including heat and salinity. Date crops in the Saudi Arabia suffer from many difficulties including high postharvest losses due to fermentation, insect infestation, birds, and mechanical damage. The dates produced should comply with international regulations and standards necessary for export (Kader and Hussein 2009). Several problems and constraints might affect the future of date palm industry in Saudi Arabia, including (a) low-quality cultivars; (b) poor farm management; (c) losses from pests and diseases and inadequate IPM control; (d) deficiencies in harvesting, processing, and marketing; (e) shortage of qualified national trained staff and laborers; (f) insufficient research and development activities.

High marketing margins and low farmer share indicate local marketing inefficiency for dates in Saudi Arabia. Moreover, a great fluctuation in prices is considered the most serious local marketing problem facing dates farmers in Saudi Arabia. Minimizing the usage of nonrenewable underground water through greater efficiencies, as well as restricting the production of low-quality date cultivars, is highly recommended. Also of importance is the conservation of genetic diversity. As a leading date-producing country with plentiful resources, Saudi Arabian scientists and concerned officials ought to consider developing a global strategy to conserve date palm germplasm utilizing all conservation technologies including in vitro cryopreservation approaches.

There are numerous research studies in Saudi Arabia aimed at finding new ways for economic utilization of high-quality dates and date surpluses, by-products, and wastes. Liquid sugar, date syrup, carbonated and non-carbonated drinks based on ultra-filtered date syrup, single-cell protein, baker's yeast, industrial alcohol, date paste, and date powder are some of the potential value-added products. Successful industrial producer and processor optimization and standardization for such value-added products will contribute to expanding the date industry. Conducting pre-feasible studies which include market structure and financial evaluation of industrial-scale production for such products from dates is highly recommended.

Governmental policy should focus on programs that limit future expansion of date palm plantations and economize on the use of nonrenewable groundwater, as well as limit the production of high-quality commercially feasible date palm cultivars. Improvement in tree yield and production quality as well as alignment of production capacity with demand is highly recommended. Launching a program to stimulate national and international demands for Saudi dates is highly recommended.

Moreover, a long-term comprehensive plan for applied research and development activities needs to be established. The main rationale for such plan is to accommodate the date palm sector's research, training, and outreach needs according to stakeholders' priorities and to provide measures for monitoring progress, evaluating outcomes, and assessing impacts. Furthermore, the operational activities for the plan should focus on the following: (a) attracting the most qualified researchers and staff; (b) generating funds; (c) improving operations and utilization of resources; (d) creating effective outreach programs to the date farming community, including the date palm industry and the society at large; (e) developing integrated research programs of high impact nationally and internationally; (f) enhancing multidisciplinary date palm research; and (g) establishing collaboration among leading research centers nationally and internationally.

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