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Review Article

Date Palm Cultivation, Consumption and Export: Current Status and Future Challenges - A Review

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Abstract: The date palm is an important horticultural crop, cultivated in all provinces of Pakistan, particularly in Khairpur and Sukkur districts of Sindh. Khairpur is biodiversity center for dates, with cultivation of elite commercially important cultivars like Aseel (predominant cultivar), Karbalain, Otakin, Kurh, Dedhi, Dhakki, Kashuwari, Kupro and Fasli etc. Aseel dates are consumed locally as table dates as well as exported to Germany, USA, Canada and Japan in the form of pitted and chopped dates by the different dates factories established in the country. Most of the Aseel dates are exported to India as yellow and brown chhuhara (boiled dried dates). Dates are also used to make different value-added products (date syrup, date paste, date pickles, date bars, date powder, date extracts, date jam). Poor pre- and post-harvest management and poor cultural practices are major obstacles in obtaining dates of international standards. Currently, date palms in Sindh face the effects of natural disasters, i.e., floods, post-flood diseases (sudden decline disease in the crown caused by *Fusarium solani*), and pests, such as, Red Palm Weevil (*Rhynchophorus ferrugineus*). Multiplication of elite and rare date palm cultivars by tissue culture technique is pre-requisite for large-scale cultivation which may fill the gap of destruction of indigenous date palm cultivars. Currently, thousands of grown-up trees of date palm have been destroyed with post-flood sudden decline disease. Proper pre- and post-harvest management and cultural practices and in addition cultivation of disease resistant cultivars are need of the time. In this review article, different aspects of date palm problems have been discussed and their solutions are suggested to benefit the date palm growers who can manage the crop in a better way.

Keywords: Horticulture, Cultivation, Biodiversity, Cultivars, Pitted, Value Addition, Red Palm Weevil, Post-harvest.

1. INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is dioecious and diploid (2n = 36) belongs to the family Arecaceae with diverse varietal collection grown in hot and arid regions of the world; where temperature reaches to 50°C during summer [1]. The date palm is called as "Tree of Life" grown in Oasis and arid areas of the world [2]. The date palm tree remains productive up to 40–50 years, and can survive up to 150 years, but with low production in certain conditions [3, 4]. The date palm can be propagated via conventional propagation methods i.e., seeds and offshoots; however, commercially important cultivars of date palm cannot be propagated via seeds due to heterozygosity [5]. The date palm propagated via seeds always show variation and slow growth, which can take 8–10 years to reach up to fruiting stage. Propagation of date palm via seeds is only done when the offshoots are not available [6]. Additionally, the production of limited number of offshoots per tree (10-20) during its whole life, low survival of offshoots after cultivation in the field, slow growth and diseases (Bayoud and Red Palm Weevil) are major hindrances in cultivation of date palm via offshoots [7, 8]. In contrast to conventional propagation methods (seeds and offshoots) of date palm, the tissue culture is an alternative and reliable procedure to produce huge number of true-to-type and disease free plantlets in a short time and space [9-12]. The date palm propagation via tissue culture restricts the spread of

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pests and diseases. Therefore, the micropropagation of date palm is reliable procedure for large scale production of commercially important cultivars of the date palm [13]. Currently, the micropropagation is applied progressively to produce huge number of disease-free plantlets [14]. The date palm is a major crop mainly cultivated in Khairpur and Sukkur districts of Sindh (85% dates produced in Khairpur) [15]. Full productive age of the tree is 15-30 years [36]; whereas, height of the tree above 15-20 meters increases risk and efforts for pollination and harvest. Several studies [16-21, 4] have been conducted at different times regarding vegetative, flowering and fruit evaluation of the date palm in different regions of the world. The developmental stages of date fruits have been categorized into hababouk and kimri (green and non-edible fruit), followed by khalal stage (fruit reaches to full size is edible and acquire a particular colour, i.e., yellow or red depending on the cultivar), rutab (half ripened) and tamar (fully ripened) obtained either on date palm tree (in case of dry date cultivars) or khalal and rutab dates are sun-dried to make tamar in case of semi-dry date cultivars [22, 4]. The date fruit is eaten fresh or processed into different products (date bars, date syrup, alcohol, breads, date powder, jam, chocolate, paste and sweet candy). Chhuhara dates are generally exported to India, UAE, Bangladesh, Nepal; whereas, fresh dates are exported to Germany, USA, Turkey, UK, Srilanka and Australia [23]. Pakistan is 8th largest exporter of dates in the world and 6th largest producer of dates [24], exporting most of the dates produced in Khairpur and Sukkur districts of Sindh. Nutritional importance of dates [25], physicochemical properties and mineral contents [26], antioxidant activities [27] and bioactive compounds of boiled dates [28] have been described previously by several workers. The dates contain vitamins, proteins, sugar, dietary fibers, flavonoid, minerals and polyphenolics [29]. Holy Quran and other literatures mentioned the ethno-medicinal uses of dates [30, 31]. Several changes occur during growth and ripening stages influencing the quality and nutritive value of the dates [32]. Poor pre- and post-harvest practices are still obstacles in getting attractive prices of dates in the international markets. There is need to maintain quality of dates for export as per requirement of international standards by establishing the factories equipped with latest machines following the international codex quality standards to prepare good quality dates. Quality indices for dates include fruit size, shape, color, texture, cleanliness, and free from defects (such as sunburn, skin separation, insect damage, sugar migration to fruit surface, fermentation and decay-causing pathogens. Codex Alimentarius Commision's standards for dates include three sizes based on the number of dates per 500 g; such as, small (> 110 dates without seeds or > 90 dates with seeds), medium (90-110 dates without seeds or 80-90 dates with seeds). Natural disasters are another threat to date production and export across the country. Thousands of grown-up trees of date palm have been died due to sudden decline disease after floods and heavy rains in the Sukkur and Khairpur districts of Sindh during the year 2022. Micropropagation of the date palm is reliable method to improve the varietal structure of the date palm in the area affected by pests, diseases and natural disasters i.e., floods and heavy rains. The objectives of the current study are to describe the cultivation trends, consumption behavior, export, post-harvest and disease and pests' management, to discuss about the introduction of exotic cultivars, and the role of micropropagation in improving the varietal structure of the date palm in the area.

2. CULTIVATION OF DATE PALM VARIETIES IN KHAIRPUR

Khairpur district is the biodiversity centre of date palm with cultivation of more than 300 commercial and non-commercial varieties [33]. The date palm cultivated on an area of 22310 hectares with production (158775 tons). Major export varieties of date palm have been cultivated in district Khairpur and Sukkur are Aseel, Karbalain, Dhakki, Otakin, Kurh, Dedhi, Kashuwari, Khar, Kupro, Gajar and Fasli [34, 35]. Different varieties of the date palm contain different colour and taste, consumed at different growth stages i.e, khalal, rutab and tamar.

2.1. Commercial Varieties of Dates

Aseel is the predominant cultivar of the date palm cultivated largely in district Khairpur and Sukkur; produces 15-20 bunches each year (Avg. 25 kg per bunch) and size (4.3 cm long × 2.5 cm in diameter), narrow at base, wide in the middle and oblong [36]. Aseel dates are processed in different ways, i.e., it is consumed at rutab stage as fresh dates, or processed to make dry dates and chhuhara. Dates which are consumed at khalal stage are Otakin, Kurh, Dedhi, Mithri are known as soft dates and has the sweet test.

The dates consumed at rutab and tamar stages are Aseel, Karbalain, Dhakki, Fasli, Kupro, Kashuwari. The dates which are consumed at tamar stage only is Khar, and is ripened on the tree. Generally, dates are consumed at rutab and tamar stages (semi-dry date category) [37], or at khalal stage (soft type) date category and the dates which are only consumed at tamar stage and ripened on the tree are placed into dry date category. Early date varieties which are harvested in June include Kashuwari and Gajar (both are semi-dry). Kashoowari is consumed at rutab and tamar stages; while, it is inedible at khalal stage due to occurrence of high tannins; whereas Gajar dates are largely utilized to make tamar dates by shaking the khalal stage dates with little quantity of salt and put for a night. Aseel dates remain green during June (Figure 1(a)). Harvesting time of Aseel (Figure 1(b)) is at the end of the July; whereas, the percentage of rutab dates depends on the rise in temperature upto 50°C, but generally only 10% of dates are turned into rutab during this period. Most of the quantity of Aseel dates is used to make yellow and brown chhuhara (boiled dried dates) [15]. Yellow chhuhara are prepared using sodium formaldehyde sulphoxylate in boiling water in an open pan; however, brown chhuhara are prepared with boiling of khalal stage dates in water without using any type of chemicals.

3. POST-HARVEST MANAGEMENT OF DATES

3.1. Harvest of Dates

Generally, the harvest of Aseel dates is done in the last week of July in Khairpur district; while harvesting of Begum Jangi originally belongs to Balochistan province of Pakistan is done during third week of August. Khalal stage dates of Begum Jangi were observed as rain tolerant in district Khairpur because the fruit skin does not break during heavy rains; therefore, such varieties can be cultivated on commercial level in the area. Post-harvest management of dates is crucial stage during which the harvested khalal stage dates are processed differently, i.e., either to make dry dates or chhuhara (brown and yellow). After harvesting, first step is the picking of rutab dates in the bunches which are sold as fresh as well as dried under sun to make tamar dates to keep for off-season. Date varieties of soft type consumed at khalal stage include Otakin, Kurh, Dedhi, Mithri are sold immediately as fresh dates after harvest [38], or processed to make chhuhara to preserve for off-season. Date varieties which are known as semi-dry are sold as fresh (Kashuwari, Naqul Kurh, Khar, Fasli etc.) or processed to make chhuhara and tamar dates (Aseel, Karbalain and Dhakki) after drying under sun [4]. Harvested khalal dates (without rutab dates) are spread on the mats under sun for drying and processing for 4-5 days. After harvest (Figure 2(a)); first step is separation of khalal stage dates carefully from bunches using wooden forked instrument (Figure 2(b)). Dates are immediately washed and kept in a large pan for boiling (Figure 2(c)), and kept under sun for 4-5 days to make chhuhara (Figure 2(d)), or khalal dates are directly spread on mats under the sun for 4-5 days for making tamar dates.

4. DATES CONSUMPTION BEHAVIOR

4.1. Soft Dates

Dates which can be consumed at khalal stage contain low tannins and high sugar concentration, and are not further processed to make tamar are

Fig. 1. (a) Date palm cultivation behavior in Sindh and (b) Date palm cultivar Aseel with fruit showing the number of bunches with dates at harvesting time.

Fig. 2. Processing of khalal stage dates for preparing chhuhara and tamar dates. (a) bunches just after harvest, (b) fruit separation from bunches, (c) boiling of khalal dates for preparation of chhuhara, and (d) spread of boiled dates on mats for sun drying process.

classified as soft dates. Dates are consumed at different ripening stages except kimri, depending on the variety and chemical composition of dates [4]. Some date varieties known as soft contain low tannins and 50-85% moisture content are usually consumed at khalal stage such as Otakin, Dedhi, Kurh and Mithri grown in district Khairpur, Pakistan [33]. Soft dates contain high sugar content and are crispy and sweet in taste. Dates at khalal stage are harvested earlier during the season, and therefore, are a good source of income for the growers [38]. Dates with low tannins at khalal stage can be consumed, but soft type date varieties are rarely found in Pakistan. International commercial date varieties consumed at khalal stage are Zaghloul, Barhi, Hayany and Khalas. Barhi is sold in France, England and Australia; whereas, other three date varieties are mainly consumed locally [39].

4.2. Semi-dry Dates

Dates consumed at rutab and tamar stages are classified as semi-dry dates. Rutab is the fourth stage of the fruit growth after khalal. Most semi-dry dates cannot be consumed at khalal stage due to high tannins such as Aseel, Kashuwari, Kupro etc. Rutab dates are a good source of income when sold as fresh, but in Pakistan poor storage conditions and packaging are big hindrances to obtain attractive prices. Aseel and Dhakki dates are mostly consumed in three forms (rutab, tamar and chhuhara) (Figure 3(a-d)) and date varieties grown in Balochistan, Pakistan are consumed as tamar (Figure 3(e)). Selected tamar dates of Aseel are consumed as table dates contain high amount of sugars and other food supplements required in daily diet. Dates are immediate source of energy,

Fig. 3. (a) Rutab stage dates of Aseel (semi-dry), (b) Rutab stage dates of Kashuwari (semi-dry), (c) Tamar stage 'A' grade dates of Aseel consumed as table dates, (d) Yellow chhuhara of cv. Dhakki consumed locally as well as exported to India, and (e) Different date varieties grown in Balochistan, Pakistan which are consumed at tamar stage. (Photos of (e) were taken by Summar A. Naqvi: University of Agriculture, Faisalabad, Pakistan).

generally in the form of rutab and tamar [40-43]. Kashuwari is the early date variety contains high tannins at khalal stage and is inedible; while, it is consumed at rutab and tamar stages [44] (Figure 3(b)). Kashuwari dates are picked from bunches at rutab stage, and directly sold in the markets. Dates are eaten as fresh, dried (tamar and chhuhara), or processed to make different products. Generally, the dates are consumed fresh after picking at rutab stage. Dates of some cultivars are consumed at rutab and khalal stages. Mainly dates are consumed at fully ripened stage (tamar). Dates at tamar stage contain very low moisture and can be stored for long period to be consumed during off-season [45].

4.3. Dry Date Varieties

Dates are classified as dry dates can be consumed only at tamar stage due to high amount of tannins at khalal and rutab, whereas, the moisture content of dry dates can be 20% at tamar stage, whereas, moisture content can be reduced depending on the soil type and climate. Dry date variety grown in Sindh, Pakistan is Khar. Ajwa cultivated in Al-Madinah, Saudi Arabia belong to dry date variety which can be consumed at tamar stage only is cultivated in Shah Abdul Latif University, Khairpur and some other places in Pakistan for field performance. Ajwa trees are fruiting well, but the moisture content of the fruits is higher than the moisture content of the Ajwa dates in its original place, i.e., Al-Madinah, Saudi Arabia. Dry date cultivars are less important due to heavy monsoon rains in Sindh which destroy the 30-50% of the crop every year. Hence, it is difficult to save the dry date cultivars up to ripening stage.

4.4. Chhuhara (Brown and Yellow)

Chhuhara is an alternative source of long-term dates storage for consumption, mostly in the form of brown chhuhara; whereas yellow chhuhara are mainly exported to India. Brown chhuhara is also used to make halwa (pudding) locally. Chhuhara can be stored for long periods due to low moisture content compared to tamar dates. Chhuhara are of two types (yellow and brown). Yellow chhuhara are prepared from khalal dates using sodium formaldehyde sulphoxylate in boiling water (Figure 3(d)) for fifteen minutes. Brown chhuhara are prepared with boiling of khalal stage dates only in water without using any type of chemicals.

5. DATES EXPORT AND VALUE-ADDED PRODUCTS

5.1. Dates Export

Dates production of Pakistan is about 5328795 tonnes cultivated on 102676 hectares and average yield per hectare is 518 tonnes [46]. In the year 2022; Pakistan exported 12124446 million tonnes of dates to different countries. Countries importing the dates from Pakistan are Canada, Malaysia, India, USA, Denmark, UK, and Germany [47]. Pakistan is one of the active exporters of dates and ranked 8th in export of dates to different countries like India, Germany, USA, UK, Turkey, Japan, Australia, Srilanka, Nepal and Bangladesh as fresh, dried, pitted and chopped dates. Different dates factories have been established in Therhi, Khairpur, Pakistan exporting mostly pitted and chopped dates of Aseel and Begum Jangi throughout the year. Tamar dates are packed in 40 kg wooden box by the farmers and sold in the local markets in Khairpur, Sukkur, Lahore and Faisalabad in Pakistan. Large wooden boxes are filled by pressing the dates which cause damage of dates' skin and cause the change in natural shape of dates, results in low prices in the market. Several factors, such as physical, physiological, pathological disorders and insect infestation are involved in post-harvest losses in quantity and quality of dates [48, 49]. It is recommended that packing boxes of dates (made of paper) should be limited to 10 kg which will definitely save the dates to be damaged or pressed. Grading of dates (Figure 4(a)) is an important aspect for getting higher prices at each date consumption stage. The graded dates were filled in the 10 kg paper boxes covered with plastic sheet for fumigation for 3 days (Figure 4(b)) before export. Quality factors in the codex standard for dates include the following: (i) dates should have the characteristic color and flavor for the variety, be of proper stage of ripeness, and be free of live insects and insect eggs and mites; (ii) moisture content should be 26%-30% depending on the variety; (iii) minimum fruit size should be 4.75g (unpitted) or 4.0g (pitted); (iv) absence of defects, such as blemishes, mechanical damage, unripe, unpollinated, embedded dirt or sand, damaged by insects and/or mites, souring, mold and decay. Consumers always prefer the selected fresh or dried dates used as table dates. Maintaining the organoleptic characteristics of dates are of great importance in dates industry regarding export. Poor

Fig. 4. (a) Women making grading of dates at Therhi, Khairpur (b) Fumigation of pitted dates for three days before export, (c) Dates paste balls with Sesame seeds, (d) Dates halwa with almonds, (e) Date bars with pistachio, and (f) Date paste balls with chopped almonds.

post-harvest practices of dates processing result in low quality of dates which should be improved to meet the international standards. Heavy winds and monsoon rains result in inferior quality of dates. However, during normal circumstances when there is no rain and winds, the quality of dates can be improved as per international standards by keeping the dates free from dust and undamaged skin during processing and packaging. Active dates exporter in Khairpur is "Khairpur Foods International" exporting dates to USA, UK and Germany as pitted and chopped dates. Quality of dates can be improved through proper management at each stage of processing. Utilization of latest technologies in post-harvest processing of dates can improve the quality of dates like solar tunnels on large scale but small farmers cannot afford to process the dates in solar tunnels due to high cost and some technical issues in drying of dates under the tunnel; which are difficult to handle like high humidity collects inside the tunnel. Pakistan earns lowest rates of dates in international markets due to lack of latest technologies compared to other countries earning five times extra revenue than Pakistan in dates sector. Tunisia, produces 2.7% of the world dates production and earns $2433/ton; compared to Pakistan earns only $565/ton. Inappropriate post-harvest practices and lack of knowledge about post-harvest technologies result in earning small revenue in international markets. Date palm growers are being faced by several hurdles in boosting the dates sector regarding dates export. Dates sector can have a significant contribution in boosting Pakistan's economy; improving the export by facilitating the farmers with latest technologies, sharing information to the farmers in major dates producing areas [34]. Annual dates festival in district Khairpur arranged by the district government in collaboration with several agencies and institutions such as, Date Palm Research Institute, Shah Abdul Latif University, Khairpur, Pakistan related to the agriculture is one of the key platforms for knowledge concerning post-harvest techniques of dates management and processing. It is worth mentioning that Pakistan organized 1st Pakistan International Date Palm Festival during 4-6 October, 2024 at expo centre Karachi in collaboration with United Arab Emirates to showcase different date varieties of Pakistan and to discuss the several problems related to dates and date palm.

5.2. Value Added Products

Dates can be utilized as fresh as well as different value-added products [50], such as, date paste balls with sesame seeds (Figure 4(c)), date paste halwa with almonds (Figure 4(d)), date paste bars with pistachio (Figure 4(e)), date paste balls with chopped almonds (Figure 4(f)). In Khairpur, Pakistan there is no any factory working on value added products of dates as per international standards. However, other countries like USA, UK, Germany and Japan importing dates from dates producing countries for utilization in different products like date juice, date paste, alcohol and in different bakery products. In Therhi, Khairpur dates are used to make date halwa, date pickle and date juice are prepared in small shops locally which do not ensure storage conditions and quality of international standards.

Government should focus on the establishment of factories for manufacture of different value-added products from dates.

5.3. Date Paste

Date pastes are characterized by their high sugar content in the form of glucose and fructose (reducing sugars). The amount and type of sugar change according to variety and ripening stage. The absence of sucrose in some cultivars has been explained by the environmental and genetic factors that may affect the qualitative and quantitative composition of the sugar by altering the activity of the enzymes involved in the synthesis and breakdown processes.

6. DATE PALM PROPAGATION (SEEDS AND OFFSHOOTS)

6.1. Seed Propagation

Easiest and quick way of date palm propagation is by naturally occurring seeds. Seed propagation does not ensure production of true-to-type plants; hence, the seed grown date palm is utilized only for breeding. The selection of date palm propagated via seeds is an economical way which may show some desirable traits such as rain or salt tolerance and increased production in the newly selected trees propagated via seeds. Date palm is dioecious; therefore, always show variation in plants propagated through seeds [8]. Generally, the seed grown date palm develops into either male or female trees; which produce mostly fruits of inferior quality due to its heterozygous nature [5]. Current genetic resources of the date palm obtained through selection are challenging due to dioecious nature i.e., seed grown date palm always produce fruits of inferior quality [51]. Therefore, the selection of elite commercial varieties via seed propagation is very difficult and time consuming but simultaneously, seeds can be exploited to get new varieties. Generally, the farmers prefer the propagation of date palm through offshoots which are produced around each tree during early age. Beside these difficulties some farmers are trying to select varieties of date palm grown through seeds (selection). Date palm farm established in Sukkur, Sindh by active farmer Mr. Imam Bux Jatoi who did selection of seed grown date palm at the time of fruiting. Varieties which produced good quality fruits (Figure 5(a-i)) were left to grow further, while the varieties which produced fruits of inferior quality were cut down and were utilized only for landscaping wherever required. Date fruits shown in the Figure 5(a, c-d) are brown at tamar indicate that these fruits were yellow-coloured at khalal stage. Date fruits shown in the Figure 5(b) and Figure 5(e-i) convert into black/dark brown coloured fruits at tamar stage; indicate that these fruits were red-coloured at khalal stage. Selection of the date palm trees was obtained through twenty years of continuous efforts. Further research should be conducted at genetic and biochemical level to check genomic constitution and food grade nutrients in the dates obtained through selection. There is need to work further on selection of date palm propagated through seeds; because the natural disasters due to climate change such as, floods and heavy rains are the big threats towards the cultivation of date palm in Pakistan.

Fig. 5(a-i). Fruits of the different seed grown varieties of date palm obtained through selection cultivated in district Sukkur, Sindh, Pakistan.

6.2. Offshoot Propagation

Date palm propagation via offshoots ensures production of true-to-type fruits [8]. There is no risk of genetic variation in the trees propagated via offshoots obtained from the parent tree. However, a tree produces 10-20 offshoots in its life [7]. In case of rare cultivars of date palm, the offshoots cannot fulfil the need due to the limited availability [1]. Offshoots can be easily available for the predominant cultivar Aseel but simultaneously most of the elite commercial date cultivars belong to soft (Otakin, Kurh and Dedhi) or semi-dry types (Kashuwari) are rarely found in different orchards in the area; therefore, is difficult to get offshoots of these varieties. The homogeneity of fruiting depends mainly on the uniformity of the initial offshoots during an orchard establishment. Nursery can provide farmers with uniform plants, their required number, complete root and free from symptoms of disease and insects. Farmers at Khairpur used to cultivate the detached offshoots at the same orchard among the adult date palms which reduced the distance between the trees and increased the moisture. The ideal distance between the trees should be 24 feet. Intercropping the vegetables result in devastation of offshoots by Diplodia disease (*Diplodia phoenica*) infection causes a substantial proportion of the new cultivation mortality. In order to establish a date palm nursery, few specifications and precautions should be taken in consideration such as, selection of an ideal offshoot which includes the age must be not less than 3 years, weight should be 10-25 kg and diameter of the wider part of stem should be 0.5-1.0 foot. Healthy and having a separate root system, and clear from any disease or pest symptoms. Further, offshoots should not obtain from an infected area.

7. OFFSHOOT DETACHMENT AND CULTIVATION IN THE FIELD

7.1. Offshoots Selection

Numerous factors regarding offshoot selection (size and weight of an offshoot), upper or lower offshoots produced around a tree, origin, offshoot removal method, preparation for cultivation in the field, post-cultivation treatments to save from the disease and pests [52]. Offshoots are produced around each date palm tree during its early stage of growth in the field (Figure 6(a)). 2-3 years old offshoots (10-25 kg) with wider part of stem (0.5-1.0 feet) (Figure 6(b)), can be detached from the parent tree for cultivation in the field (Figure 6(c)), and in this way each newly cultivated offshoot produce 10-20 offshoots once established in the field. During detachment of offshoots, it should ensure first that tree should be free from any type of disease and pests. During detachment extra fronds of offshoots should be cut down from the base. Offshoots are removed using chisel made of iron which is used to cut down the side of offshoot attached to the parent tree (Figure 6(a)). Roots and base of offshoots should not be damaged during removal from the tree; because the offshoots with damaged roots will not survive in the field. Considerations related to offshoot selection and detachment include, cutting-off the non-erect outer fronds and trim other fronds and ties them with a rope. Dipping or spraying the

Fig. 6. Offshoot detachment from parent tree and cultivation in the field. (a) Removal of offshoot from parent tree, (b) Preparing offshoot for cultivation in the field, (c) Cultivating offshoot in the field, (d) Offshoot cultivated in the field, and (e) Well developed offshoots in nursery, shifting for cultivating in another field.

offshoot with copper-based fungicides such as, Benomyl (Bavistin), Thiophanate Methyl (Topsin M) and Bordeaux mixture has been found effective against the Diplodia disease. Immerse the offshoot base in the fungicide solution 3-5 grams per liter for 4-5 minutes then leave for a while. Cover the base of detached offshoots with wetted piece of cloth and covering the fronds if possible. Spraying with pesticide to the cut surfaces which made in the mother palm or the offshoot; is important to avoid Red Palm Weevil attack; since, the smell of fresh date palm tissues attract the insects, and enter through any injured area of the tree trunk.

7.2. Irrigation

After removal from parent tree, the offshoots should immediately cultivate in the field (Figure 6(d)) and should be irrigated regularly as per need until it starts to grow properly in the field and its roots go deep inside the soil. Regular irrigation of the planted offshoots can be managed well by drip irrigation systems [15]. Irrigation to newly cultivated offshoots should be carried out as needed regularly; otherwise, the growth of roots will be stopped, which will suddenly cause drying of whole plant gradually. Irrigation requirement of offshoots depends on the soil types. Daily irrigation should be carried out to the offshoots planted in sandy soils during the first summer. Offshoots planted in clay soils should be irrigated once a week; whereas, irrigation is carried out every second or third day in most of the soils. Planted offshoots should be monitored regularly during first six weeks of planting until start of new growth and make sure that soil surface should remain wet around the planted offshoot and should not shrink away. Offshoots should be covered with a mulch of hay or straw may enhance moisture, control weeds and improve humus.

7.3. Field Preparation

Hole in the field for cultivation of offshoot is prepared according to offshoot size. Basal side of offshoot up to 1.5 feet should be submerged in the field. Fertilizer treatments should start when the offshoot start to grow well in the field.

7.4. Tree Management after Offshoot Excision

After removal of offshoots the damaged side of parent tree should be sprayed with systemic fungicide (Carbendazim) to save the tree from all types of fungal infections, and insecticide (Polytrin-C) to protect the tree from the attack of Red Palm Weevil and other types of insects. The injured side of the tree then must be covered completely with mud. Pesticide treatments should be repeated 2-3 times after every week on the open side of trunk of parent tree after offshoot removal [15].

7.5. Date Palm Nurseries

Offshoots exhibit lower survival rate in the field, when cultivated directly without growing further in the small nurseries (Figure 6(d)). During detachment of offshoots from the tree results in damage to the offshoot's base resulting in the lower survival rate in the field. However, growing the newly detached offshoots in nurseries before planting in the fields resulted in the maximum survival rate when shifted to another field. Recently, most growers applying such techniques (Figure 6(e)). In nurseries, offshoots develop better roots and canopy in two years, ready to cultivate in another field (Figure 6(e)) to get 100% survival rate.

8. MICROPROPAGATION AND FIELD EVALUATION OF TISSUE CULTURE DERIVED DATE PALM PLANTS

Micropropagation of date palm is the production of plants from cell, tissue or organ culture under sterile conditions inside the laboratory [53] (Figure 7(a)). Plantlets about 15 cm long can be acclimatized in the greenhouse for further growth (Figure 7(b)), and after growing in the greenhouse for two years, the plants were shifted in the open field (Figure 7(c)) for further vegetative growth and fruiting (Figure 7(d-i)). It is worth mentioning that Date Palm Research Institute, Shah Abdul Latif University, Khairpur, Pakistan successfully produced three thousand plants of three elite local cultivars of date palm (Dedhi, Kashuwari and Gulistan) originally belonged to Pakistan and three exotic cultivars (Samany, Bertamoda and Barhi) through micropropagation process using offshoot and inflorescence explants [11, 12]. All cultivars of date palm showed normal vegetative growth and produced true-to-type fruits [38]. Tissue cultured plants were disseminated among the active date palm farmers for cultivation in different fields in

Fig. 7. (a) Tissue culture derived plantlets of date palm, (b) Micropropagated plants in the greenhouse ready for shifting in open field, (c) Tissue cultured plants growing in the field, (d) Tissue cultured plants at fruiting stage in the field, (e-f) Tissue culture obtained date palm cultivars Gulistan and Kashuwari respectively with fruits, (f, g, h, i) True-to-type fruits of date palm cultivars Samany (Egypt), Dedhi, Kashuwari and Gulistan respectively.

districts Khairpur and Sukkur, Pakistan. Tissue cultured cultivars include belong to soft type (Dedhi, Samany, Barhi), semi-dry (Kashuwari, Gulistan) and dry (Bertamoda) cultivars [44, 11]. More than 70 date palm growers cultivated tissue cultured plants of different varieties produced in Date Palm Research Institute which are currently ten years old and all the trees are bearing normal fruits (Figure 7(e-i)).

8.1. Field Performance of Exotic and Local Cultivars of Date Palm

8.1.1. Exotic cultivars

Field performance of different exotic cultivars of date palm was carried out in Research Orchard of Date Palm Research Institute, Shah Abdul Latif University, Khairpur, Pakistan. Orchard includes eight cultivars of date palm belong to Balochistan, Pakistan are Aab-e-dandan (Figure 8(a)), Begum Jangi (Figure 8(b)), Gogna (Figure 8(c)), Halini (Figure 8(d)), Kooznabad (Figure 8(e)), Muzawati (Figure 8(f)), Pashna (Figure 8(g)) and Shakri (Figure 8(h)), and three cultivars of Saudi Arabia, i.e., Ajwa (Figure 8(i)), Safawi (Figure 8(j)) and Ruthana (Figure 8(k)). Offshoots of Saudi Arabian date palm cultivars were brought from Al-Madinah, Saudi Arabia in the year 2005, and planted in orchard [54]. Studies conducted on the tree and fruit evaluation confirmed that all three varieties of Saudi Arabia showed normal vegetative and fruit growth including number of bunches, bunch weight, fruit size, shape, weight and taste [4]. All fruit characteristics were similar to the fruits of parent trees as in Saudi Arabia.

Fig. 8. (a) Aab-e-dandan, (b) Begum Jangi, (c) Gogna, (d) Halini, (e) Kooznabad, (f) Muzawati, (g) Pashna, (h) Shakri, (i) Ajwa, (j) Safawi, and (k) Ruthana.

8.1.2. Local cultivars

Field evaluation performed for eight date palm cultivars of Balochistan, Pakistan include Aab-e-dandan, Begum Jangi, Gogna, Halini, Kooznabad, Muzawati, Pashna, Shakri (Figure 8(a-h)) showed that all trees produced normal fruits as fruiting in their native place (Balochistan). Due to variations in soil and climatic conditions of Khairpur district of Sindh and Balochistan; fruits produced in trees in climate of Khairpur were healthier than fruits in their native place; reason could be raised water table in this area; which provides enough water to the trees for vegetative growth and fruiting. This phenomenon is general for all date cultivars in the area except those growing in mountainous soils at Shadi Shaheed, Khairpur, Pakistan. Fruits of date palm growing in mountainous soils contain less moisture due to lower water table; hence, such fruits have long shelf life compared to fruits obtained from all non-mountainous soils [33]. Dates of Ajwa (Figure 9(a)) and Safawi (Figure 9(b)) are red at khalal stage, while Ruthana (Figure 9(c)) is yellow at khalal [4]. Two date palm cultivars of Balochistan (Muzawati (Figure 8(f)) and Shakri (Figure 8(h)) were red-coloured fruits at khalal stage, while rest of the cultivars including Halini (Figure 9(d)) and Begum Jangi (Figure 9(e)) were yellow coloured at khalal stage. Field performance of different exotic cultivars recommends introducing same and other date cultivars in the area in addition to existing cultivars of date palm. New varieties of date palm may have resistance to decline disease which is one of the major threats in this area. Additionally, there are few commercial varieties; and most of them belong to soft types which are consumed as fresh at khalal stage and cannot be stored in the form of tamar dates. Growers have established date palm orchards of exotic cultivars at Dera Ghazi Khan, Pakistan in the supervision of Agriculture University, Faisalabad, Pakistan. Trees are at fruiting stage in orchard. Orchard includes elite cultivars of date palm like Sukkary, Medjool, Shishi, Zaghlool, Khalas and Sagai. Additionally, there are several other orchards of the exotic cultivars of date palm in Sindh contained international commercial cultivars, but on small scale.

Fig. 9. Different exotic cultivars of date palm cultivated in district Khairpur, Pakistan: (a) Ajwa, (b) Safawi, (c) Ruthana, (d) Halini, (e) Begum Jangi, and (f) Shakri.

8.1.3. Field evaluation of tissue culture derived date palm

Solangi *et al*. [11] conducted a comprehensive study on micropropagation and field transfer of micropropagated plants of cvs. Samany and Bertamoda, and confirmed that all plants produced true-to-type fruits in the field. Solangi *et al*. [12] also conducted another comprehensive study on micropropagation of date palm cv. Barhi using shoot tip explants; evaluated tissue cultured plants in open field, and observed production of true-to-type fruits in open field trials conducted in agro-climatic conditions of district Khairpur, Sindh, Pakistan.

9. INTERNATIONAL VARIETIES OF DATES

9.1. Ajwa

Date palm cultivar Ajwa cultivated largely in in Al-Madinah, Saudi Arabia. Fruit is oval-shaped, medium sized (3.38 cm long and 2.68 cm in diameter). Fruit colour is red at khalal stage which turns into black at tamar. Ajwa cultivation surrounds Al-Madinah, yield thousands of tons of dates which are consumed locally as well as exported to Pakistan and other countries. Moisture content range of Ajwa dates at tamar stage is 10%-25% (Figure 10(a)).

9.2. Medjool

Date palm cultivar Medjool or in Arabic “majhul” which means unknown is a sweet and large in size (3-6 cm long and 2-3 cm in diameter), yellow colour at khalal stage and brown colour at tamar stage, cultivated originally in Tafilalt, Morocco. In addition, it is also grown in USA, Saudi Arabia, Israel, Jordan. Moisture content percentage of

Medjool dates range from 17%-25% at tamar (Figure 10(b)).

9.3. Mabroom

Mabroom dates fall into dry date cultivar similar to Ajwa dates but are narrow and large in size, are mainly grown in Saudi Arabia. Mabroom dates are brown colored. Mabroom dates may have size (6-8 cm long). Dates are sweet in taste and chewy. Mabroom dates are long and slender (Figure 10(c)).

9.4. Lulu

Lulu dates cultivated in south of Iran is small in size and delicious in taste with moisture content less than 15%. It has an extended shelf life (18 months) under normal room temperature. Size of Lulu dates is 1.5-2 cm and weight is 3-5 grams. Fruit colour is dark brown at tamar (Figure 10(d)).

9.5. Zahidi

Zahidi is one of the important commercial cultivars of date palm, cultivated largely in Iraq. It has light brown skin at tamar. Dates fall into a semi-dry date category with medium size (3-4 cm). Moisture content of dates is about 12% at tamar stage (Figure 10(e)).

9.6. Shishi

Shishi dates are brown coloured, oval shaped, with thick skin and somewhat dry texture. Shishi is a distinct reddish-brown coloured variety, caramel-like flavour and soft and chewy texture (Figure 10(f)).

9.7. Khalas

Khalas is oblong, oval-shaped fruit widely cultivated in Saudi Arabia, Persian Gulf and United Arab Emirates. It covers large area in Oman and is considered as original cultivar in the region. Fruit size of Khalas is 4.4 cm x 3.0 cm. Khalas is expensive date variety with brown skin colour (Figure 10(g)).

9.8. Muzafati

Mazafati is generally grown in Iran Bam, Ji-roft, Kahnuj in Kerman province, Saravan, Nikshahr, Haji Abad. Muzafati dates are soft, fleshy, sweet, medium sized (2.5–4.5 cm). Moisture content of dates at tamar stage is 32%-35%. Harvest time vary with varying location of orchards (Figure 10(h)).

9.9. Zaghlool

Zaghloul dates are basically grown in Egypt and also cultivated in India. Cultivation of date palm in Egypt was carried out 4000 BCE after Pakistan and eastern Arabia. Zaghloul dates cultivated largely in district Kutch, India on the west coast beside southern border of Pakistan. Size of Zaghlool dates is about 7 cm long, with red fruit colour at khalal stage (Figure 10(i)).

9.10. Siwi

Siwi dates are native to the Egyptian Oasis from which this delicious fruit derives its name. The Siwi date is renowned for its creamy texture and golden brown color (Figure 10(j)).

9.11. Deglet Nour

Deglet Nour is a famous date cultivar whose name originates from Arabic *daqlatu (a)n-nūr*, literally, called “date palm of light”, “heavenly date” from oldest Arabic daqal, a type of date palm cultivar originated in Tolga oasis, Algeria (Figure 10(k)).

9.12. Sagai

Sagai date cultivar originated in Arabian Peninsula and also propagated in Saudi Arabia. Sagai dates are famous for their two-toned colors. Tip of dates is golden and dry, while remaining part of fruit is soft and brown (Figure 10(l)).

9.13. Sukkary

Sukkary is a famous Saudi Arabian date cultivar. Fruit skin is light yellow or golden brown with fruit size 4.0 cm long and 3.0 cm in diameter. Sukkary dates are soft and extremely sweet (Figure 10(m)).

9.14. Safawi

Safawi dates are a special variety of dates mainly grown in Saudi Arabia, Al-Madinah region. Safawi dates are a soft, semi-dried date variety characteristically identified by their particular

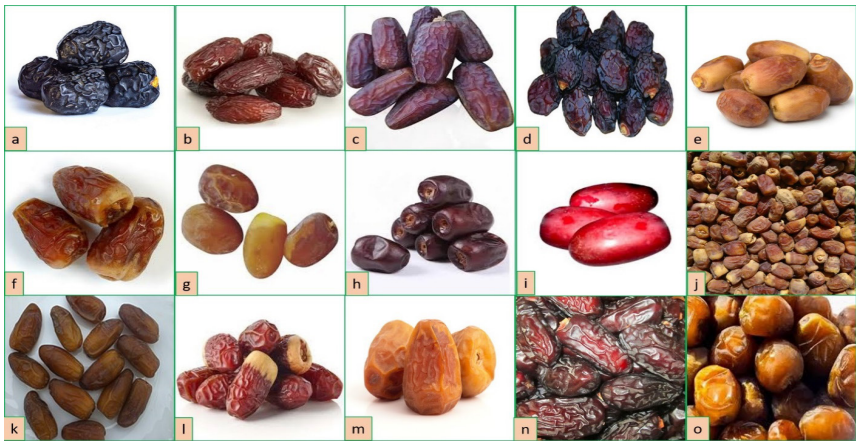

Fig. 10. International commercial varieties of dates: (a) Ajwa, (b) Medjool, (c) Mabroom, (d) Lulu, (e) Zahidi, (f) Shishi (g) Khalas, (h) Muzafati, (i) Zaghlool, (j) Siwi, (k) Deglet Nour, (l) Sagai, (m) Sukkary, (n) Safawi, and (o) Barhi.

dark brown colour at tamar stage, their length, and medium-size (Figure 10(n)).

9.15. Barhi

Barhi dates are a rare variety of dates native to Iraq, and belongs to the soft date type. It is very sweet in taste, crispy, and is consumed mainly at khalal stage. Barhi date palms were introduced from Basra, Iraq in 1913. Meaning of the name Barhi is possibly associated with the hot summer winds "bahr" at Basra. Size of the Barhi dates is 2-4 cm long and 2-3 cm in diameter. Barhi has earned the name in the international markets, where it is sold at high prices. Moisture content of Barhi dates at Khalal stage is about 60% (Figure 10(o)).

10. DISEASES IN DATE PALM (SUDDEN DECLINE DISEASE AND RED PALM WEEVIL)

Date palm is threatened by the sudden decline disease (bayoud like disease) and the Red Palm Weevil [55-59].

10.1. Sudden Decline Disease

Bayoud Arabic "Abiadh" meaning white, refers to the whitening of fronds of infected date palm. Bayoud was reported initially in 1870 in Morocco. Disease had already affected several date palm orchards in 1940, and after a century, disease had infected all Moroccan date palm orchards and western and central Algerian Sahara [60, 61]. In decline disease whole the crown of the mature date palm tree dried within 2-3 months (Figure 10(a-b)) depending on severity of disease in different areas. Decline disease was started few decades before in the area. Maitlo *et al*. [62] identified the pathogen and possible remedy to cure the disease. Identified pathogen was *Fusarium solani* which could be cured with a systemic fungicide Bavistin-DF (Carbendazim). The recommended dose of fungicide to control the disease is 3 g l^{-1}. Fungicide should be applied on the tree base and crown as needed to ensure that the fungicide completely reaches to the infected roots and base of fronds in the crown [62]. Initially, disease symptoms appear on the leaves starting from one side of the frond gradually spread to other side in this way whole the crown of the tree fall down in 2-3 months. Drying of fronds showed similar symptoms of Bayoud disease caused by *Fusarium oxysporum* in Morocco and Algeria [60, 63]. Decline disease destroyed many orchards and dispersed trees in district Khairpur [64]. Infected trees are increasing day by day. In some areas disease severely affected huge number of date palm trees. Recently, sudden decline disease is a big threat to current date palm cultivation generally in Khairpur (Figure 11(a-b)). Additionally, it restricts the extension of new cultivation in the area. In district Khairpur, after heavy rain and flood during the year 2022, it is expected that more than 0.1 million adult date palm trees have been destroyed with decline disease and number of infected trees is increasing day by day. Currently, it is recommended that diseased trees should thoroughly cut down and burned. On the other side un-infected trees should be treated with systemic fungicides as per recommendations of available literature. Previous studies observed

that decline disease is soil borne pathogen which infecting roots first causing blockage of xylem vessels which definitely stop transport of water and nutrients to aerial parts of the tree. Current disease situation is also result of the standing of the rain and flood water in the fields of date palm orchards caused rotting of the roots which is major cause of the spread of the disease in the area during floods in 2022.

10.2. Red Palm Weevil (*Rhynchophorus ferrugineus*).

Red Palm Weevil (RPW) is insect which eat soft tissues inside the trunk [65]. Generally, it enters in the trunk after removal of offshoots around the tree, if the injured side of the trunk are not sprayed with insecticide or not covered with mud [66]. In some cases, RPW enters in the trunk during growth of soft roots around the trunk [67, 69]. Slowly, RPW enter in the trunk and make the permanent big holes if tree is not cured or sometime trees fall down. Treatment with fumigating tablets Phosphotoxin (Aluminum phosphide 55%) is generally carried out. Tablets are applied in the holes, the insects are going through the holes inside the trunk, covered with a piece of plastic and then with mud. The treatments should be repeated until RPW is completely destroyed. Aluminum phosphide reacts with atmospheric moisture to liberate phosphine gas which kills the RPW [15]. International methods to control RPW include plant quarantine (transport of infected date palm should avoided), cultural (avoid cuts and injuries), mechanical (burn immediately all infected tissues), trapping (destroying the Weevil by trapping), biological and chemical (chemical control of RPW is very effective and applicable. RPW complete its life cycle during attack on the tree. Growth stages of RPW include egg (Figure 11(c)), larva (Figure 11(d)) and adult with wings (Figure 11(e)). Generally, insects cause harm to the tree at larva stage (Figure 11(d)), while at adult stage, RPW comes out to the tree trunk and fly to attack other trees and for reproduction. Adult Red Palm Weevil go inside the fibrous sheath covering around the trunk, and lays eggs which grow into feather less larva, and go inside the trunk for food; therefore, the control at initial stage is important to save the tree from further damage to the tree.

11. CONCLUSIONS AND RECOMMENDATIONS

This review study conclude that Pre- and Post-harvest practices are still need to be improved in the area. There is no applicable method to save the trees from monsoon rain and only fruits of early date varieties harvested before onset of monsoon rains can be saved. Different date factories exporting dates to other countries rely on the quality of dates prepared by the farmers which need to be improved according to international standards. Selection of new varieties of date palm through seed propagation is difficult and time consuming. Field evaluation of exotic cultivars showed that soil and climate of district Khairpur are suitable for cultivation of commercially important date varieties. Micropropagation is an alternative way and is an applicable procedure to multiply elite and rare date varieties for the cultivation in the area. Elite cultivars of date palm (Dedhi, Kashuwari, Gulistan, Samany and Barhi) have

Fig. 11. Adult trees of date palm infected with Sudden Decline Disease after heavy rains (a-b). Different growth stages of Red Palm Weevil, (c) egg, (d) larva, and (e) adult.

been successfully multiplied through tissue culture technique which must be extended to commercial level. Currently, date palm in Sindh is suffering from post-flood and rain effects which is big threat to date palm cultivation. It is recommended that fungicides should be applied in the fields which may reduce the disease spread, and the completely dried trees should be cut down and burned. Currently, in Pakistan, is a need for post-harvest management, to cultivate commercial varieties growing in the area and to import offshoots of commercially important cultivars of date palm, which will improve the varietal structure in the area.

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13. CONFLICT OF INTEREST

Authors declare that they have no any conflict of interest.

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