Chapter 20
Date Palm Cultivation in the Changing Scenario of Indian Arid Zones: Challenges and Prospects

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Abstract The arid zone of Rajasthan or Great Indian Thar Desert, popularly known as Thar, is a vast tract of dry land of about 2.34 million square kilometres. The whole tract is distinguished by low and erratic rainfall, low humidity, high solar radiation, strong dust-raising winds, scant vegetation and a dry, sand-dune-dominated landscape. During the past five decades, strenuous efforts have been made towards control of desertification, ecological regeneration and restoration of the Thar desert in order to reclaim the productivity of this vast unproductive desert land. For this purpose, a 649-km-long man-made canal was constructed to bring Himalayan water into the water-starved desert. Although the Thar desert becomes lush green with the slightest precipitation, its natural sustainable regeneration has been very slow due to intense biotic (overgrazing, extraction of fodder and fuel wood) and abiotic pressures. Over-exploitation of fodder and fuel wood, the two basic necessities of life for desert people, leads to destruction of desert ecosystems and enhances desertification. Perhaps the over-exploitation of land, water and biological resources since the earliest times have made the Rajasthan desert a 'man-maintained' if not 'man-made' landscape. Introduction of fast-growing exotic species of trees and grasses from isoclimatic regions of the world in attempts to stabilise shifting sand dunes, creating 'microclimates' through shelterbelt plantations, and 'fencing and enclosures' for regeneration of indigenous species have proved highly successful in the control of desertification. Various practices of date palm cultivation for the control of desertification in arid zones have been elaborated over the last three decades. The climatic features existing in the Indian arid zone are compatible with the requirements of successful date palm plant production. Weather data and date palm growth parameters go hand-in-hand from planting to production level. Introduction of conventional offshoot and hi-tech methods of tissue culture to supply superior planting material have been described. Planners,

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researchers and modern farmers are making serious efforts at converting this vast mass of arid land into profitable green land, thereby changing the economic status of the region.

20.1 Introduction

20.1.1 Indian Arid Zone

The Great Indian Desert, known as the Thar Desert, in Western Rajasthan is the biggest desert in India. It encompasses about 70% (208,110 km^2) of the total landmass of Rajasthan – hence the "Desert State of India". Most of the Thar Desert is spread across the Western part of Rajasthan in India and South-Eastern Pakistan, stretching between 22° 30″ to 32° 05″ N and from 68° 05″ to 75° 45″E, covering Western Rajasthan (19.6 million ha), Gujarat (6.22 million ha) and South Western parts of Haryana and Punjab (2.75 million ha; Kar 1996; Faroda and Harsh 1999), and embracing the districts of Jaisalmer, Barmer, Bikaner and Jodhpur. Thus this huge stretch of barren land extends into the Southern part of Haryana, Punjab and Northern Gujarat and Sind province of Pakistan. The desert in Rajasthan is bounded by the Sutlej River in the northwest, the Aravali mountains in the east, the salty marshland of the Rann of Kachchh in the South and the Indus River in the west (Anonymous 1965). The Aravali hills also demarcate the state of Rajasthan into two distinct climatic regions i.e. semi-arid to the east of the Aravalies, and an arid region lying to the west.

The Thar desert has sand dunes of various types, sizes and structures; some are tall (70–120 m) and run in chains several kilometers in length. The desert is characterised by these massive rolling sand dunes, excessive heat (50°C in May and June, with surface sand temperatures rising to 70°C; Krishnan and Rao 1978). Dust storms and dust-raising winds often blow with high velocities of 140–150 km h^{-1}, and are common in May and June. From March onwards, when the surface is dry and temperatures soar, the summer winds associated with the South-West monsoon reach a maximum speed of 20 km h^{-1}. During the dry period in May is the ideal time for winds to carry or move sands from place to place. The moving sand during this period can be termed "dynamic sand" (Kar et al. 1994; Kar 1996). The arrival of the monsoon in July puts an end to this activity. Mirage (naturally occurring optical phenomenon) is also a distinctive feature of the desert areas, falsely suggesting the presence of large areas of water adjacent to the arid land.

The annual average rainfall is less than 10 inches (250 mm); 90% of this rain occurs during the Monsoon or "rainy season", falling between July and September. Water is scarce, but is found at a depth of 100–200 feet (∼30–60 m) below ground. Arid zones are characterised by low and highly variable precipitation compared to high evaporative demand. Therefore, moisture stress is the characterising feature of arid zones (Krishnan 1974).

20.1.2 Vegetation

The vegetation cover in arid regions of India falls under the category of "Thorn Forest Type" (xerophytic nature), i.e. extremely slow growing and thinly populated. The population of many plant species in the Indian arid zone has declined to an alarming level due to environmental changes and over-exploitation of natural resources in the past (Raj Bhansali and Jindal 2000). The desert climatic, soil and water conditions threaten the establishment and propagation of many economically important plants including fruit and forest trees. Furthermore, pests and diseases also limit growth and cultivation under the harsh climatic conditions of the desert. Natural regeneration in some desert plant species is extremely poor. Moreover, methods for vegetative propagation of these woody trees have limited success for rapid multiplication of selected plant species (Abrol and Venkateswarlu 1995; Harsh and Tewari 2007).

20.1.3 Climatic Features

The arid zone is characterised by sub-tropical climatic conditions. Great uncertainty exists in the prediction of the response of arid ecosystems to elevated CO_2 and global warming. The complexities of changes in precipitation, vegetation-climate feedback, and the direct physiological effects of CO_2 on vegetation present particular challenges for climate change modelling of arid regions, which are expected to undergo significant changes under a scenario of climate warming (Lioubimtseva 2004). Rainfall in the arid zone is scant, varying from <100 to >400 mm with an average of 250 mm rainfall per annum (Table 20.1). The usual dates of the arrival and withdrawal of monsoon are 1 July and 15 September, respectively. The contribution of this seasonal rainfall to annual rainfall is very high (91–96%) over the South and central parts of Western Rajasthan and Gujarat (Rao 2009). Another interesting feature of the rainfall is the high coefficient of variability in annual rainfall, which often exceeds 50% in the North-Western Indian arid zone and can be higher than 70% in the extreme Western regions of arid Rajasthan, where annual rainfall is very low (Ramakrishna and Rao 1992; Rao 2009).

Table 20.1 Climatological features of potential date palm growing areas of the Indian arid zone. *PE* Potential evapotranspiration, *HSU* Heat summation unit

Region	PE (mm)	HSU (> base 18°C)	Fruiting period (days)	Rainy days	Humidity (%)	Rainfall (mm)	Temperature [range (mean); °C]
Kachachh	1,897	2,900–3,056	165	17	52	350	20–33 (26)
Jaisalmer	2,069	2,900–3,240	145	13	64	215	19–34 (26)
Bikaner	1,772	2,900–3,200	145	19	58	305	18–33 (26)
Jodhpur	1,843	2,900–3,200	145	20	65	350	20–33 (26)
Ganganagar	1,662	2,400–2,900	122	16	56	296	17–33 (25)
Hissar	1,615	2,400–2,513	122	25	64	446	17–33 (25)
Ferozpur	1,362	2,400–2,600	122	19	65	300	16–31 (24)

Sandy soils associated with dunes and inter-dunes occupy about 31% area of the arid zone. These soils are characterised by 85–90% sand, low water retention capacity (150–200 mm m^{-1}) and low fertility status, moderate to severe wind erosion, surface crusting and high water infiltration. High salinity in soil and ground water are associated with these soils (Dhir 2003). The soils of the Thar desert of Rajasthan have been classified into six types, viz. dune soil, sandy plain soil, brown light loam soil, grey brown loam soil, hardpan soil and indus alluvial soil (Dhir and Singh 1985; Venkateswarlu and Kar 1996), with dune soil and sandy plain soils occurring most commonly. Natural underground water resources, as well as man-made tube wells, hydrological reservoirs, and canals [e.g. the Indira Gandhi Nahar Project (IGNP) canal discussed below] are ideal ways to boost agriculture production and improve the desert economy.

20.1.4 Project IGNP

The IGNP is one of the gigantic canal projects in India aimed at transforming the desert wasteland into agriculturally productive land. The IGNP starts from the Harike Barrage, a few kilometres below the confluence of the Sutlej and Beas rivers in Punjab State. It runs South-West in Punjab and Haryana but mainly in Rajasthan for a total of 650 km and ends near Jaisalmer, in Rajasthan. It uses water released from the Pong dam and will provide irrigation facilities to the North-Western region of Rajasthan, i.e. a part of the Thar Desert. It consists of the Rajasthan feeder canal (with the first 167 km in Punjab and Haryana and the remaining 37 km in Rajasthan), with the 445 km main canal being located entirely within Rajasthan. Seven districts of Rajasthan are covered: Barmer, Bikaner, Churu, Hanumangarh, Jaisalmer, Jodhpur, and Sriganganagar. The IGNP project will enhance the living standards of the people of the state. A tree-planting programme for greening the desert in IGNP areas was started in 1965 that involved planting of shelterbelts along roads and canals, block plantations and sand dune stabilisation to check the spread of desert. Tree species used for planting were *Dalbergia sissoo*, *Eucalyptus terticornis*, *Eucalyptus camaldulensis*, *Morus alba*, *Tecomella undulata*, *Acacia tortilis*, *Azadirachta indica*, *Albizia lebbeck*, *Cassia fistula*, *Popular ciliata*, *Melia azedarch*, and *Acacia nilotica*.

20.2 Requirements for Date Palm Cultivation

20.2.1 Agro Climatic Zones

Date palms require very specific climatic conditions for successful cultivation, and their ability to produce abundant fruit at extremely low humidity is possible only if the supply of groundwater/canal irrigation is sufficient. A relatively dry rainy

season is required to attain the Pind stage (when the fruit is fully ripe and dark reddish and the fruit is soft). At the time of fruit ripening, rainfall adversely affects the quality of fruits. Late onset of monsoon, lower total rainfall and fewer rainy days are the primary requirements of date palm cultivation as these conditions produce a high quantity of good quality fully ripened soft dates (Pind Khajoor). The climatic parameters governing the success of date palm cultivation in arid regions depends on the availability of heat units with the pattern of rainfall. Date palms in the Mediterranean region have a rainless summer from February to September. This enables complete ripening (up to Pind stage) of fruit on the tree (Chih Cheng and Krueger 2007). In the Thar Desert, rainless summer occurs only rarely. The June–September monsoon coincides with the fruit ripening season. This shortens the period of date ripening from 180–200 days to 100–170 days (Chandra et al. 1992). Therefore, cultivation of date palm varies with rainfall and rainfall pattern. Thus, on the basis of the main climatic parameters, the potential of date palm cultivation in arid zones can be categorised into four zones (Fig. 20.1):

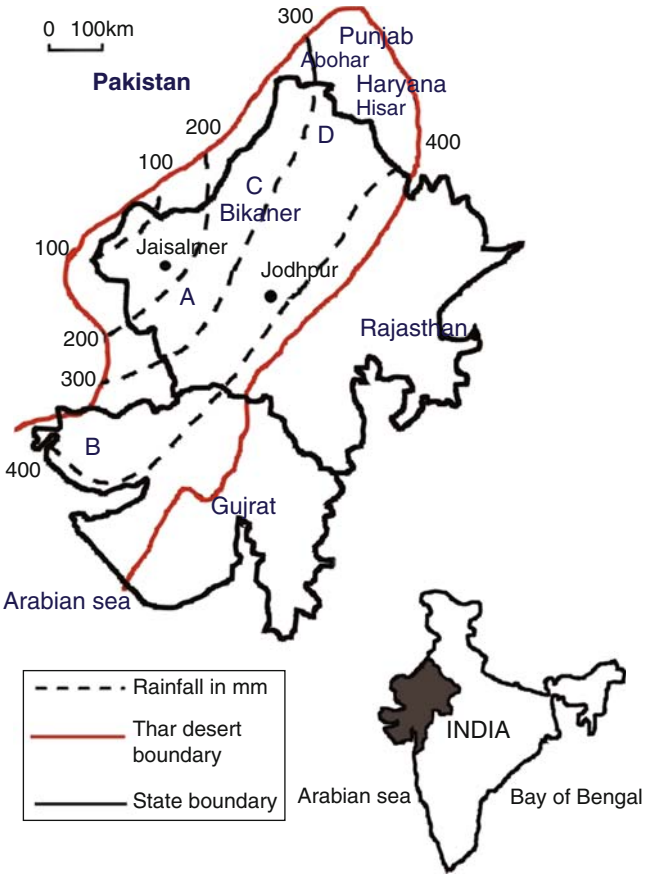

Fig. 20.1 Potential date palm growing zones in Indian arid zone

1. Extremely dry areas with lowest rainfall and highest heat summation units (HSU), viz. Jaisalmer and Western parts of Barmer, Bikaner and Jodhpur districts. This zone has the highest potential.
2. Arid coastal areas of Kachchh and part of Saurashtra. Date palm regions of Kachchh can be divided into three zones: (i) Area (Mundra, Dhrub and Zarpara) close to the coast, having deep coastal soil and a very high water table (1–3 m). This is a major date palm growing area where little irrigation is required; (ii) deep sandy soil away from coast villages (Anjar and Khedoi), with a low water table (10–20 m); and (iii) sides of rivulets, rivers and where water accumulates near Kera, Tera and Vada. The area has a high water table (1–2 m). Maturity of fruits is earlier than in zones (1) and (ii). At present, in the arid Kachchh region, 1.9 million date palm plants produce 95,000 Mt date palm fruits. Forward-looking farmers in this region have planted "Barhee date palm" in 10,000 acres of land.
3. Dry areas with storm-type rains, comprising Jodhpur, Bikaner, eastern part of Barmer, western part of Nagaur, Churu and Ganganagar district.
4. Dry areas with rains followed by cloudy weather, viz. Abohar, Sirsa, Ganganagar, eastern part of Churu and Western part of Sikar districts.

Accordingly, fruits can be harvested at Doka stage in zone 4, at Doka or Dang stage in zones 2 and 3 and at Dang or early Pind stage in zone 1. Rainfall accompanied with high relative humidity spoils the fruit due to rotting and splitting.

20.2.2 Soils

Dates grow in various types of soil – light, medium and heavy – but require good drainage and air penetration into the deep loamy soils. Date palms are the crop plants most tolerant to high pH, as well as being resistant to alkaline and saline conditions (Chundawat 1990; Chandra et al. 1992). In view of the large investment required to bring a date plantation into being and to maintain profitable production, a sandy loam soil, 2–3 m deep with good water holding capacity and drainage is most desirable. Dates can survive well in soil with a salt concentration of 4%, provided the root system does not come into contact with a stratum of soil where the sodicity is more than 1%.

20.2.3 Temperature

High temperatures (higher than early in the fruiting season) are essential at the time of date palm ripening. Prolonged, hot and dry summers and a moderate winter temperature are the primary prerequisites. The principal climatic parameters, viz. temperature and rainfall (total amount and distribution pattern) therefore primarily

govern date palm performance. The ideal mean temperature during flowering and fruit ripening varies from 25°C to 40°C, depending on the cultivar. The rate with which the fruit reaches maturity, and the development of its quality depend upon the pattern of maximum temperatures. The effect of temperature is generally evaluated on the basis of 'Heat Units' (Zaid and de Wet 2002a).

The term 'Heat Summation Units' is a means of expressing this energy. At Jaisalmer and Bikaner, the accumulation of sufficient HSU between the flowering to fruit ripening period is required for the date fruits to attain the "Dang" stage while still on the trees. Chandra and Chaudhary (1990) have observed that the requirement of HSUs differs from one cultivar to the next in reaching the "colour turning" and "Pind" stages. To reach the colour turning stage from spathe initiation, 1,951 HSU are required in Halawy, as compared to 2,411 HSU in cultivar Shamran and 2,648 HSU in cultivar Medjool. To attain Pind stage, cultivar Gangangar requires most HSU (3,843) with the least (3,101 HSU) in Halawy. Due to variations in climate from one place to another, the time of maturity as well as the quality of fruit produced in different date palm growing regions differs considerably.

HSU during the period March to August, work out at 2,000–2,400 above 18°C and 3,500–4,000 above 10°C. On the basis of a base temperature of 10°C, the HSU requirement for date palm varies in the range of 1,950–3,650 depending upon the cultivar. It is obvious, therefore, that the Thar desert meets this requirement (Chundawat 1990; Chandra et al. 1992). However, the rate of maturity of the fruit, and the development of its quality depend on the pattern of daily maximum temperature and HSU during the fruit-ripening period. Thus, the time of maturity as well as the quality of fruit produced in different regions varies.

20.3 Horticultural Aspects of Date Palm

20.3.1 Date Palm (Phoenix dactylifera L.)

Date palm is the tree of life ('*Nakhla*' in Arabic), and is the oldest of all cultivated fruit trees. It is a monocotyledonous, dioecious plant belonging to the family Palmaceae. It has large number of secondary roots with smaller lateral roots, which arise from the base of the stem. The larger air passages in the stele and extra-stellar regions of roots indicate its requirements of plentiful water and air supply. The genus *Phoenix* has characteristic upward and lengthwise folding of pinnae. It produces furrowed seeds yielding either male or female plants. Date palm may reach an age of over 100 years and a height of over 20 m. There are about 12 species native to tropical and subtropical parts of Africa and Asia (Chih Cheng and Krueger 2007). The date palm most probably originated from the area around northeastern Africa (the Nile delta), northern Arabia, Iraq and western Iran (Nixon 1950; Nixon and Carpenter 1978). This area is known as the "Fertile Crescent" (ancient Mesopotamia), where Old World agriculture is thought to have arisen.

Indeed, the date palm has been cultivated in this area from ancient times, possibly being one of the first domesticated crops. The tree is considered as a blessed tree, whose history has been linked to the Arabian Region since ancient times. It is believed to have been established as early as 4000 B.C. in Mesopotomia (South Iraq; Zohary and Hopf 1993). The tree was used in the construction of the Temple of the Moon God in Ur (Iraq) some 4,000–5,000 years ago. Over several millennia, date palm culture spread to other parts of the world, including Western India.

20.3.2 Production Status

Worldwide date production has increased tremendously from 1,809,091 t in 1962 to 6,924,975 t in 2005 (FAO 2006). The top ten date-producing countries in 2005 were Egypt, Saudi Arabia, Iran, United Arab Emirates (UAE), Pakistan, Algeria, Sudan, Oman, Libyan Arab Jamahiriya and Tunisia. The top five date-importing countries in 2004 were India, Pakistan, Yemen, Morocco, and UAE. At present, India imports 60,000 t dry and soft dates every year. To help meet this demand, various arid regions of India congenial for date palm cultivation are being considered. The United States (California and Arizona) produced 16,500 t dates in 2005 and exported 4,202 t. The largest production of dates is in Egypt, where production has increased from 439,539 t in 1982 to 1,170,000 t in 2005 (16.9% of worldwide production). In UAE, there were about 1.5 million date palms producing 8,400 t when the country was founded in 1971. This has increased more than 90-fold to an estimated 18 million date palms producing 760,000 tons in 2005. Date palm plantations are distributed throughout the Middle East, North Africa and South Sahel, areas of East and South Africa, the southwestern United States, Central and South America and even in Southern Europe (notably in Spain and Italy) – the total number of date palm trees in the world is approximately 105 million, covering an area of 800,000 ha (FAO 2006). Date palms have yet to be developed in other suitable areas of the globe in which dry climates are experienced, and where there is a desperate need to stabilise and create new sustainable macro- and micro-environments.

20.3.3 Nutritional Status

Date palm fruits are eaten as raw dates (fresh fruits), dry dates (Chuhhara) and soft dates (Pind Khajoor). Dates are highly nutritious and delicious, containing sugars, proteins, fats and minerals. The fully ripe fruits contain 75–80% sugars (glucose and fructose). Dates are also good sources of iron, potassium, calcium, magnesium, sulphur, copper and phosphorus, along with various vitamins, including thiamine, riboflavin, biotin, folic and ascorbic acid. The date fruits are relatively easy to store due to the high sugar content. The fruit plays an important role in the daily nutrition

of human populations in regions where date palms are grown. Its additional use as a livestock feed supplement gives the tree much added value. The secondary products generated from the fruits include syrups, jams, ice-creams, baby foods, alcoholic beverages and soft drinks. In addition to producing a valuable dessert fruit, important by-products, such as building materials and versatile starting materials for handicrafts, can be derived from date palm leaves and trunks, making it an important multi-purpose tree and a significant earner of revenue for both small and large farmers. The date palm also makes a significant contribution towards the creation of equable micro-climates within oasis ecosystems, thus enabling agricultural development to be sustained in many drought- and saline-affected regions. This is reflected in its widely acknowledged sustainability value in social, economic and ecological terms (Zohary and Hopf 1993). Planting of date palm has been considered suitable in the states of Rajasthan, Gujarat, Haryana and Punjab (Manohar and Chandra 1995).

20.3.4 Promising Cultivars

Date varieties have been developed over thousands of years of selection of seedlings, propagating only those possessing desirable characteristics through offshoots. Several date specialists have attempted to list and to describe the varieties botanically (Srivastava and Dhavan 1981; Kalra and Jawanda 1992; Pundir and Porwal 1998). An estimated 3,000 cultivars of date palm are available worldwide. Various superior cultivars have been selected and developed as having desirable traits, i.e. high quality, pest resistant and vibrant coloured fruits (Fig. 20.2). Prominent date palm cultivars suitable for the arid climatic conditions of India are listed in Table 20.2, and include varieties such as Halawy, Shamran, Khadrawy, Medjool, Barhee, Zagloul, Hayani, Zahidi, Khalas and Sewi. The wild species of date palm, viz. *P. sylvestris* (L. Roxb), which is found growing in almost all states of India, produces inferior quality fruit with little flesh. This palm is used for production of gur and a drink known as neera.

20.3.5 Irrigation

Date palms require large quantities of water. The shape of the leaves also influences the evaporation rate. Dates grow in hot climates with high levels of radiation, and the evaporation rate is high. Water consumption per hectare is high during the hottest months (April–June). The golden rule is to ensure that the greatest diameter of the bulb of the plant is at the same level as the soil surface after transplanting, and to ensure that water does not go over the top of the date plant. The fully grown date palm is known as a drought-resistant fruit tree and is able to survive for long periods

Fig. 20.2 Date palm cultivars having different types of fruits (*insets*)

Table 20.2 Promising date palm cultivars for the Indian arid zone

Cultivar	Colour of fruit	Fruit size (cm)	Time of maturity	Yield/ Doka stage (kg)
Halawy	Light orange with yellow	3.56 x 2.10	Two weeks in July	100
Shamran	Yellow with slightly pink	3.50 x 2.18	End of July	100
Barhee	Golden yellow	2.90 x 2.30	Mid August	100
Khalas	Yellow	3.2 x 2.4	Mid July	75
Medjool	Yellow	3.90 x 2.80	Mid August	75
Sewi	Yellowish green	2.9 x 1.90	Early August	50
Kuneizi	Red	3.50 x 2.20	Mid July	40
Zaagloul	Red	3.90 x 2.20	Mid July	150
Zahidi	Yellow	3.0 x 2.20	Mid August	125
Khadrawy	Greenish yellow	3.10 x 2.10	End of July	40

without irrigation. However, continuous drought conditions will retard the growth of the plant.

20.3.6 Fertiliser

Nutrient management in date palm trees is essential for optimum growth and production. Date palm trees should be provided with organic manure as well as inorganic fertiliser. Well rotted farmyard manure (20–40 kg per tree) should be

applied to date-bearing trees during the period September–December. Besides organics, each date-bearing tree should be given 0.5–1.0 kg nitrogen, 0.5–1.0 kg phosphorus and 0.25–0.5 kg potash per year. Ammonium sulphate (1–2 kg per palm) should be added along with manure. The entire quantity of phosphorus and potassium and 60% of nitrogen should be given 3 weeks before flowering, with the remaining nitrogen being applied during the months of March and April after fruit set. Fertiliser is applied according to the size and age of the tree, in a ratio of 2:1:3:1. It is recommended to test for microelement deficiencies, and to spray the foliage when necessary with S, Cu, Fe, Mg, Mn. Farmyard manure is also applied during December–January. The nitrogen dose should be given 2 weeks before flowering, i.e. in the 1st week of February. However, nutritional studies conducted on 30-year-old palms using 500–2,000 g N, 500 g P_2O_5 and 500 g K did not show any significant response under a canal irrigation system at Abohar (Chandra et al. 1992; Pareek and Nath 1996).

20.3.7 Intercropping

Intercropping date palm with other suitable crops bring a good income and also improves the fertility of the soil. During the first few years, intercropping can be practiced with no shortage of irrigation. Intercrops such as cluster bean, cowpea, moong, moth bean, mustard and gram can be sown during summer and winter in rain-fed or irrigated fields (Chandra et al. 1992; Pareek and Nath 1996).

20.3.8 Pruning and Training

Being monocotyledonous, date palm trees have a single stem, therefore very little pruning and training is involved in the production of fruits. Trees are usually pruned once a year. In some growing regions trees are pruned after harvesting, while elsewhere trees are pruned in the spring, before the clusters are covered with sacks. The best period for pruning is during the winter months (November and December). Removal of one-third of the central strands after fruit set leads to better development of fruits and hastens ripening.

20.3.9 Flowering and Pollination

The dioecious nature of date palm means that male and female flowers are borne on separate trees (Fig. 20.3). Spathe initiates in the axillary branch of crown leaves in February in arid zones. Female plants require artificial pollination for good fruit setting as pollination through natural means such as wind and insects is negligible.

Fig. 20.3 Female flowers produced in tissue-cultured date palm

Pollination is a cumbersome and expensive practice due to the pattern of flowering of palm trees and the requirement of climbing several times to the crown. Hand pollination is performed by dusting pollen through cotton balls onto freshly opened female spathes in the early morning for 2–3 days (Zaid and de Wet 2002c). Pollen should be collected from mature male plants and dried (6 h in sunlight followed by 18 h in shade), and can be stored in air-tight glass vials at ambient temperature for 8 weeks or in a refrigerator at 9°C for a year. Pollination of the female spathe just after cracking gave higher fruit set percentage. The pollen of *P. dactylifera*, and of other *Phoenix* species, has been found to exert a direct influence on the size, shape and colour of the seed, and also on the size of the fruit, the speed of development of the fruit, and the time of fruit ripening of vegetatively propagated female varieties of date palm (Zaid and de Wet 2002c).

Spathe emergence occurs from the 2nd week of January to the 3rd week of March in Jodhpur and Bikaner, in the last 2 weeks of April in Abohar, and in February in Kachchh (Pareek and Nath 1996). The time required from flowering to different stages of fruit production depends on climatic conditions, date variety and management practices (Table 20.3).

20.3.10 Fruit Thinning

Excess fruit load may cause shrivelling of berries, breaking of spathe stalks, more damage due to rain and humidity, and delayed ripening. It also reduces the size and

Table 20.3 Flowering characteristics of important date palm cultivars in arid climates

Cultivar	Spathe Emergence Month	Days	Opening Days	Length of spathe (cm)	Number of bunches	Strands per bunch	Length of strand (cm)	Days to fruit maturity
Halawy	January–February	28–46	24–37	33	6–9	43.6	37.0	112
Shamran	February	30–48	23–36	28	5–8	34.3	32.6	136
Khadrawy	January–February	32–43	29–35	33	3–5	28.2	27.6	126
Zagloul	Early February	17–22	11–18	30	3–8	31.2	25.2	129
Zahidi	February	26–41	20–29	30	3–6	36.1	30.7	129
Medjool	February	19–34	21–30	30	4–6	40.6	40.1	130

Table 20.4 Fruitt characteristics of important date palm cultivars in arid climate. *TSS* Total soluble solids

Cultivar	Colour (Doka)	Shape	Pulp:stone ratio	TSS	Taste	Fruit skin	Maturity
Halawy	Yellow	Oblong	9.0	42	Very sweet	Thin	Early
Shamran	Reddish yellow	Obovate	6.7	36	Astringent	Thin	Late
Khadrawy	Light yellow	Oval	7.3	35	Astringent	Thin	Medium
Zagloul	Purple red	Obovate	7.3	71	Sweet	Medium thick	Early
Muscut–2	Red	Oblong	6.8	38	Sweet	Thin	Medium
Zahidi	Yellow	Obovate	7.5	34	Slightly sweet	Medium thick	Medium
Medjool	Orange	Oblong round	6.38	35	Astringent	–	Late

quality of the fruit. It is therefore necessary to keep the optimum quantity of fruit and thin out the rest. This is usually accomplished either by reducing the number of fruit on each bunch and/or by removing some bunches (Table 20.4). The number of fruit that a palm can safely carry depends on the cultivar, age, size and vigour of the palm, and number of green leaves it has. Under normal conditions, 1–2 bunches in the 4th year and 3–4 bunches in the 5th year may be left. Normally 8–10 bunches per palm are retained in India.

In short-stranded varieties like Khadrawy, the strands are generally cut back to even up the bunch from the top. Most fruit thinning is done by removing one-half to two-third of the strands from the centre. In long-stranded varieties like Deglet Noor, one-third to one-half of strands are cut in similar way as in Khadrawy. In addition, strands are also cut back to remove about one-third of the flowers. The optimal number of fruits to be left is between 1,300 and 1,600 per palm depending on the variety. The percent thinning is generally 40–50 in Khadrawy, 50–55 in Hallawi, and 50–60 in Zahidi and Barhee.

20.3.11 Fruit Development

Fruit set takes place after fertilisation, which is characterised by the loss of two unfertilised carpels. The fruit goes through four developmental stages, viz. Gandora or Kimiri (fruit is still hard and green); Doka or Khalal (fruits are fully grown but remain hard; their colour becomes yellow or red); Dang or Rutab (softening of fruits start from tips and finally the whole fruit is softened), and Pind or tamer (fruit is fully ripened; fruit weight decreases as a result of fruit dehydration). The fruits become edible from the Doka stage onwards, except for varieties that are highly astringent at that stage. Pre-harvest application of ethrel (2-chloroethyl phosphonic acid) at 1,000 ppm on fruit bunches at the colour break stage (when fruits start changing their colour from green to yellow or red) hastened ripening of fruits and also increased the size and weight of the fruit. Ethephon also advances the ripening of fruit. Application of ethephon (1,000 ppm) and gibberellic acid (GA_3; 100 ppm) at the fruit colour turning stage induced earlier ripening by 1 week (Manohar and Chandra 1995).

20.3.12 Harvesting

Bunches are harvested at full Doka stage for fresh date varieties edible at this stage. The fruits are separated from strands and graded. Any shrivelled, diseased and undersized fruits are discarded to make the produce more attractive for the market. For the preparation of dry dates, fruits are harvested at full Doka, and, for soft dates (Pind Khajoor), partial-to-full-Dang fruits are harvested. Date palm trees bear commercial fruit 6 years after planting. Initially, yields are low but increase with the age of the trees. Fruit yield differs from variety to variety and also depends upon the age of tree and orchard management. On average, 50 kg Doka fruits per year can be harvested from trees aged up to 15 years and thereafter 75 kg can be harvested per tree per year by using a recommended package of practices (Chundawat 1990).

20.3.13 Post Harvest and Storage

Fresh Doka (Khalal stage) fruit cannot be stored at room temperature for more than 4 days, whereas they can be stored up to 30 days under refrigeration and up to 50 days at freezing temperatures. Fresh dates are washed and packed in cardboard boxes. Fruits of Halawy turn to Dang stage in the refrigerator. For the preparation of dry dates, full Doka fruits are washed and dipped in boiling water for 10 or 20 min, sulfiltated in 1,500 ppm potassium metabisulphite and dried either in an air-circulating oven at 48–52°C for 70–95 h or through sun drying for 80–120 h if the weather is dry. Halawy is the most suitable variety for making high quality dry dates by immersing the fruit in boiling water for 20 min and subsequently drying in an air-circulating tray drier at

45°C for 60–65 h. Fully Dang fruits can be converted into soft dates simply by drying them in air-circulating oven (Manohar and Chandra 1995).

20.3.14 Diseases and Pests

Date palm plants are affected by various diseases like Bayoud disease (*Fusarium oxysporum* f. sp. *albedinis*; Zaid et al. 2002), Black scorch – also called medjnoon or fool's disease – (*Ceratocystis paradoxa*), Diplodia disease (*Diplodia phoenicum*) and Graphiola leaf spot (*Graphiola phoenicis*). In deserts, these plants are also affected by scale insects (*Parlatoria blanchardi* Targ.), termites (*Odontotermes obesus*; Chandra et al. 1992; Manohar and Chandra 1995) and birds.

20.3.15 Propagation

Date palm can be propagated naturally in only two ways: by seed and by the offshoots or suckers that spring up around the base, or sometimes on the stem, of the palm until it attains an age of 10–20 years (Fig. 20.4). The use of tissue culture techniques is a recently developed third method, which has now been adopted by advanced commercial laboratories.

Fig. 20.4 Development of offshoots from mother plant of different ages

20.3.15.1 Seed Germination

Propagation by seed is sexual method of propagation. Seed is the most convenient material with which to propagate date palm: seeds can be stored for years, they germinate easily and are available in large numbers. However, for several reasons, this method cannot be used commercially for propagating desired date palm cultivars in a true-to-type manner.

20.3.15.2 Offshoots

For commercial plantations, date palm is always propagated through offshoots (suckers). This is the only commercial method of vegetative clonal propagation used to multiply the best varieties. Offshoots are produced from axillary buds situated on the base of the trunk during the juvenile life of the palm. However, they develop slowly and the numbers produced per tree are limited. Furthermore, suckers are produced only within a certain period in the mother palm's life. Thus, during the lifetime of an individual plant, only a low number of transplantable offshoots is available. Offshoot production varies from 10 to 30 depending on the cultivar and the cultivation practices used. No field-based method is as yet available with which to increase the numbers of offshoots produced by each tree (Zaid and de Wet 2002b). Offshoots have to be large enough (i.e. 8–15 kg) to survive when transplanted in the field.

Offshoot propagation, which represents asexual or vegetative propagation, offers the following advantages:

1. Offshoot plants are true-to-type to the parent palm. The offshoots develop from axillary buds on the trunk of the mother plant and consequently the fruit produced will be of the same quality as the mother palm, thus ensuring product uniformity.
2. The offshoot plant will bear fruits 2–3 years earlier than seedlings. The life span of the date palm is divided into two distinct developmental phases: vegetative, in which buds forming in the leaf axils develop into offshoots; and generative, in which buds form inflorescences and offshoots cease. The axillary bud of a leaf differentiates into an offshoot. Offshoots are separated for planting after growing for up to 3–5 years (Nixon and Carpenter 1978). Their curved form distinguishes offshoots while mother plants have a straight form. Zahidi, Berim and Hayani varieties are known to produce large numbers of offshoots, while Mektoum and Barhee varieties produce relatively low numbers of offshoots.

20.3.15.3 Transplantation Methods

Selection

Ground offshoots (suckers), which have reached at least 8–15 kg average weight and have a well-developed root system, are selected for planting. Aerial offshoots

are not used for planting, as these are either devoid of roots or have very poor root development (Zaid and de Wet 2002b). The best time for the removal of offshoots and transplanting into the nursery for rooting is after the soil begins to warm up in the spring and early summer.

Rooting

Two types of offshoots occur on a date palm tree: basal and upper offshoots. Basal offshoots are more physiologically active than upper ones, growing faster as the number of leaves produced increases with age. Numerous factors should be considered for rooting of offshoots, including the size of the offshoot (often expressed in weight), type (upper or lower), origin of the offshoot, the method of removal and preparation for planting, as well as treatment of the offshoot after planting (Nixon and Carpenter 1978). To promote rooting, the base of the offshoot should be in contact with moist soil for at least 12 months before removal.

Detachment

Around 4–5 days before the offshoots are to be removed from the mother palm, their inner leaves should be cut back to one-half and the outer leaves to two-thirds of their length. For the production of offshoots, no green leaves should be removed from an offshoot until it is cut from the mother palm. If leaves interfere with cultivation, they may be tied together. After 3–5 years of attachment to the parent palm, offshoots will form their own roots and start producing a second generation of offshoots (Nixon 1936; Nixon and Carpenter 1978). Offshoots are removed from the mother palm tree using a sharp chisel.

Planting

Offshoots can be planted in a nursery bed of 1 m^3 for rooting for 1–2 years. A mixture of 10–15 kg well-rotted farmyard manure, fertile topsoil, 50 g captan and 50–100 g insecticidal dusts are used for refilling the pits. Moreover, the offshoots are dipped in a solution of carbendazim and chloropyrophos or endosulfan. In addition, the root initials of offshoots may be dipped in IBA solution (1,000 ppm) for 2–5 min to ensure better root development.

Spacing and Density

Date palm offshoots are planted in the field in a square system of planting at a distance of 8–10 m depending on soil fertility and irrigation regime. A total of 156 suckers can be planted in a 1-ha area at 8 m planting distance in such a square

system. Normally, dates are grown at a density of about 120–200 trees per hectare on average (Chandra et al. 1992). Young offshoots and tissue culture-derived plants should be protected from harsh climatic conditions.

20.4 Tissue Culture

Micropropagation of plants through plant tissue culture techniques has already attained the dimensions of a full plant-based industry in several countries. The advantages of this technology over conventional propagation are: (1) only a small laboratory space is required; (2) a large number of plants can be produced in short duration; (3) cloning of selected material is possible; (4) there is no seasonal effect on plants because they can be multiplied under controlled conditions in the laboratory throughout the year; (5) genetically uniform plants are produced; (6) easy and fast exchange of plant material between different regions of a country or between countries is ensured without any risk of the spread of diseases and pests; (7) large-scale production is economically reliable; and (8) the plantlets are easy to handle and transport, and do not requires phyto-sanitary regulation.

Three methods of micropropagation are currently been used depending upon the objectives and plant species: (1) organogenesis (shoot, root and plantlet formation from callus), (2) bud proliferation, and (3) somatic embryogenesis (direct or indirect, with the possibility of scale-up of the technology through cell culture in bioreactors; Sangwan and Harada 1975; Welander 1976; Reynolds 1979; Tisserat 1982; Raj Bhansali 1990, 1993; Raj Bhansali et al. 1991).

Date palm trees have benefited greatly from the application of plant tissue culture techniques, since, for large-scale propagation, the offshoots growing at the base of the mother tree constitute the only source of explants used for the initiation stage. Because of the low success level at this initial stage, a large number of offshoots are often needed. Therefore, over the past more than 30 years, various in vitro techniques for the production of planting materials have been developed in different parts of the world (Welander 1976; Reynolds 1979; Tisserat 1981a, 1981b; Zaid and Tisserat 1983; Sharma et al. 1986; Raj Bhansali and Kaul 1991; Loutfi and El Hadrami 2007; Al-Khayri 2007). Growth and development of tissue-cultured date palm plants involves several steps: (1) the best quality germplasm from around the world is used; (2) the actively growing tissues are taken from the desired plant under the highest hygienic conditions; (3) explants are then planted on suitable media in the laboratory; (4) direct organogenesis to plantlets from the developing somatic embryos takes place under laboratory-controlled temperature, humidity and light regimes. (5) the regenerated plants are then transferred to the greenhouse, where they gradually become hardened and accustomed to the normal environment in which they will be planted in the field. This process takes almost 3 months. The nursery period takes 3–6 months, during which the plant develops further and becomes accustomed to the actual temperatures and conditions it will

experience in the field. This process is closely monitored; (6) after this period the plants are ready to be planted anywhere.

In most cases, females plant are preferred for date palm commercialisation, but there are many cases where excellent male plants are also indispensable, exhibiting a metaxenia effect. An Al Ain city male is a unique date palm with many interesting and exceptional metaxenia effects on inflorescences, but no offshoots are available. In such a plant, the only source of primary explants for the large-scale propagation of Al Ain city male is that specimen only. In all such cases, female/male healthy date palm offshoots of about 2 to 4 years old are used as sources of explants from desired cultivars. The suckers/inflorescences are obtained from adult palms after careful elimination of all leaves and adjoining tissues, and the shoot tips are excised from the offshoots (Fig. 20.5). These explants are surface sterilised in 2% sodium hypochlorite. Plantlets are obtained directly from shoot tip explants of date palm in culture through shoot development. Both somatic embryogenesis and organogenesis are used in clonal propagation of date palm plants on a commercial scale. Callus and morphogenesis in culture have been induced from different explants including zygotic embryos, roots (Sharma et al. 1980), young leaves (Sharma et al. 1984), shoot tips (Zaid and Tisserat 1983; Raj Bhansali et al. 1988), inflorescence (Drira and Benbadis 1985; Bhaskaran and Smith 1992; Loutfi and Chlyah 1998) and axillary buds (Bouguedoura et al. 1990).

MS (Murashige and Skoog 1962) tissue culture medium is the most extensively used nutritive media in date palm propagation as it helps to release the formation of new buds and somatic embryos. The following chemicals are also added to this basal nutrient MS solution: amino acids (arginine, asparagine, glycine, adenine and glutamine); vitamins (inositol, biotin, pyrodoxine, nicotinic acid and thiamine), which are important in enhancing the formation of new buds; and other organic materials, e.g. sucrose (30–40 g/l). Activated charcoal (0.3–3 g/l)/polyvinylpyrrolidone (PVP; 2 g/l) reduces the phenolic toxicity produced by explants and increases growth of living explants and formation of date palm organs (Tisserat 1979). Agar is used at a concentration of 8 g/l. The various types of auxins and cytokinins and their concentrations (according to explant quality, physiological status and developmental stage of the cultivated explants) are added. This basal medium is augmented with various combinations of auxins and cytokinins. The different media contain 2,4-dichlorophenoxy acetic acid (2,4-D), indole acetic

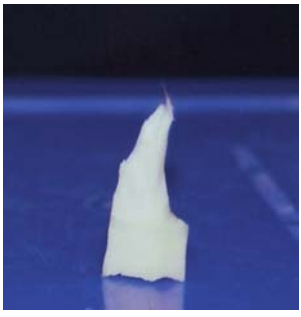

Fig. 20.5 Apical shoot tip extracted from the offshoot for tissue culture

Table 20.5 Date palm explants and their in vitro responses

Explant	Availability	Morphogenetic potential	Remark
Apical tip	One per tree/ offshoot	Very high	Sacrifice whole plant or offshoot
Inflorescence	Abundant	Immature–high Mature–low	Dependent on flowering time
Lateral bud	Several	Variable Young–high Old–low	Sacrifice the plant to obtain explant
Zygotic embryo	Abundant	Variable Immature–high Mature–low	Non-clonal, specific genotype
Leaf	Abundant	Cultures developed but with no roots	Clonal but difficult to culture
Stem	Abundant	Failed	Clonal but difficult to culture
Root	Abundant	No shoots	Regeneration not reported

acid (IAA), naphthoxy acetic acid (NOA), or naphthalene acetic acid (NAA) as auxins, while the cytokinins used include 6-benzylaminopurine (BAP), kinetin or N6-isopentenenyladenine (2-ip; Al-Khayri 2001, Al-Khayri and Al-Bahrany 2001). Auxin concentrations range from 0 to 10 mg/l while cytokinins range from 0 to 5 mg/l. Before adding the agar and the activated charcoal, the pH is fixed at 5.8 ± 0.1. The solution is then poured either into a tube (2.5 x 20–25 cm) at 15–17 ml per tube, or into a 100–150 ml flask. These nutrient media are autoclaved at 121°C for 20 min. After cultivating the explants in a suitable medium, they are incubated in a growth room, in complete darkness at the early stages, and in specific light conditions in the advanced stages. The cultures are kept at 26°C in the dark for 8 h; and at 28°C during illumination for 16 h, and are subcultured at 30 day intervals. Several explant sources and types of media that have been used to obtain morphogenetic responses in vitro are given in Table 20.5.

20.4.1 Somatic Embryogenesis

Asexual embryogenesis has been achieved from excised zygotic embryos (Ammar and Benbadis 1977; Reynolds and Murashige 1979) and also from somatic tissues (Tisserat et al. 1979; Mater 1986; Sharma et al. 1984, 1986; Raj Bhansali et al. 1988; Daquin and Letouze 1988; Dass et al. 1989; Raj Bhansali and Kaul 1991; Bhaskaran and Smith 1992; Sudhersan et al. 1993; Al-Khayri 2003). Callus tissues are induced in various date palm cultivars (e.g. Muscut, Medjool, Sayar, Samran, Jaglool and Khadrawy) when explants are incubated in complete darkness for 3–6 months at 25°C (Sharma et al. 1984, 1986; Raj Bhansali et al. 1988; Yadav et al. 1998; Bhargava et al. 2003).

During growth of embryogenic callus, date palm explants release excessive browning substances, which causes serious problems with this technique. These substances (phenols) have profound physiological effects on the establishment and growth of embryogenic callus. Browning of explant tissues and culture medium is due to oxidation of polyphenols and formation of quinones. These are highly reactive and toxic to the tissues. The inhibitory effects may result from the bonding of phenols with proteins and their subsequent oxidation into quinones. Presoaking of explants in ascorbic acid and citric acid solutions, and adding these compounds to the culture medium, helps to curtail the oxidation of phenols. Incorporation of polyvinylpyrrolidone (PVP), cysteine-HCl and ascorbic acid also minimised browning problems in several date palm species (Dass et al. 1989). Zaid and Tisserat (1983) suggested soaking date palm explants in an antioxidant solution (150 mg/l citric acid and 100 mg/l ascorbic acid) prior to surface sterilisation treatment. Raj Bhansali and Kaul (1991) also used these antioxidant solutions for 30–60 min in cold storage (0–4°C). Furthermore, use of nutritionally balanced media containing activated charcoal (3 g/l) has significantly checked the browning problems in date palm explants. Raj Bhansali et al. (1988) found that shoot tips and lateral bud cultures grew successfully if transferred frequently (after periods of incubation of 7–15 days) to fresh medium. The influence of physical conditions, nutrient medium and carbon source has been studied in various varieties (Tisserat 1979, 1981a, 1981b; Wangkaew et al. 1991; Veramendi and Navarro 1996, 1997).

Complete protocols (callus initiation, diagnosis of somatic embryos, nodular callus, embryo development and multiplication) for propagation of date palm via somatic embryogenesis have been reported by various workers (Sharma et al. 1986; Raj Bhansali et al. 1988; Sudhersan et al. 1993; El Hadarami et al. 1995; Figs. 20.6–20.10). At the Central Arid Zone Research Institute (CAZRI), Jodhpur, a method for the clonal propagation of date palm through repetitive somatic embryogenesis (RSE) was developed during 1986–1989. Nowadays, the principles involved in multiplication of date palm plantlets are adequate to produce large numbers of plantlets through somatic embryogenesis (Fig. 20.11). Free-living plants have been established in pots and in the field at CAZRI (Fig. 20.12).

Various workers have now field-tested tissue-culture raised and zygotic seedlings. Tissue culture plants raised from explants taken from female mother plants produce female flowers (Fig. 20.13, 20.14), whereas zygotic seedlings produced male/female flowers with different plant characteristics and flowering behaviour. Flowers are pollinated as usual by conventional methods, and fruit setting and development of the fruits are normal (Figs. 20.15, 20.16). This indicated the true-to-type behaviour of plantlets developed from the RSE process, which has now been developed sufficiently with certain varieties to be highly efficient in raising date palm from tissue culture (Raj Bhansali et al. 1988; Raj Bhansali and Singh 2000, 2003). Comparison of the quality of fruits of Hilali cultivar grown from tissue culture and from offshoots revealed no significant differences in the chemical and physical characteristics of fruits, indicating clearly that tissue culture techniques are now a viable method of date palm propagation.

Fig. 20.6 Development of callus from apical shoot tip for induction of somatic embryogenesis

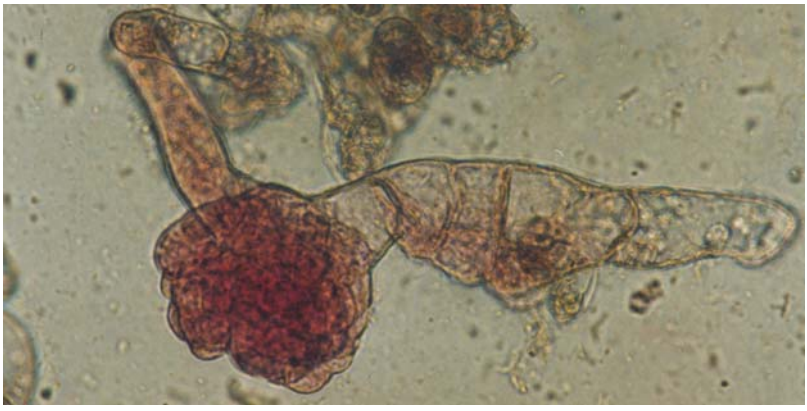

Fig. 20.7 Early diagnosis of embryogenic cultures through staining technique, indicating globular embryo

20.4.2 Suspension Culture

Several workers have also attempted to establish suspension culture of date palm friable callus for rapid embryogenesis (Sharma et al. 1986; Bhaskaran and Smith 1992). Embryogenic callus tissues are cut with a sterile scalpel into as small pieces as possible and then transferred to 50 ml liquid medium in 250 ml Erlenmeyer flasks. The flask contents are filtered using a sieve (500 μm diameter); the filtrate

Fig. 20.8 Initiation of somatic embryos from callus

Fig. 20.9 Germination of somatic embryos producing leafy shoots

obtained is incubated on a rotary shaker (100 rpm) at 25°C under the same light conditions. The liquid MS culture medium is diluted to half strength and supplemented with 2,4-D (0.1 mg/l), BAP (0.5 mg/l) and sucrose (3%). The pro-embryo

Fig. 20.10 Complete germinated somatic seedling

Fig. 20.11 Various stages of germination of somatic seedlings

masses develop into embryos after passing through several sequential and distinct embryo developmental phases. Hundreds of embryos can be developed from suspension culture within 3 weeks. These embryos need to be subcultured for 1 month to promote further growth. Approximately 1,000 embryos can be obtained from 200 mg embryogenic friable callus cultured per vessel (Bhaskaran and Smith 1992). Up to 40% of these embryos germinated into normal plantlets upon plating

Fig. 20.12 Free-living tissue cultured date palm somatic seedling

on solid medium. The somatic embryogenesis method in date palm will help in studies on developmental embryogenesis and could be used for encapsulation of embryos for long-term storage and shipment for export.

20.4.3 Somaclonal Variation

The procedures developed initially for in vitro multiplication of date palm employed somatic embryogenesis, which requires explants to first produce callus from which somatic embryos are derived, and from which the final plantlets are subsequently developed. This method is still widely used with tremendous success (Tisserat 1982; Ammar and Benbadis 1997; Daquin and Letouze 1988; El Hadrami and Baaziz 1995). However, concerns regarding the fidelity of some plants obtained through somatic embryogenesis have emerged, with reference to the mother plant. Some abnormal vegetative traits as well as unusual flowering behaviour and fruiting habits have been reported (McCubbin et al. 2000). This is most probably due to somaclonal variations encountered as a result of callus formation and/or maintaining a long callus phase prior to embryogenesis. Corniquel and Mercier (1994) used restriction fragment length polymorphism (RFLP) and randomly amplified polymorphic DNA (RAPD) methods for cultivar identification of date palm. Off-types are quite common among tissue culture-produced date palm trees of the cultivar

Fig. 20.13 Emergence of flowering from date palm established from repetitive somatic embryogenesis (RSE) tissue culture method

'Barhee' (Cohen et al. 2004) – characterised mostly as a low fruit setting phenotype. Most flowers in such trees turn into parthenocarpic fruitlets having three carpels. Other flower abnormalities include distortions of carpels and stigmas. About 50% of trees reverted to normal within 10 years of planting. Eshraghi et al. (2005) reported that the genetic similarity between the mother plant and the somatic embryogenesis-derived regenerates ranged between 94% (for R1, R2) and 83% (for R5) when RAPD markers were used. Molecular techniques (RAPD markers/CTAB

Fig. 20.14 Female flower developed from somatic date palm seedling

method) have been employed in more than 50 cultivars in order to confirm varietal authenticity in the case of date palm micropropagated through somatic embryogenesis, with very promising results (Javouhey et al. 2000).

20.4.4 Direct Organogenesis

Date palm can also be propagated successfully by organogenesis tissue culture methods. Serious efforts have been made to develop date palm tissue culture as a means of mass producing high-yielding, disease resistant clones in large numbers for plantation (Reuveni 1979). Initially, several problems occurred in date palm tissue culture for indirect and direct organogenesis. These included browning of media and explants, resulting in premature death of tissues. The growing tip produced roots, whereas the callus was short-lived and could not survive in subculture.

Refinements in culture conditions, type of media, addition of charcoal and anti-oxidising chemicals, type of growth hormones, and media composition have now been improved significantly by various workers (Zaid and de Wet 2002c; Sudhersan et al. 1993; Al-Khateeb 2006, 2008). During the first 2 months in culture, the explants enlarge on the medium and, in some cases, readily initiate again into shoots. In other cases, growth subsequently slowed down, the explants became

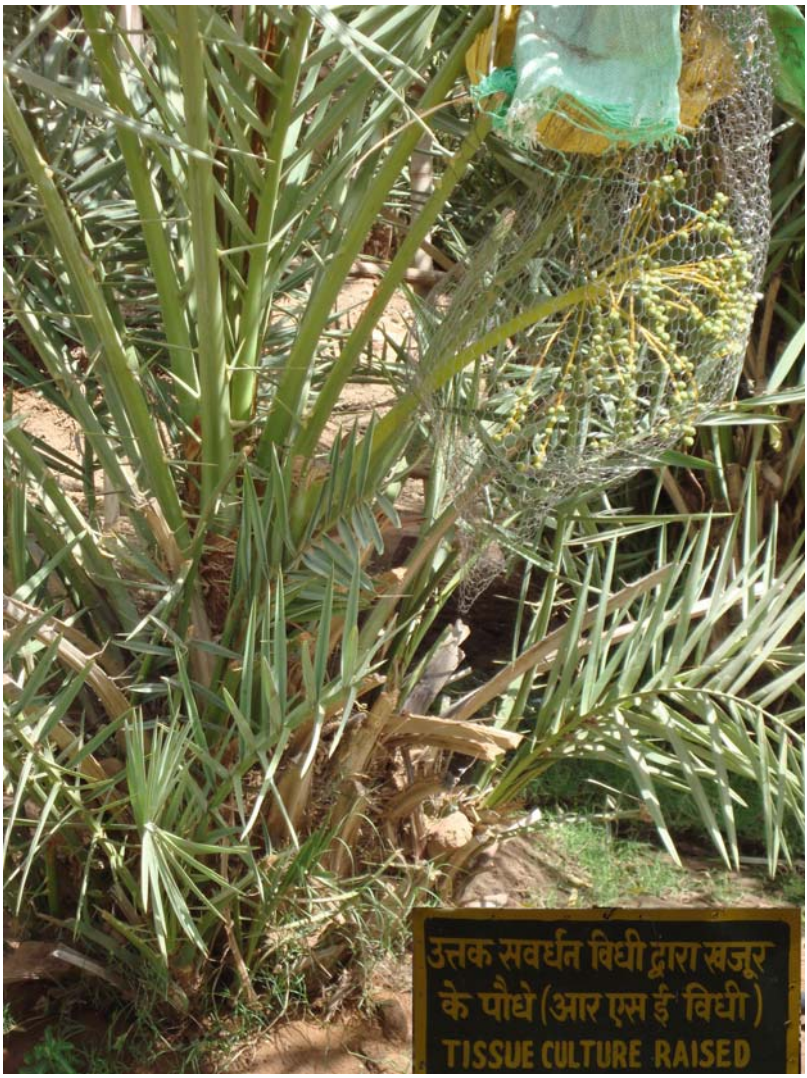

Fig. 20.15 Fruit setting and developments of fruits – in vitro raised date palm

whitish and later adventitious buds could be seen. However, browning is also seen on some explants. Some media promoted the development of axillary buds while others did not. The new meristems or buds thus produced developed further into shoots. Well-developed shoot growth is first observed after about 6 months in culture. The shoots subsequently elongate in the following months, and other shoots begin to appear from the same explant. The initial number of shoots produced is low, between two and five per explant but, over time, these shoots are harvested as they grow and new ones form. The shoots are transferred to a rooting medium,

Fig. 20.16 Fully matured date palm fruits developed on Muscut-2 variety raised from RSE tissue culture method

which is the same basal medium but containing NAA. In an earlier report of direct organogenesis in date palm, Tisserat (1984) obtained few recoverable shoots. A similar observation was also made by Varughese (2000). Beauchesne (1983) reported many more adventive buds and shoots from explants in culture from direct organogenesis. Induction of vegetative bud development from shoot-tip or axillary bud explants in culture has been reported (Tisserat 1984; Bouguedoura et al. 1990; Raj Bhansali and Kaul 1991). Recently, MS medium with 20 mg/l adenine sulphate, BAP (1.0 mg/l), IBA (0.1–6.0 mg/l), 30 g/l sucrose, 3 g/l activated charcoal, myo-inositol (100 mg/l) and thiamine HCl (0.4 mg/l) has been employed for shoot initiation (Eshraghi et al. 2005). The cultures are initially kept under complete darkness at 25°C and then transferred to a multiplication media containing 2-isopentyladenine (2iP; 1.0 mg/l) and thidiazuron (TDZ; 0.1–0.5 mg/l). Low cytokinin and auxin concentrations supported bud and shoot multiplication in date palm cv. Sukry (Al-Khateeb 2006, 2008). Similarly, Taha et al. (2001) developed a rapid method of in vitro multiplication of date palm from shoot tips on MS medium supplemented with 2iP (2 mg/l) and NAA (1 mg/l). Shoot bud proliferation was strongly enhanced when cultured on MS medium containing 2iP (3 mg/l) and NAA (0.5 mg/l). Culturing on full-strength MS medium showed a higher multiplication rate compared with half-strength MS medium. Khierallah and Bader (2007) developed a stepwise method through direct organogenesis. The best combinations of plant growth regulators and other conditions in order to achieve organogenesis and multiplication directly from shoot tips without callus formation

have been reported. MS modified medium supplemented with 2 mg/l 2iP, 1 mg/l BAP, 1 mg/l NAA and 1 mg/l naphthoxy acetic acid (NOA) supported bud formation from shoot tips after 16 weeks (6.2 bud/explant). Subculturing the formed buds on agitated liquid multiplication medium supplemented with 4 mg/l 2iP, 2 mg/L BAP, 1 mg/l NAA and 1.0 mg/l NOA gave the optimum average bud number (12.6 buds). In the elongation stage, MS medium with 0.5 mg/l GA_3 and 0.1 mg/l NAA enhanced plantlet length to 5.3 cm. Optimum rooting percentage (90%) was achieved when shoots were transferred to medium containing 1 mg/l NAA. The average root number after 8 weeks was 5.4, with a length of 9 cm. Rooted shoots (plantlets) were transplanted into small pots containing a mixture of peat moss and Perlite (2:1) and placed in plastic tunnels or in a greenhouse. The survival percentage was 85% after 3 months when the plants were transferred to bigger pots (Raj Bhansali et al. 1988). These results define a successful protocol for the in vitro propagation of date palm cv. Maktoom. Belal and El Deeb (1997) have also reported direct organogenesis in Egyptian cultivars (Zaghloul and Samani) on MS medium supplemented with a combination of auxins and cytokinins for shoot initiation, differentiation, shoot growth and shoot rooting. The influence of different carbon sources and concentrations on in vitro shoot multiplication of date palm cv. Khuneizi has been investigated. However, the number of buds produced per explant tissues is limited in comparison to somatic embryogenesis. Zaid et al. (2007) successfully developed a method for mass propagation through organogenesis (initiation, multiplication, elongation and rooting) from inflorescence tissues of a rare and unique male.

20.4.5 Advantages of Direct Organogenesis

In date palm, clonal propagation through suckers is the normal way of propagation but a more efficient method of cloning is highly desirable for large-scale production. There is also a need for further experiments to seek alternative ways of in vitro propagation that could reduce culture-induced variation in tissue culture plants. One of the methods currently advocated is the direct organogenesis method of plant propagation in vitro. Direct organogenesis has emerged as the most promising potential tissue culture method due to the lower occurrence of variation in regenerants. This technique has resulted from serious efforts aimed at finding ways to control abnormalities in regenerated plants, to maintain the quality of the plants, and to test their conformity with their parental genotype and phenotype during callus cultures due to the possibility of somaclonal variation. The successful development of this new technique is expected to greatly reduce the number of steps in culture, and possibly also the length of culture time. Gains in these two factors should help minimise the risk of somaclonal variation. There have been ongoing experiments all over world to develop in vitro propagation procedures for the date palm without somaclonal variation. The direct organogenesis method has the advantage of omitting the callus and embryo phases and significantly reducing

the total number of stages in culture by forming new shoots direct from the explants. Various date varieties have been developed through direct organogenesis. In addition, unlike the procedure in some aspects of somatic embryogenesis, direct organogenesis occurs in the presence of light.

The current yield of plantlets is relatively low and further experiments are needed to substantially increase the number of plantlets recoverable per explant. The number of plants obtainable is important, first because large numbers of plants are required for the establishment of large plantations, and secondly because the incidence of contamination in culture can sometimes lead to substantial losses of young plants. Many more plants could be recovered by the somatic organogenesis method but the use of high auxin concentrations and the length of time of callus culture have been cited as possible reasons for tissue-culture-related variation (McCubbin et al. 2000). Planting of the material produced, relatively longer generation cycles, and high investment in the initial cost of plantation are needed to produce true-to-type progeny. The direct organogenesis method has the advantage of completely eliminating both the use of high auxin concentrations and the callus phase from the in vitro culture programme.

20.4.6 Molecular Characterisation

Improvement of date palm is very difficult due to its long life cycle, strongly heterozygous nature and non-availability of a method to determine sex at an early stage of development. Most earlier studies on genetic characterisation, detection of genetic variation and gene mutation have been conducted on the basis of variation in chromosome number, isoenzyme polymorphism and biochemical diversity (Booij et al. 1995). However, the chromosomes are numerous and small, and mitotic examination of tissue-culture-derived palm plants is unreliable. Recently, various workers have demonstrated the utility of RAPD markers for the analysis of genetic diversity among cultivars and within plant populations. Talaat and Al-Qaradawi (2009) have studied the genetic diversity among 15 different cultivars of date palm using simple sequence repeat (SSR) markers to determine the genetic similarity and/or diversity among the well-known Qatari date palm cultivars. Similarly, molecular techniques including mitochondrial plasmid-like DNAs markers have been used for molecular characterisation of Tunisian date palm varieties and to develop preventive procedures to protect them against Bayoud disease (*Fusarium oxysporum albedinis*), which causes vascular fusariosis. Recently, clonal plants of date palm were regenerated from juvenile leaves on 2,4-D-containing medium by producing adventitious shoot buds directly from the basal part of leaves as well as excessive calli. RAPD profiles were used to test for the somaclonal variation in plantlets that can sometimes be induced by 2,4-D during recurrent somatic embryogenesis. Nine arbitrary 10-mer primers were used to amplify DNA from 180 plantlets. The RAPD patterns of the plantlets were identical to those of the original

mother plant, indicating that 2,4-D did not induce somaclonal variation that can be detected by the RAPD technique (Ahmed et al. 2009).

20.5 Conclusion

There is evidence that the climate has changed repeatedly during Earth's history and, in the past, regions that are now deserts were not always so arid, so devoid of life and vegetation (Singh et al. 1974).

Land-use changes continue to influence the microclimate, rainfall patterns and fauna of the Thar region. The introduction of irrigation to the Thar Desert via the construction of the IGNP has resulted in substantial man-induced changes in the microclimate, flora and fauna of the area due to the conversion of grasslands into irrigated cultivated lands. Land-use changes continue to influence the microclimate, rainfall patterns and fauna of the Thar region. In this changing scenario, date palm trees can represent essential and integral components of arid and semi-arid farming systems in dry and desert regions. The tremendous advantage of the date palm come from its various qualities such as resilience, requirement for limited inputs, long-term productivity and multi-purpose attributes. At the present time the yield of offshoots is almost as valuable as that of fruit, and growers therefore desire to secure as many offshoots of their best varieties as possible.

The demand for date palm planting material can be met by using in vitro technology. Plant tissue culture – considered a separate subject associated with plant biotechnology – is a rapidly expanding area of biology that has tremendous potential applications in hi-tech horticulture. Significant advances have been made in plant cell and tissue culture, and regeneration of whole plants is now a routine procedure for many plant species. These can subsequently been exploited as 'model' species for genetic transformation studies. These technologies have already led to many breakthroughs in the developed world, particularly in the United States, Europe, the United Kingdom, Germany and France, in making the agricultural cultivation of certain plants a commercially viable business. Currently, UAE, Israel, the United Kingdom and France have modern, very well developed date palm tissue culture facilities, where several million date palms are produced annually to meet the high demand for offshoot production (Date Palm Tissue Culture Laboratory 2006). Plant tissue culture has already opened up vast commercial possibilities, especially in the propagation of elite forest trees, horticulture, and ornamental and plantation crops. In the Indian arid zone context, tissue culture techniques may be even more useful in solving relevant and intractable problems. Building up trained manpower for commercial exploitation of developed technology, particularly for date palm, will be essential. Appropriate mechanisms should be evolved to integrate date palm tissue culture technology with conventional methods of date palm propagation. Planting date palm in Western Rajasthan can help check desertification and can strengthen rural economies by generation of employment besides providing net monetary income to farmers. Considering the various agriculture

advances and recent technological innovations in various fields aimed at regenerating and revitalising the arid zone biosphere, it is not hard to visualise Great Indian Thar Desert full of lush green forest, orchards and crop plants.

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