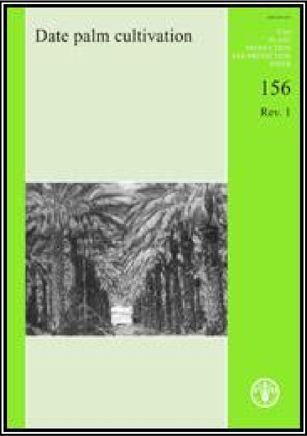

DATE PALM CULTIVATION

FAO PLANT PRODUCTION AND PROTECTION PAPER

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Rev. 1

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FOREWORD

This publication attempts to provide a basic introduction to date palm propagation, production and protection, and to summarise the body of information that has been acquired concerning date palm cultural techniques. It should serve as a reference volume for research workers, and a source of much more detailed information for extension specialists, date growers and anyone interested in the date palm industry. The book's 12 chapters cover the botanical and systematical description, origin, geographical distribution and nutritional value, economic importance, climatic requirements, orchard management, harvesting, and pest and diseases of date palm.

Illustrations are an essential component in any technical document and the included drawings and photographs have been carefully selected by the authors to assist readers to grasp the salient points developed in each section.

The present publication updates and complements technical information included in the two earlier FAO books: "Dates Handling, Processing and Packaging" (1962) and "Date Production and Protection" (1982).

This was achieved thanks to the enthusiastic cooperation of all the authors who are involved in the UTF/NAM/004/NAM "Date Production Support Programme in Namibia" either as national or international personnel.

Thanks also go to Ms. Delita Strauss and Ms. Lucie Herzigova for their excellent and valuable assistance in typing and formatting the manuscript; and to Me. Sami K. Al-Shahed for the final systematic editing of the second edition.

We sincerely hope that this publication shall prove fruitful and useful. Authors welcome any views or suggestions to assist in improving subsequent editions, so that it remains a meaningful and valuable tool to date specialists.

Abdelouahhab Zaid
Editor

Enrique Arias
Coordinator

PREFACE

One of the areas of excellence of the Food and Agriculture Organization of the United Nations (FAO) is to provide information covering aspects related to its mandate areas. FAO is well known for the quality and quantity of information provided to member countries and will continue to maintain its comparative advantage on disseminating information related to food and agriculture.

This has been the case of information on date palm. As mentioned in the Foreword, the present publication updates and complements technical information included in two earlier FAO books on date palms: "Dates Handling, Processing and Packaging" (1962), and "Date Production and Protection"(1982).

This book updates the existing information on aspects related to date palm production, protection and a number of technologies available for the implementation of a modern date palm industry. It covers a wide array of topics of interest for a diverse clientele formed by researchers, extensionists, farmers and agro-industrialists from all areas of the world where the date industry is already established or where it has the potential to be implemented.

The Crop and Grassland Service (AGPC) of FAO's Plant Production and Protection Division is convinced that this publication is one more important contribution for food production and income generation by different types of farmers, especially those living in the less developed areas of the world. The Service acknowledges the contributions provided by the authors and the invaluable work of its Editor, Dr. Abdelouahhab Zaid, and its Coordinator, Mr. Enrique Arias.

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PRESENTATION

With the present uncertainty in the world food production and the expected increase in demand for food with a population exceeding 6 billion inhabitants, the date palm offers a good food source of high nutritive value; this tree gives many date growing countries in remote areas, the main food for a considerable number of people and provides working conditions to considerable numbers of labourers in the rural areas.

Furthermore, the date palm tree tolerates relatively harsh climatic and soil conditions under which no other crop may give reasonable returns. In fact, date palm which is an irreplaceable tree in irrigable desert lands, provides protection to under-crops from heat, wind and even cold weather, and plays a big role to stop desertification and to give life to desert areas. Its fruit generate good income and foreign exchange earnings. Its dried fruit benches, fronds, leaflets fibre and trunks are utilized in many small industries which provide packing materials for local marketing of fruits and vegetables as well as for many other uses. The tree and fruit by-products offer an extra income.

However, the date palm industry is facing many serious problems, related to low yields, to lack of appropriate packing and presentation and to the limited production of sound industrial date products etc.

The estimated average yield bearing date palm tree in the main date growing areas is around 20 kg, which is very low compared to the average yield of more than 100 kg in some date growing areas (USA, Qassim in Saudi Arabia, Namibia, Israel, for example). The low yields in most countries are due to soil salinity, poor fertility, insect and diseases infestations, lack of maintenance and care due to increasing cost of labour and to shortage of trained personnel to introduce improved cultural practices. As a result of high cost of production and low prices of the produce, farmers tend to neglect or even abandon their gardens.

The packing and presentation of dates in local markets and for export at many date growing countries are not up to the standards which attract consumers and increase the demand for this commodity. The production of high value industrial date products (paste, spread, syrup, liquid sugar, wines, distilled liquors, industrial alcohol, animal feed, organic acids and pharmaceuticals, special foods, etc.) remains very limited.

In light of the above-mentioned problems and obstacles, FAO has been engaged since 1965 in a long-term endeavours to develop the date palm industry in many date growing areas. It organized three technical conferences on the improvement of date production and processing, respectively in Tripoli (1959) and in Baghdad (1965 and 1975) as well as the 2nd Session of the FAO Commission on Horticultural Production in the Near East and North Africa in Algiers (1970). All these meetings recommended to governments of date producing countries to promote research and training in date production, handling, processing and packing. FAO was requested to support the efforts of governments in these matters in all possible ways, and to disseminate scientific and technical information on the improvement of the date palm production, processing and marketing. Many projects were implemented accordingly in order to develop this important crop. In the frame of these projects three documents dealing with date palm were published.

In the FAO Plant Production and Protection papers, a document was published, based on the annual reports of the Date Grower's Institute Coachella, California, and on the papers presented at the three FAO Technical Conferences. Two other FAO Publications "Diseases of the Date Palm" and "the Date Palm" were published respectively in the frame of the Regional Project for Palm and Dates Research Centre GCPN/REM/021/MUL and in the Regional Project on Bayoud Control, UNDP/FAO RAB/88/024. Some others documents, published up to now in some countries were a compilation of the work carried out by different institutes and investigators.

It appears clearly that there is a limited number of technical and scientific documents, based on the experience of their authors.

This lack of information and the scarcity of documents dealing with date palm are related to the limited number of investigators working in this field, given the difficulties encountered in the study of this tree, characterized by its slow growth, height and its nature as well as by its broad geographical distribution. These difficulties are aggravated by the socio-economic environment in many date producing countries.

The present publication has been prepared by Abdelouahhab Zaid, Ex-Chief Technical Adviser of the Date Production Support Programme UTF/NAM/004/NAM, and presently Chief Technical Advisor of the Date Palm Research and Development Project in the United Arab Emirates (UAE/2000/002), and Enrique Arias, FAO Horticulturist Officer, AGP Rome, who have played a significant role in the development of the Date Palm industry in the Southern Hemisphere. Other contributors to this book are scientists acknowledged as world authorities in the field of date palm production, processing and marketing.

Without the dedication and generosity of all those who have voluntarily agreed to give their time and share their experience, this book would not have been written.

As indicated earlier, the present publication is based on the proper experience of the authors as well as to the experience gained in and from FAO projects implemented during the last three decades, and attempts to provide basic information on date palm production, protection, propagation, processing and marketing. It summarizes the body of information that has been acquired by FAO, not only in date producing countries in the Northern Hemisphere but also those in the Southern Hemisphere, and accordingly constitutes the first report on date cultivation in these areas.

The material in this publication has been arranged in a manner to facilitate access to specific information on any aspect of date production, protection, propagation and marketing.

In addition, the illustrations presented in this publication have been carefully prepared by the authors to aid the reader to grasp the salient points developed in each chapter.

It is hoped that this book will be useful to all those interested in the development and improvement of the date industry in all date growing and new potential areas in the Northern and Southern Hemispheres.

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LIST OF COMMON ABBREVIATIONS AND SIGNS

%	Percentage
µ	Micron
=	is a synonym of
£	British Pound
°C	Degree Celsius
2,4-D	2,4-dichlorophenoxy acetic acid
2-iP	N6-(2-isopentyo) adenine
AMR	Amount of Water Required
APW	African Palm Weevil *(Rhynchophorus phoenicis* F.)
AW	Depth of Water
B.C.	Before Christ
B	Boron
Ca	Calcium
CBI	Centre for the Promotion of Imports from Developing Countries
CD	Codex Alimentarius
CF	Crop Factor
CH_3Br	Methyl Bromide
Cl	Chloride
cm	Centimetre
Cu	Copper
DMSO	Dimethylsulfoxide
DNA	Desoxyribonucleic Acid
e.g.	exempli gratia; for example
EC	European Commission
EC	Electric Conductivity
et al.	and others
ET	Evapotranspiration
f.sp.	forma specialis
Fam.	Family
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
Fe	Iron
Fig.	Figure
FOB	Free On Board
g	Gram
ha	Hectare
HACCP	Hazardus Analytical Critical Control Point
IAA	Indol acetic acid
IBA	Indol butyric acid

ISO	International Organisation for Standardisation
kg	Kilogram
km	Kilometre
L	Litre
Lb	Pound
LN	Liquid Nitrogen
LR	Leaching Requirement
m	Metre
m^2	Square metre
m^3	Cubic metre
mg	Milligram
Mg	Magnesium
ml	Millilitre
Mn	Manganese
Mo	Molybdium
MRL	Minimum Residue Limit
MS	Murashige and Skoog medium
MT	Metric Ton
N	North
NAA	Naphtalene acetic acid
NPK	Nitrogen, Phosphorus and Potassium
O	Order
PCR	Polymerase Chain Reaction
pH	A measure of acidity or alkalinity
PVC	Poliyoritan Vinyl Chloride
RAPD	Randomly Amplified Polymorphic DNA
RFLP	Restriction Fragment Length Polymorphism
RPW	Red Palm Weevil *(Rhynchophorus ferrugineus* Oliv.)
RSA	Republic of South Africa
S	South
Su	Sulphur
sp.	Species
TAM	Total available soil moisture
TDS	Total dissolvable solubles
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Program
US$	United States Dollar
USA	United States of America
WHO	World Health Organisation
Zn	Zinc

CHAPTER I: BOTANICAL AND SYSTEMATIC DESCRIPTION OF THE DATE PALM

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Date Production Support Programme

1. Introduction

The botanical name of the date palm, *Phoenix dactylifera L*., is presumably derived from a Phoenician name "phoenix", which means date palm, and "dactylifera" derived from a Greek word "daktulos" meaning a finger, illustrating the fruit's form (Linné, 1734).

Another source refers this botanical name to the legendary Egyptian bird, "Phoenix", which lived to be 500 years old, and cast itself into a fire from which it rose with renewed growth (Pliny, 1489; Van Zyl, 1983). This resemblance to the date palm, which can also re-grow after fire damage, makes the bird and the date palm share this name, while "dactylifera" originates from the Hebrew word "dachel" which describes the fruit's shape (Popenoe, 1938).

2. Systematic distribution

Belonging to the Angiosperms-Monocotyledones, *Palmaceae* is a family of about 200 genera and 1, 500 species (Dowson, 1982). Phoenix (*Coryphoideae Phoeniceae*) is one of the genera which contains a dozen species, all native to the tropical or subtropical regions of Africa or Southern Asia, including *Phoenix dactylifera L.* (Munier, 1973). According to Dransfield and Uhl, (1986) date palm is classified as follows:

- Group: Spadiciflora
- Order: Palmea
- Family: Palmaceae
- Sub-family: Coryphyoideae
- Tribe: Phoeniceae
- Genus: Phoenix
- Species: *Dactylifera L.*

Twelve species of the genus "Phoenix", along with their geographical distribution, were first listed by Chevalier (1952):

Species	**Common Name**	**Distribution**
Phoenix dactylifera L.	Date Palm	Mediterranean countries, Africa and part of Asia; introduced in North America and Australia
P. atlantica A. Chev.		Occidental Africa and Canary Islands
P. canariensis chabeaud.	Canary Palm	Canary Islands and Cape Verde
P. reclinata Jacq.	Dwarf Palm	Tropical Africa (Senegal and Uganda) and Yemen (Asia)
P. sylvestris Roxb.	Wild Date Palm or Sugar Palm	India and Pakistan
P. humilis Royle.		India, Burma, and China
P. hanceana Naudin.		Meridional China and Thailand
P. robelinic O'Brein.		Sri Lanka, Toukin, Annam, Laos and Thailand
P. farinifera Roxb.	Pigmy Palm	India, Ceylon and Annam
P. rupicola T.	Rocky Date Palm	India

Anders.		
P. acaulis Roxb.	Dwarf Palm	Bengaladesh and India
P. paludosa Roxb.	Hental or Juliana Palm	Bengaladesh, Tenasherim, Andaman, Nikobaren and Thailand

Besides date palm, five of the above species bear edible fruit (*P. atlantica* chev., *P. reclinata* Jacq., *P. farinifera* Roxb., *P. humilis* Royle., and *P. acaulis* Roxb.).

Most of the 12 *Phoenix* species are well known as ornamentals, the most highly valued is *P. canariensis* Chabeaud, commonly called the Canary Island Palm. *P. sylvestris* Roxb. is widely used in India as a source of sugar. *P. dactylifera* L. is distinguished from the above two species by several characteristics which could be summarised as follows:

- production of offshoots;

- tall, columnar and relatively thick trunk. If the crown of fronds is included, the date palm could reach a height of over 20 m (Blatter, 1926); and

- dark green leaves, (instead of the shiny green colour of the two other species).

Close relationship among the 12 species is illustrated by the ease of hybridisation and cross-pollination (Moore, 1963; Munier, 1973). Several natural hybrids were hence obtained: *P. dactylifera* X. *P. sylvestris* (India); *P. dactylifera* × *P. canariensis* (Morocco, Algeria and Israel); *P. dactylifera* × *P. reclinata* (Senegal).

Phoenix dactylifera L. has 36 chromosomes (n = 18; 2n = 36) (Beal, 1937), but polyploidy cases were reported by Al- Salih and Al Najjar (1987) with Iraqui date varieties (2n = 64). The same authors reported differences between varieties: Sayer as an early variety (2n = 32) and Khasab, a late variety (2n=36). Furthermore, in both varieties, aneuploidy and euploidy were observed: (Sayer: 32, 34, 36 and 64 and Khasab: 32 and 36).

3. Botanical description

3.1 Vegetative organs

3.1.1 Root system

Being a monocotyledon, date palm has no tap root. Its root system is fasciculated and roots are fibrous, similar to a maize plant. Secondary roots appear on the primary root which develop directly from the seed. These secondary roots produce lateral roots (tertiary roots and so on) of the same type with approximately the same diameter throughout their length.

The date palm root morphology and distribution are illustrated in Table 1.

TABLE 1
Date palm root morphology and distribution

Roots Order	Origin	Form	Average length (m)	Average diameter (mm)	Characteristics
Primary	Trunk base	Cylinder	4 (up to 10)	9.5 (7-12.5)	- vertical - adventitious - no root hair - conic tip - called auxirhyzes and also main roots
Secondary	Primary roots	Similar to primary roots	0.20 - 0.25	3.5	- called mesorhyzes
Tertiary	Secondary roots	Similar to secondary roots but thin	0.02-0.1	0.3 - 1.5	- Low growth - short and - abundant called brachyrhizes

All date palm roots present pneumatics, which are respiratory organs. Roots are found as far as 25 m from the palm and deeper than 6 m, but 85 percent of the roots are distributed in the zone of 2 m deep and 2 m on both lateral sides in a deep loamy soil (Munier, 1973). It is worth mentioning that date roots can withstand wet soil for many months, but if such conditions spread over longer periods, they become harmful to the health of the roots and to fruit production. Figure 1 diagrammatically shows a date palm's construction with its root system.

From Figure 1, it is clear that the date palm root system is divided into four zones (Oihabi, 1991):

- *Zone I, called respiratory zone:* It is localised at the palm base's surrounding area with no more than 25 cm depth and a lateral distribution of a maximum of 0.5 m away from the stipe. Found in this zone are mainly roots of primary and secondary nature. Most of these roots have a negative geotropism and play a respiratory role.

- *Zone II, called nutritional zone:* It is a large zone and contains the highest proportion of primary and secondary roots. It could contain 1000 roots per m² and more than 1.60 gm of roots/100 gm soil (Oihabi, 1991). They develop between 0.90 and 1.50 m depth and could laterally be found outside of the projection of the tree's canopy. In the case of Deglet Nour variety, lateral roots were found up to 10.5 m from the trunk (Bliss, 1944). Recently planted offshoots develop their roots at zone II then at zone III. At one year old, they could reach 1 m, while 3 m depth is easily reached at the second year.

- *Zone III, called absorbing zone:* The importance of this zone is dependent on the type of culture and on the depth of underground water. It is usually found at a depth of 1.5 to 1.8 m. Mostly primary roots with a decreasing density from top to bottom are found here. The density of this zone is lower than in zone II - only about 200 roots are found per m².

- *Zone IV:* The largest portion of this zone is dependent on underground water. At a shallower depth, it becomes difficult to distinguish between Zone III and Zone IV as both types of roots are found here. When the underground water is deep, roots of this zone could reach a greater depth. They usually are presented as vaissels with a positive geotropism.

In conclusion, the root type and distribution illustrate the role of the date palm. The lack of roots in the top soil allows other cultures such as wheat, lucerne and vegetables to be inter-cropped. While, the high concentration and deep presence of primary roots allows the date palm to benefit from underground moisture and consequently, unlike most fruit palms, resist water stress and drought conditions.

Date palm root development and distribution depends on soil characteristics, type of culture, depth of the underground water and variety.

3.1.2 Trunk

The date palm trunk, also called stem or stipe is vertical, cylindrical and columnar of the same girth all the way up. The girth does not increase once the canopy of fronds has fully developed. It is brown in colour, lignified and without any ramification (Figure 1). Its average circumference is about 1 to 1.10 m.

The trunk is composed of tough, fibrous vascular bundles cemented together in a matrix of cellular tissue which is much lignified near the outer part of the trunk. Being a monocotyledon, date palm does not have a cambium layer.

The trunk is covered for several years with the bases of the old dry fronds, making it rough, but with age these bases weather and the trunk becomes smoother with visible cicatrices of these bases. Vertical growth of date palm is ensured by its terminal bud, called phyllophor, and its height could reach 20 metres.

Horizontal or lateral growth is ensured by an extra fascicular cambium which soon disappears, and which results in a constant and uniform trunk width during the palm's entire life. However, the terminal bud could experience an abnormal growth caused by a nutritional deficiency, which leads to shrinkage of the trunk. This stage is mainly caused by drought conditions.

Sometimes date palms show a branching phenomenon (Figure 2) which was studied by Zaid (1987) and found to be attributed to several causes. The author's findings are summarised as follows:

- Branching in date palm is a result of either dichotomy, axillary bud development, polyembryony or attack by a disease.

- Branched date palms are fertile and can produce as much fruit as a single headed palm.

- There is a need of an analysis of the vascular system of branched date palm by cinematographic techniques. This anatomical study is necessary to show the continuity of growth from the single to the divided state of the shoot.

- It is necessary to study *in vitro* the regenerating capacity of divided portions of the apical meristem and axillary buds of these specimens in the hope of establishing a rapid mass propagation technique for date palm.

3.1.3 Leaves

Depending on variety, age of a palm and environmental conditions, leaves of a date palm are 3 to 6 m long (4 m average) and have a normal life of 3 to 7 years. The greatest width of the frond midrib attains 0.5 m, but elsewhere it is only half this size and rapidly narrows from the base upwards. The frond midrib or petiole is relatively triangular in cross section with two lateral angles and one dorsal. It is bare of spines for a short distance but full of spines on both sides thereafter. (Figures 3, 10 and 14). Intermediate zones have spine-like leaflets, also called leaflet-like spines.

At the tip of the leaf, there may be a single terminal leaflet or two leaflets forming a V (Figure 3). Leaf structure is variety and environment dependent, but usually the whole length of a frond has the following proportions:

- The distance from the fibre at the base of the frond to the base of the spine-leaflets is about 28 % of the whole frond;

- The spine-leaflets occupy about 4 %;

- The leaflets occupy about 62 %; and

- The terminal leaflets occupy about 6 %.

All these characteristics coupled with others, are used as a taxonomical index to differentiate between varieties. Unlike other fruit trees, dead or old leaves are not shed and do not drop on their own, but are removed under cultivation.

An adult date palm has approximately 100 to 125 green leaves with an annual formation of 10 to 26 new leaves. The functional value of the leaf to the palm declines with age and no two leaves are the same age. Furthermore, leaves which are four years old are only about 65 percent as efficient in photosynthesis per unit area, compared to leaves of one year old (Nixon and Wedding, 1956). Under good cultural conditions a leaf can support the production of 1 to 1.5 kg of dates.

Depending on their position in the palm's canopy, leaves could be divided into 3 categories:

- On the outside, leaves are green and photosynthically active;
- At the centre, fast growing green leaves;
- On the inside, at the palm's heart, juvenile leaves, not yet photosynthetic with a white colour.

On average, there are 40 % of juvenile leaves, 10 % fast growing leaves and 50 % photosynthetic leaves.

Leaves are grouped in 13 nearly vertical columns, spiralling slightly to the left on some palms and to the right on others. The grower must only count the number of leaves in one of these columns and multiply it by 13 (Figure 4). According to Nixon and Carpenter (1978) and in order to allow for uneven pruning at the base, counts could be made on opposite sides and divided by two. This technique will allow the grower to calculate the total number of leaves on the palm. A ratio of 8 leaves per fruit bunch will indicate how many bunches to leave on that palm.

Leaves of seedling date plants are characterised by a slightly developed petiole and a juvenile leaf which develops during the first three years after seed germination (Figure 5). These leaves are also called primordia, non-pinnae or entire leaves. Adult leaves are pinnate and arise, in a flattish ascending spiral, from buds produced by the apical growing point.

At the base of each leaf, there is an axillary bud which could yield an inflorescence at the palm's top level or an offshoot at its base. According to Bouguedoura (1982), there are three distinct development phases:

- Juvenile phase which is sterile and leads the palm to produce more inflorescence buds than vegetative ones, which will abort very soon.

- Second phase called vegetative, where vegetative and flowering buds are produced in equal numbers; however, vegetative buds are the ones which develop.

- Third phase, usually after the palm is more than 10 years old, where most of the buds produced are flowering ones.

3.1.4 Fibre, spines and leaflets

As well described by Dowson (1982), the base of the frond is a sheath encircling the palm. This sheath consists of white connective tissue ramified by vascular bundles. As the frond grows upwards, the connective tissue largely disappears leaving the dried, and now brown, vascular bundles as a band of tough, rough fibre attached to the lateral edges of the lower part of the midribs of the fronds and ensheathing the trunk. Varieties differ in the height to which the fibre grows up the central column of unopened fronds, and in the texture of the fibre and also somewhat in colour.

Spines, also called thorns, vary from a few cm to 24 cm in length and from a few mm to 1 cm in thickness. They are differentially arranged on the two outer edges of the fronds while their number varies from 10 to about 60. Spines can be single, in groups of two, or in groups of three.

Leaflets or pinnae are between 120 to 240 per frond, entirely lanceolate, folded longitudinally and oblically attached to the petiole. Their length ranges from 15 to over 100 cm and in width from 1 to 6.3 cm. Their arrangement depends on variety and could be in groups of 1, 2, 3, 4, or 5 pinnae (Figure 14).

3.2 Reproductive organs

Date palm is a dioecious species with male and female flowers being produced in clusters on separate palms. These flowering clusters are produced with axils of leaves of the previous year's growth. In rare cases both pistillate and staminate flowers are produced on the same spike while the presence of hermaphrodite flowers in the inflorescence has also been reported (Mason, 1915; Milne, 1918). Palms which carry both unisexual and hermaphrodite flowers are known as polygamous.

The unisexual flowers are pistillate (female) and staminate (male) in character; they are borne in a big cluster (inflorescence) called spadix or spike, which consists of a central stem called rachis and several strands or spikelets (usually 50 - 150 lateral branches); (Figures 6a, b and 7a, b).

3.2.1 Inflorescences/Flowers

The inflorescence, also called flower cluster, in its early stages is enclosed in a hard covering/envelope known as spathe which splits open as the flowers mature exposing the entire inflorescence for pollination purposes (Figure 8). The spathe protects the delicate flowers from being shrivelled up by the intense heat until these are mature and ready to perform their function. The spathe at the beginning is greenish, becoming brown when near splitting - splitting is longitudinal. The male spathes are shorter and wider than the female ones. Each spikelet carries a large number of tiny flowers as many as 8,000 to 10,000 in female and more in male inflorescence (Chandler, 1958). The annual number of spathes born by a palm varies from none to about 25 in females and to even more in males, but the average is a dozen for females and more for males.

The male inflorescence is crowded at the end of the rachis, while branches of the inflorescence of the female cluster are less densely crowded at the end of the rachis. These characteristics allow the recognition of the inflorescence's sex before its opening (Figure 8). The male flower is sweet-scented and normally has six stamens, surrounded by waxy scale-like petals and sepals (3 each). Each stamen is composed of two little yellowish pollen sacs.

The female flower has a diameter of about 3 to 4 mm and has rudimentary stamens and three carpels closely pressed together and the ovary is superior (hypogynous). The three sepals and three petals are united together so that only tips diverge. On opening the female flowers show more yellow colour while the male ones show white colour dust, produced on shaking. The pollen sacs usually open within an hour or two after the bursting of the spathe.

Only one ovule per flower is fertilised, leading to the development of one carpel which in turn gives a fruit called a date; the other ovules aborted. The aborted carpels persist as two brown spots in the calyx of ripe fruits.

3.2.2 Fruit

Depending on the variety, environmental conditions and the technical care given (fertilisation, pollination, thinning,...), fruit characteristics vary tremendously. Table 2 illustrates this variation:

TABLE 2
Variation of date palm fruit characteristics

Fruit characteristics	Weight (g)	Length (mm)	Width (mm)	Colour	Taste	Consistency
Range of variation	2 to 60	18 to 110	8 to 32	Large variation (yellow to black)	Large variation	Soft to dry

The date fruit is a single, oblong, terette, one-seeded berry, with a terminal stigma, a fleshy pericarp and a membranous endocarp (between the seed and the flesh) (Figure 9).

3.2.3 Seed

As with the fruit, seed characteristics vary according to variety, environmental and growing conditions. A seed's weight could range from less than 0.5 g to about 4 g, in length from about 12 to 36 mm and in breadth from 6 to 13 mm. (Figure 9). The seed is usually oblong, ventrally grooved, with a small embryo, and with a hard endosperm made of a cellulose deposit on the inside of the cell walls.

3.2.4 Variety description

Date varieties have been developed by thousands of years of selection of seedlings and only those possessing desirable characteristics have been propagated. Date palm counts for more than 3,000 varieties all around the world. There are about 400 in Iran, 370 in Iraq, 250 in Tunisia, 244 in Morocco, as well as many additional varieties in the other major date growing countries.

Several date specialists attempted to list and to botanically describe the varieties grown in their respective countries. Table 3 illustrates this effort in botanical description of date palm varieties.

TABLE 3
Number of date varieties described per country

	Number of varieties described	Author/Reference
Egypt	26	Brown, 1924
Egypt and Sudan	22	Mason, 1925
Iran	400	FAO, 1996
Iraq	370	Dowson, 1923
Morocco	244	Saaidi, 1974
Tunisia	250	Kearney, 1906
USA	196	Nixon, 1950

In the present document, the authors decided to include an updated variety description of the two renowned varieties, Medjool and Barhee, which have a high marketing potential.

The aim of this description is to present these two varieties in such a way that the date grower will become fully familiarised with their main characteristics. The study was based on 20 random date fruits of each variety.

Medjool variety

Synonyms: Mejhool, Medjoul, Majhoul, Majul, Medjhool, Medjehuel, Majhol and Me-jool.

Meaning: (Arabic); referring to its origin: Unknown

History: Originally from Morocco (Tafilalet area) where it was the principal export date since the 17th century and was sold in a fancy gift box for Christmas in Paris, Madrid and London, but largely introduced into the new world of date culture: USA (1927) and Israel (1934).

Distinguishing characteristics: Medium size trunk, short to medium leaves which are organised with little curvature. Has a high fruit quality (large size and attractive). It outshines all other varieties with regard to fruit quality and size. It is of high commercial value and is considered date No. 1 for export market.

Description

Palm: Leaves are short to medium (3.5-3.8m), about 1m shorter than Deglet Nour and Barhee with a slight curvature. Dark green at early age then change to yellow with brown strips at the middle.

Trunk: Narrow to medium diameter.

Leaf bases: Average in size with light and inconspicuous scurf on edges.

Spines: 30 to 35 in number, thick and significantly developed at the base, 1/4 of the leaf's length; usually in 2's and sometimes in 3's (Figure 10). Lower spine's length from 5 to 10 cm and the upper ones from 15 to 20 cm.

Pinnae: Straight but could be found curved to the middle; a taller pinnae (70 to 80 cm × 2.5 to 4 cm); width (36 to 54 × 4.5 to 5.0 cm). On the outer centre side of the leaf they are open fl at to 160° - 180°, and on the inner side to 50° to 90°. At the end of the leaf, the pinnae are at 45° on both inner and outer sides. At the base of the leaf, the pinnae start at 50° opening to 90°. Along the length of the leaf, pinnae protrude at various angles (45° to 180°), in a unique formation, specific to Medjool.

Inflorescence: Short orange base with a large number of spikelets each with 50 to 60 flowers.

Fruitstalk: Orange-yellow in colour; short to medium size but thick; a wax cover is usually found at its lower half. The fruitstalk with its short length, if not properly supported, could be broken when bearing heavily.

Fruit: Very large (20 to 40 gram) and elongated - broadly oblong oval to somewhat ovate (5cm long by 3.2cm in diameter). Irregularities in shape are common and are associated with ridges on the seed. Yellow-orange with clear dark red strips at Khalal stage. Amber at Rutab and transparent dark brown to black at Tamar (ripe) (Figure 11). Mature fruit colour is related to the climate and growing conditions. Covered with a waxy structure.

The skin is irregularly wrinkled, shiny at the peak and dull at the lower part. Skin is medium thick and tender, tied to the flesh, but at tamar stage it shrinks; thickness of the flesh: ± 5 to 7 mm with little fibre. Flesh is firm, meaty and thick, brownish amber, translucent with practically no fibre around the seed. Taste is excellent, sweet, but not concentrated.

Seed: Walnut - Brown shiny colour darker at the end, 1.5 gram. Seedling canal is closed approximately 50 % of the seed diameter with small wrinkles. On each side of the seed there is a protrusion forming a "wing shape" that is typical of Medjool and different from all other varieties.

Fruit defects: Two main non- pathogenic defects are typical to Medjool:

> a) Loose skin: During drying, on the palm and after picking, as the flesh looses water, the skin tends to separate from the flesh. Loose skin is mainly the result of growing and habitat conditions. It is not affected much by the naturally or artificially drying process. Loose skin is an aesthetic defect rather than a taste defect and fruit with more than 20 to 25 % loose skin are graded as Class II.
>
> b) Sugar crystallising: A common problem with loose skin fruit, mainly where the skin is broken, is that aromatic sugar crystals are formed on the flesh and under loose skin. Sugar crystallising is more common in fruit with high moisture content at harvest. Again this is an aesthetic defect that will categorise the fruit as Class II.

Pests and Fungi: During drying, many fruits fall from the bunch without the calyx, leaving a hole at the base of the fruit before drying is completed. Through this hole, fermenting beetles and fungi enter the fruit and that causes the fruit to sour. A slow drying process results in a higher level of fruit spoiling.

Special treatment in Medjool

Fruit size

To achieve large and jumbo sizes, the number of fruits per spikelet and bunch and the yield per palm must be monitored by the grower. Depending on the overall growing conditions the following is suggested:

Yield per palm: 80 - 120 kg
Number of spikelets per bunch: 25 - 35
Number of fruits per spikelet: 5 - 10

Reducing the number of fruits per spikelet could be achieved by:

1. Non- effective pollination.
2. Decreasing the number of fruit setting from flowers by chemical spraying (not advised).
3. Hand thinning. The best results are still by hand thinning when the fruit is at 1 to 1.5 cm in size.

Comments

- It is estimated that in 1996 100,000 Medjool palms, half in USA and half in Israel, supplied the world market with 1,000 tons of Medjool fruit.
- All the Medjool palms in the world, have originated from one palm in Bou Denib (Morocco).
- Medjool is an early ripening variety.
- Although classified as a soft date, Medjool is firmer than varieties like Barhee and Khadrawy.
- Very little damage from rain. Fruit quality however, is very sensitive to temperature and humidity. Both low and high extremes are not suitable for achieving high quality fruits.

- Extra heavy thinning is required to obtain a high value commercial fruit.
- Easily produces 20 to 25 offshoots per palm.
- In Israel Namibia RSA and USA the Medjool and Barhee superficies are increasing annually (Figures 12 and 13).

Barhee variety

Synonyms: Barhi, Berhi, Birhi.

Meaning: Uncertain (Arabic)

History: Barhee originates from Basrash Iiraq). Inroduced into the USA by Popenoe (1913); also found in Egypt and Israel.

Distinguishing Characteristics: Heavy trunk of a medium height, moderately curved green leaves, slightly drooping pinnae. The palm has a dusty greenish colour and looks dense and spherical. The fruit is broadly ovate round with relatively no astringency or objectionable tannin flavour at Khalal stage.

Description

Palm: Leaves light elm green with a heavy whitish bloom: Sometimes the trunk has a slight curvature near the apex caused by the weight of a heavy crop. Leaf is long and wide. Blade length about 380 to 415 cm. Maximum leaf width reaches 70 cm. Leaf stalk is wide and strong.

Leaf bases: Broad, green leaves with old ones slightly narrow on edges. Sparse scurf on edges, extending along rachis into lower blade.

Spines: 28 to 36 in number and cover approximately 1/5 of the leaf. Are short and thin; length from 2 to 4 cm; below to 8 or 12 cm; above slender to medium heavy; rachis angle about 15° to 40° (Figure 14). 3/4 of spines are by pair but also found arranged in a group of 3 - 5 on each side of the stalk. Above these, there are 5 - 6 separated spines on each side, which are longer and thicker than the first.

Pinnae: Are relatively wide and crowded. Rather stiff with occasional slight to moderate drooping. Length: 60 to 72. Width: 4.5 to 5.2 cm. Grouping usually in 2's in lower blade with a few in 3's near midblade and above, very distinct near the apex.

Fruitstalk: Wide, long and heavy. It is deep green at bloom and becomes greenish yellow to orange yellow at the Khalal stage Slight to moderate scurf on lower portion. Fruitstalk length ± 150 cm, breadth and thickness immediately below fruiting head 64 × 26 mm. Length of fruiting head ± 55 cm. Strands are mid size and have the same colour as the fruitstalk. Number of strands differs from 90 to 140. Longest strand: ± 75 to 80 cm; breadth and thickness 3.7 × 3.0 mm; fruiting area ± 42 cm; number of flowers ± 45. Shortest strand: ± 35 cm; breadth and thickness 3.9 × 2.7 mm; fruiting area ± 26 cm; number of flowers ± 42.

Bunches: Wide, mid length and heavy with a lot of strands (up to 140 per bunch).

Fruit: Khalal colour is opaque yellow (± apricot yellow to near antimony yellow) internal colour of the bunch is pale; while rutab is amber (raw sienna to amber brown) and becomes very soft and can be easily separated from the skin. Develops into a golden brown colour in the early tamar stage (ripe). The fruit is medium sized. Shape broadly ovate to somewhat rounded (egg-shaped), commonly with a wedge shaped taper from middle to bluntly pointed apex. Calyx flattened and a little submerged, rounded-triangular, usually with 1 to 3 slight breaks in margin. Small fruit length (± 32.5 mm) with a big diameter (± 25.4 mm); size ± 32 to 37 × 23 to 30 mm. Fruit of thinned bunches may be about 31 mm long and 27 mm wide (length to width ratio is about 1:15). Medium weight (± 15 - 20g). Flavour rich and delicate with a low total soluble solids (± 30 %); Flesh is thick and juicy. At rutab stage, the fruit is very sweet. At tamar stage skin is completely separated from the flesh, except around the calyx. The skin is greyish yellow and the flesh loses its transparency and turns into bright to dark brown (Figure 15).

Seed: The seed fills the whole volume of the seed cavity. Light brown to wood brown; oblong, slightly wider above middle, somewhat tapering to the blunt apex. It is short and wide, (18 to 23 × 8.4 to 10.5 mm). Germ pore central or nearly so and can be clearly seen at the centre of seed's dorsal side. Furrow commonly medium in width and depth. Light seed weight (± 0.88g) and a high pulp: seed ratio (± 12.75) (Figure 15).

Comments:

- Barhee is a medium to late fruit ripening variety.

- Yield of Barhee variety is high, reaching up to 500 kg per palm (in Israel) with an average of 200 kg per palm.

- The fruit at Khalal stage has an excellent flavour, with little astringency, distinguishing it from all other date varieties.

- The fruit is more subject to checking and splitting than that of other varieties.

- Checking is mostly longitudinal lines from middle to apex. The skin could be a little tough and this texture is accentuated by over thinning.

- At the tamar stage, ripe fruits are so soft and the bunches so dense that it is heavily damaged by rain.

- Offshoots production is low (usually only 3 - 5 per palm) but offshoots are large and vigorous for their age. Palms originated from tissue culture bear many more offshoots (up to 10 or even more).

- Barhee palm and offshoots are sensitive to frost (Barhee palms were severely damaged by the 1937 frost in the USA).

- In Iraq, Israel, as well as in international commerce, Barhee is marketed and consumed only as fresh fruit on strands, at the Khalal stage.

3.2.5 Growth and development stages of date palm fruit

The growth and development of date palm fruit involves several external and internal changes. These changes are often classified on the basis of change in colour and chemical composition of the fruit, as five (5) distinct stages of fruit development, known as Hababouk, Kimri, Khalal, Rutab and Tamar.

These terms are Arabic and have been internationally used by various authors including American and Israeli date growers. There are no equivalent English words.

a) *HABABOUK STAGE*

Synonyms: Habbabok, Hababauk.

Starts soon after fertilisation and continues until the beginning of the kimri stage. It usually takes four to five weeks to complete and is characterised by the loss of two unfertilised carpels; a very slow growth rate is another characteristic. Fruit at this stage is immature and is completely covered by the calyx and only the sharp end of the ovary is visible. Its average weight is one gram and the size is about that of a pea.

b) *KIMRI STAGE*

Synonyms: Khimri, Jimri, also called green stage.

At this stage the fruit is quite hard, the colour is apple green and it is not suitable for eating. This stage lasts from a small green berry to an almost full sized green date (Figure 16). It is the longest stage of growth and development of dates and lasts a total of nine to fourteen weeks, depending on varieties.

During the first 4 to 5 weeks, there is an average relative weekly growth of 90 %, while during the second period of kimri stage there is only about 22 % growth.

The first phase is characterised by a rapid increase in weight and volume, rapid accumulation of reducing sugars, low but increasing rate of accumulation of total sugars and total solids, highest active acidity, high moisture content though slightly less than that of the second phase.

c) *KHALAL STAGE*

Synonyms: Khalaal, called also colour stage.

The fruit is physiologically mature, hard ripe and the colour changes completely from green to greenish yellow, yellow, pink, red or scarlet depending on the variety. It lasts three to five weeks depending on varieties, with a low average relative weekly increase in fruit weight (3 to 4 %). At the end of this stage, date fruit reaches its maximum weight and size, but sugar concentration (saccharose), total sugar and active acidity have a rapid increase associated with a decrease in water content (around 50-85 % moisture content). It is to be noted that date fruit accumulate most of their sugar, both the sucrose type and the reducing sugar type, as sucrose during the Khalal stage (Table 4). At this stage colour of the seed changes at the end from white to brown.

Some varieties such as Barhee, Hallawi, Hayani and Zaghloul are consumed in this stage, as they are very sweet, juicy and fibrous but not sour. However, Khalal dates must be eaten immediately after harvesting as they will keep for only a few days without cold storage (7°C for one week or 0-1 °C for longer periods) due to their high sugar and water content which cause fermentation during hot weather. If supply and demand are in equilibrium, the Khalal season will last for a couple of weeks.

Varieties harvested and marketed at Khalal stage present the following advantages: minimum infestation, possibility of cutting the whole bunch, easy handling and packing, high yield and consequently high income.

d) *RUTAB STAGE*

Synonyms: Routab; meaning wet. Also called soft ripe stage.

At this stage the tip at the apex starts ripening, changes in colour to brown or black and becomes soft. It begins to lose its astringency and starts acquiring a darker and less attractive colour from the previous stage. However, some varieties such as Khadraoui (Iraq) and Bousekri (Morocco) turn green at this stage.

At this stage, which in total lasts for 2 to 4 weeks, there is a continuous decrease in fresh fruit weight mainly due to loss of moisture (Table 5). The average weekly decrease in fresh fruit weight is 10 % during the last week of the rutab stage.

An increase in reducing sugar, a rapidly increasing rate of conversion of sucrose, a gain of total sugars and total solids also characterise this stage. It has already been observed in respect of the reducing sugar type date, i.e. Barhee, that all the sucrose accumulated during the previous, Khalal stage, inverts and there is a continuous decrease in active acidity and decrease also in moisture content (average 30 - 45 %). With softening, the last of the tannin under the skin is precipitated in an insoluble form, so that the fruit loses any astringency that may have remained in the Khalal stage from the Kimri stage.

It is a very good stage for consumption as a hard ripe date. With the exception of a few varieties, fruit at this stage is very sweet. It is, however, very important to harvest and market the fruit at this stage. Unless they are cold stored, the fruits quickly turn sour and become of no commercial value. For dessert purposes, most people prefer dates after they have passed the Rutab stage.

e) *TAMAR STAGE*

Synonyms: Tamer, Tamr, also called full ripe stage or final stage in the ripening.

This is the stage when the dates are fully ripe, and they completely change the colour from yellow to dull brown or almost black. The texture of the flesh is soft. The skin in most varieties adheres to the flesh, and wrinkles as the flesh shrinks. The colour of the skin and of the underlying flesh darkens with time.

At this stage, the date contains the maximum total solids and has lost most of its water to such an extent (below 25 % down to 10 % and less) that it makes the sugar water proportion sufficiently high to prevent fermentation. This is the best condition for storage. The average relative decrease in fruit weight during this stage is 35 %. The loss in fruit weight continues if fruits are left on the palm. This stage is equivalent to that of the raisin in the grape and the dried prune in the prune type of plum.

At the Tamar stage, the fruits on a bunch do not all ripen simultaneously, but over almost a month. Hence, three to four harvest times are necessary.

Comments

- Dates in all the above stages except the Tamar are perishable, due to their high water content.

- Whole dates are harvested and marketed at three stages of their development (Khalal, Rutab and Tamar) depending on variety, climatic conditions and market demand.

TABLE 4
Main changes in the composition of the Californian Barhee during development

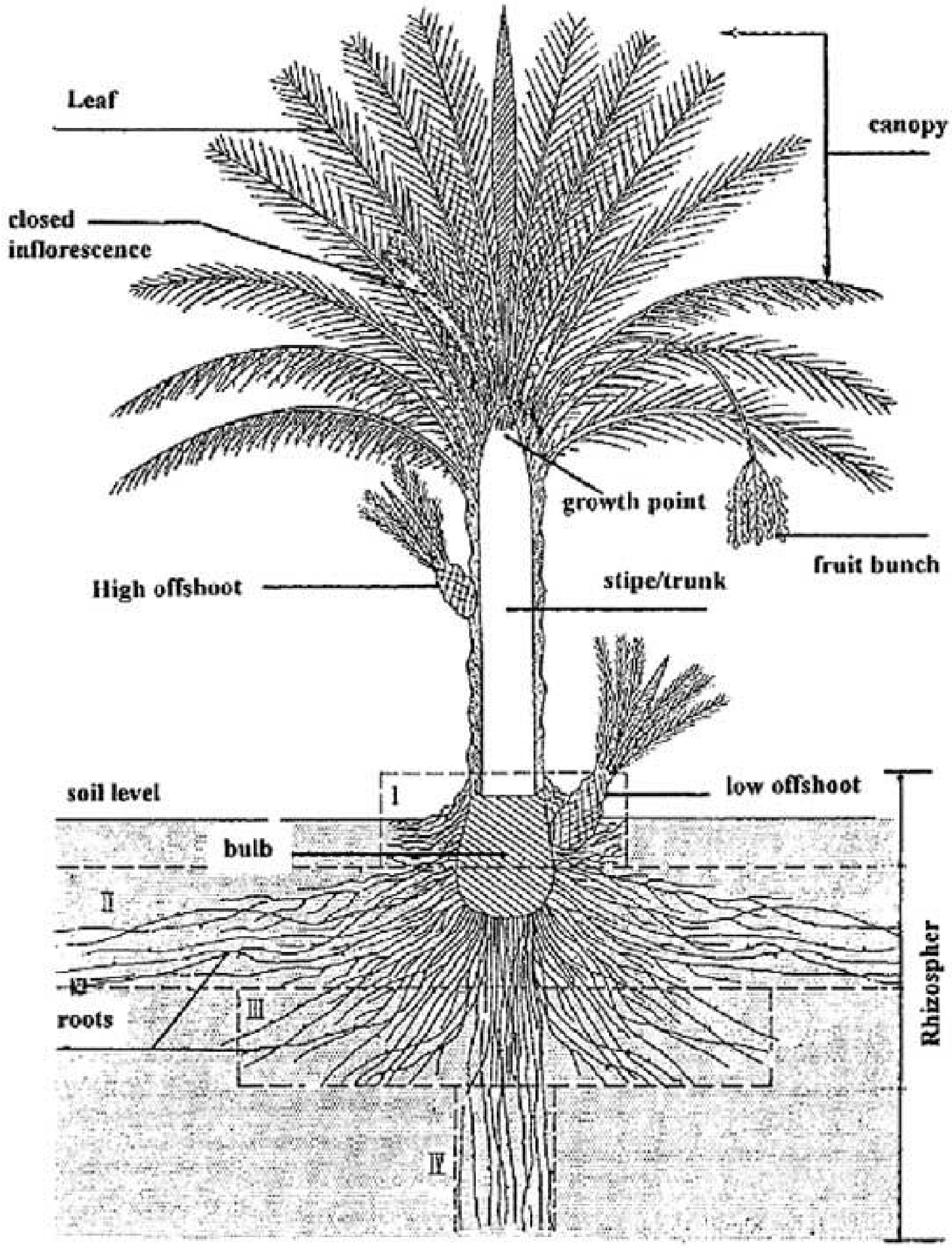
Day of sampling	Stage of ripening	Fresh weight of fruit in grams	Percentage			
			of fresh weight	of dry weight	water	reducing sugars

23.5.39	Kimri	0.5	81	17	5	22
21.6	Kimri	5	86	43	5	48
2.8	Kimri	14	85	45	14	59
2.9	Khalal	16	64	17	62	79
11.9	Tree-ripe (rutab)	14	39	79	0.25	79

TABLE 5
Water content of a date fruit during its maturation from Khalal to Tamar stage

Stage	Water content (%)
Kimri and Early Khalal	85
Late Khalal	50
Early Rutab (tip browning)	45
50% Rutab	40
100% Rutab	30
Tamar	24 and less

Figure 1. Diagrammatic construction of a date palm with its root system



(Source: Munier, 1973 and Oihabi, 1991)

Figure 2. A young dichotomously branched date palm (*Phoenix dactylifera* L.) at Afechtal grove (Marrakesh, Morocco).

Figure 3. Date palm leaf characteristics.

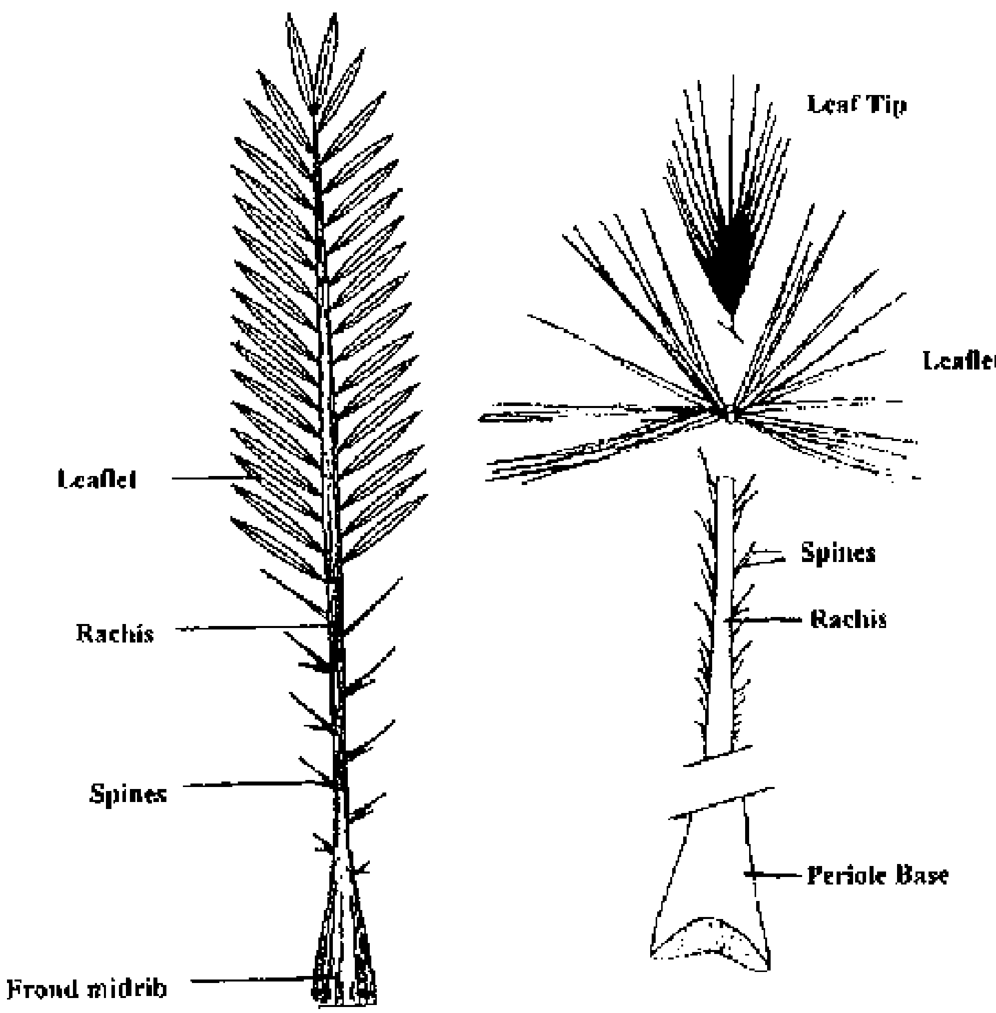
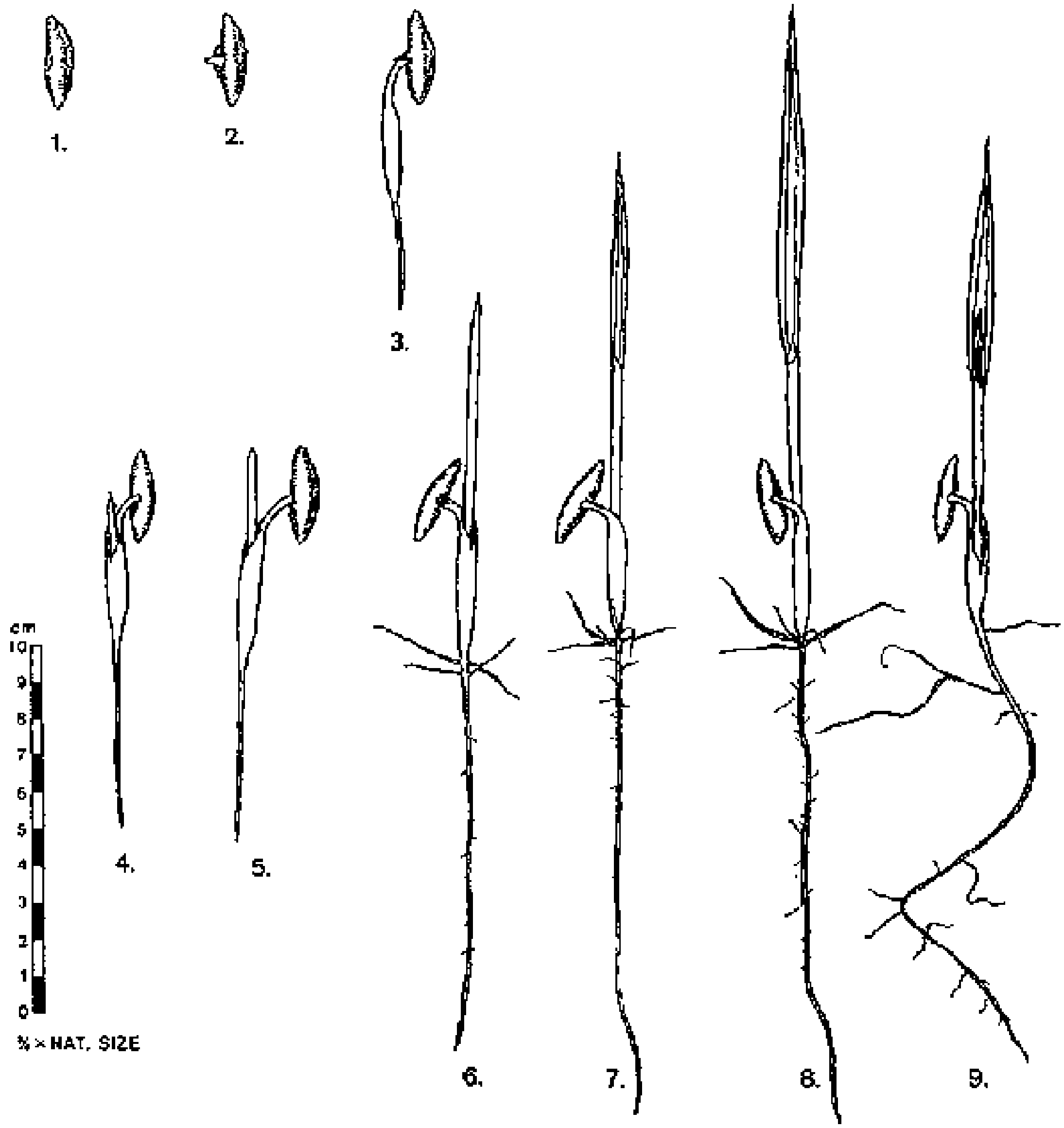


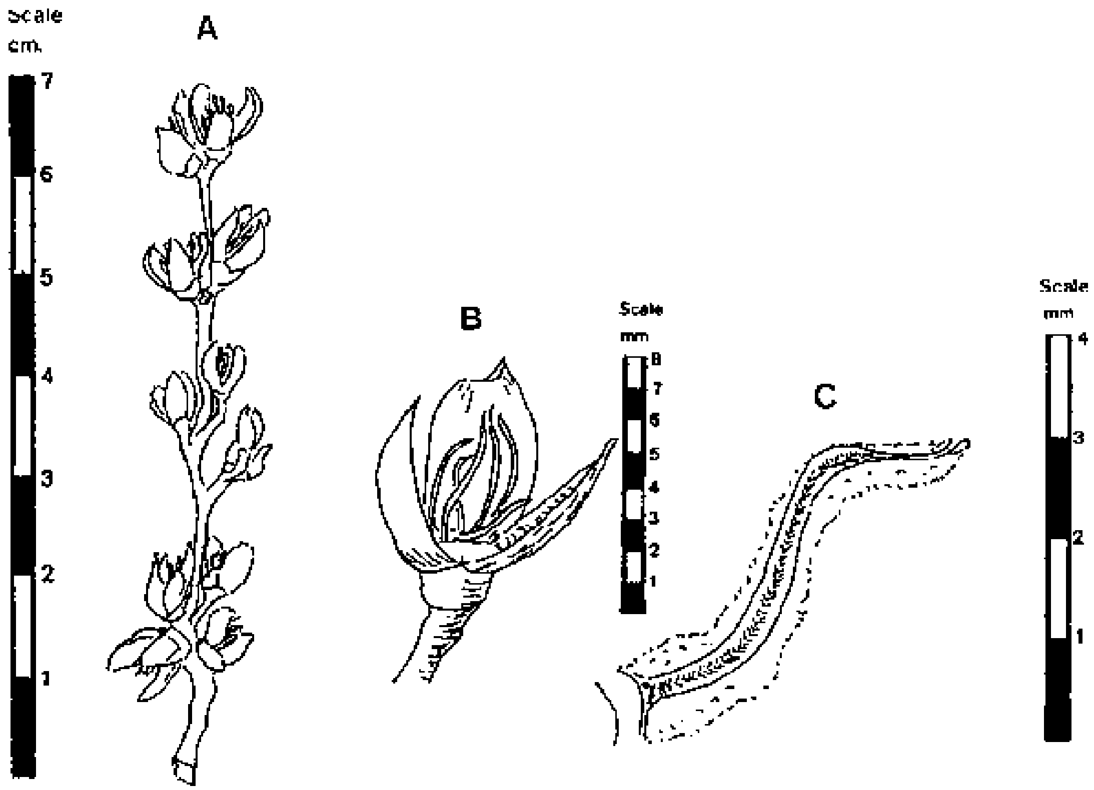
Figure 4. Date palm leaves grouped in 13 columns, spiralling to the right or to the left.

Figure 5. Various development stages of a date palm seedling of Deglet Nour variety.



(Source: Dowson, 1982)

Figure 6a. Date palm male flowers (Source: Dowson, 1982).



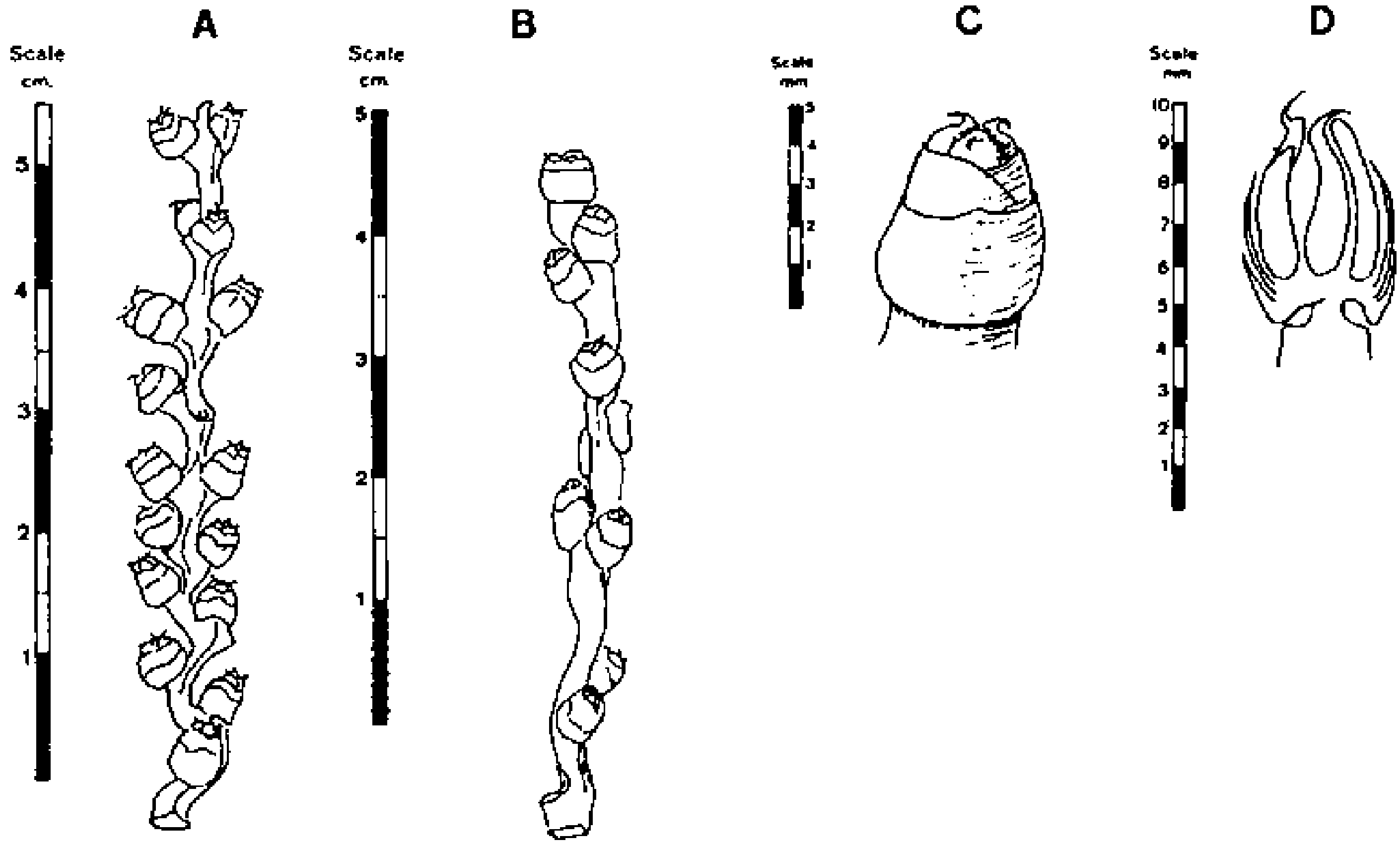
A. Spikelet

B. Flower: 6 stamens, 3 petals, and three-toothed calyx. Most of the flowers have 3 petals but a few have 4.

C. Stamen: Length about 4 mm.

Figure 6b. Date palm male inflorescence 4 days after opening.

Figure 7a. Date palm female flowers (Source: Dowson, 1982).



A.& B Two (short) spikes
From different palms of the Burunsi variety

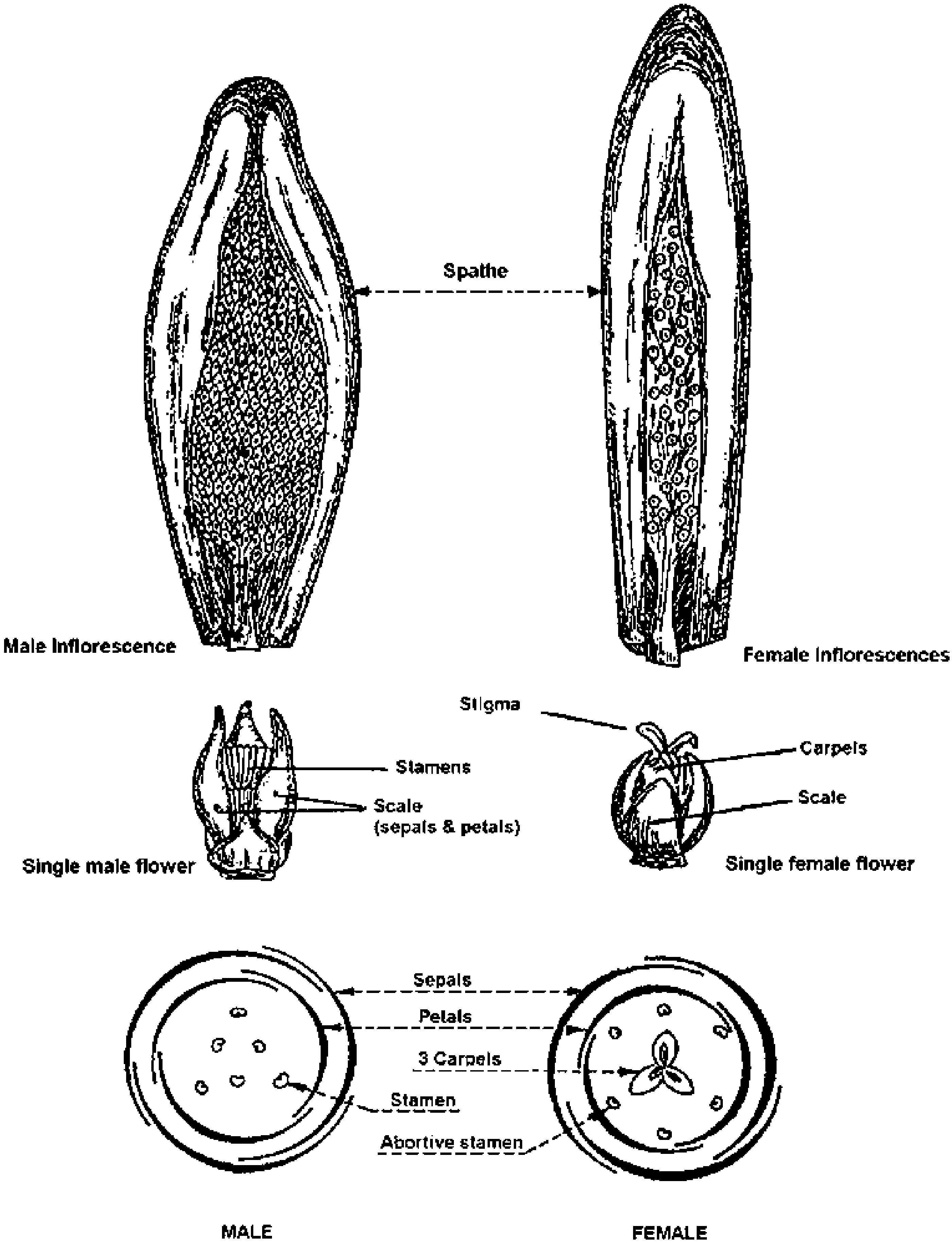
B. Four days after emergence from spathe

C. Unpollinated flower showing two of the three petals, the three-toothed calyx, and three unfertilized carpels.

D. Unpollinated flower: Vertical section six days after emergence from spathe.

Figure 7b. Female inflorescence of a seeding date palm 3 days after opening.

Figure 8. Date palm male and female inflorescences and flowers.



(Source: Munier, 1973)

Figure 9. Morphology and anatomy of date palm fruit and seed.

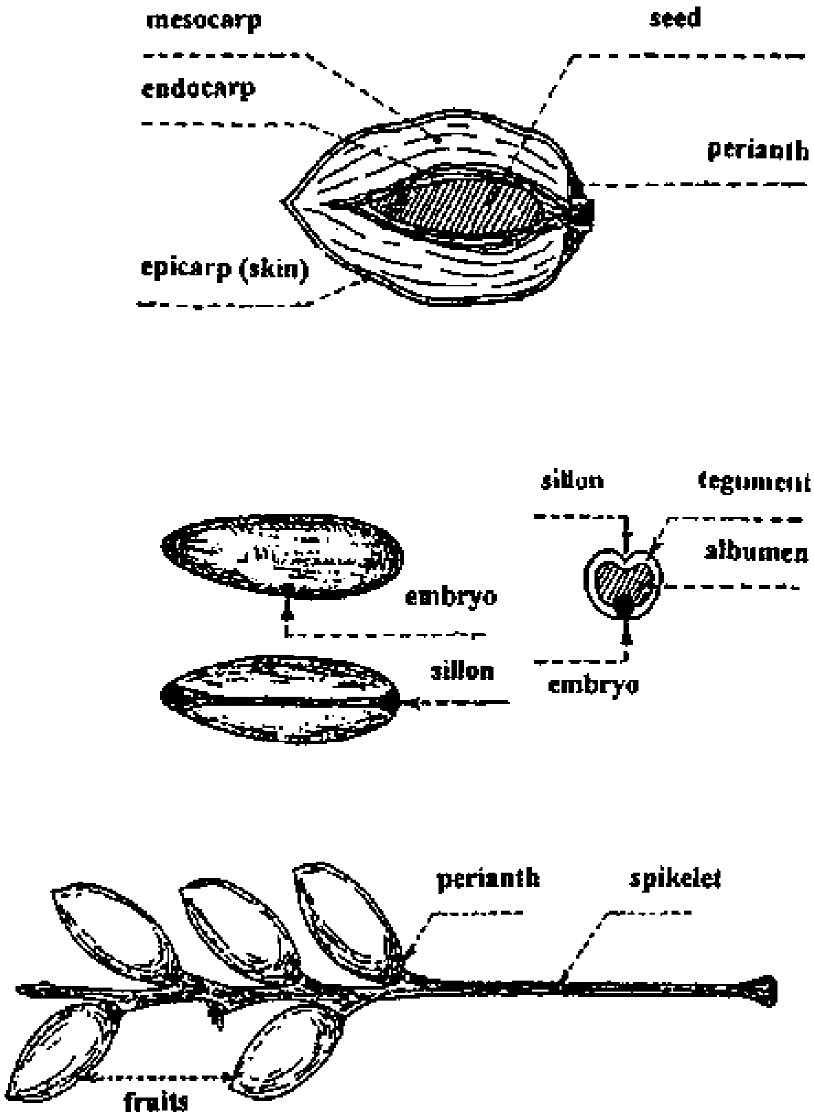


Figure 10. Lower section of a Medjool leaf showing spines and leaflets characteristics and distribution

Figure 11. Medjool samples showing fruit and seed characteristics

Figure 12. Commercial plantation of Medjool in Namibia (Naute Dam, March 1997)

Figure 13. First Barhee dates produced in Namibia (April, 1997)

Figure 14. Lower section of leaves showing spine characteristics of five commercial date varieties: A - Barhee; **B -** Dayri**; C -** Deglet Nour; **E -** Halawy

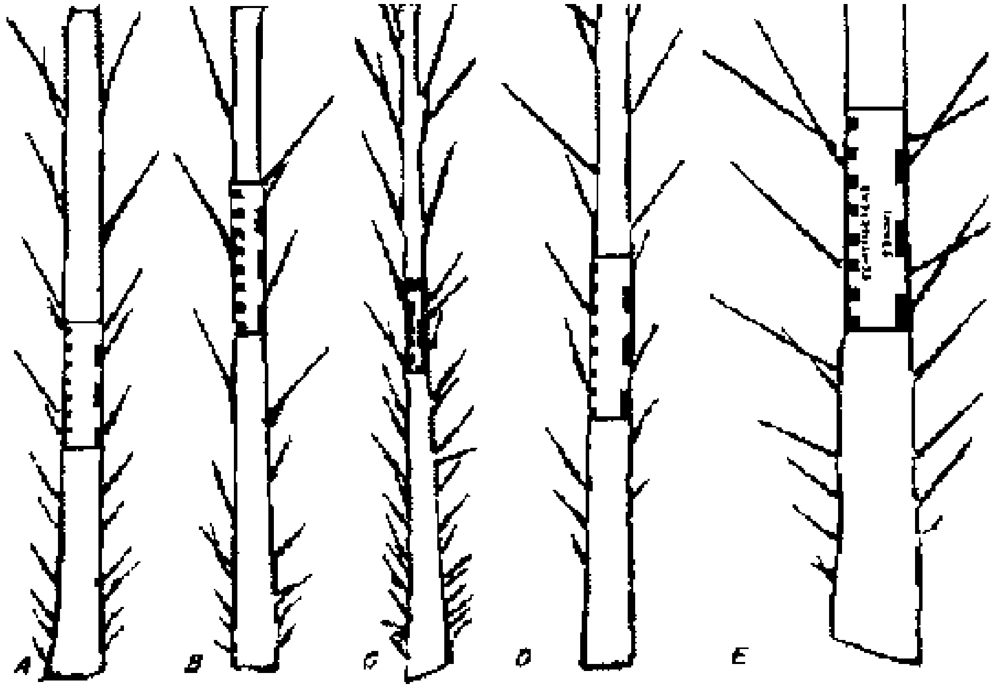


Figure 15. Barhee samples (Khalal stage) showing fruit and seed characteristics

Figure 16. Fruit Kimri stage of Barhee variety

CHAPTER II: ORIGIN, GEOGRAPHICAL DISTRIBUTION AND NUTRITIONAL VALUES OF DATE PALM

by A. Zaid and P.F. de Wet
Date Production Support Programme

1. Origin of date palm

The exact origin of the date palm *(Phoenix dactylifera* L.) is considered to be lost in Antiquity. However, it is certain that the date palm was cultivated as early as 4000 B.C. since it was used for the construction of the temple of the moon god near Ur in Southern Iraq - Mesopotamia (Popenoe, 1913; 1973).

More proof of the great antiquity of the date palm is in Egypt's Nile Valley where it was used as the symbol for a year in Egyptian hieroglyphics and its frond as a symbol for a month (Dowson, 1982). However, the culture of date palm did not become important in Egypt until somewhat later than that of Iraq (Danthine, 1937), about 3000 - 2000 B.C.

The above is confirmed by history, and corroborated by the archaeological research into ancient historical remains of the Sumerians, Akadians and Babylonians (Figure 17a). Houses of these very ancient people were roofed with palm tree trunks and fronds. The uses of date for medicinal purposes, in addition to its food value, were also documented.

In conclusion, date palm is probably the most ancient cultivated tree in the world. It could be safely assumed that the reason for mentioning dates and date palms in the Jewish, Christian, and Islamic religions was due mainly to the influence of the Prophet Abraham, who was born and raised in the old city of Ur where date palms were grown. Ibrahim's love of the date and date palm left a lasting influence on these religions.

The Jews consider the date as one of the seven holy fruits and they celebrate Palm Sunday. But no other religion has stressed the holiness of the date and date palm as much as the Islamic religion. The Holy Koran mentioned date and date palm in 17 Suras (chapters), of the original 114 Suras and 20 verses of 6,263 verses. Prophet Muhammed (peace be upon him) is reported to have said that the best property is date palm, that dates cure many disorders, and he urged Muslims to eat the date and tend the date palm. "And they came to Elim, where were twelve wells of water and three score and ten palms, and they encamped there by the waters". Elim was one of the oases where the Israelites set up camp during their flight from Egypt across the Sinai to the Promised Land, and the 70 palms mentioned in the book of Exodus, 45:27, were date palms.

During Biblical times, the date palm was common throughout Egypt and the Levant, including present-day Israel. Phoenicia, the name by which part of the Levant, particularly the portion including Tyre and Sidon, was known to the Romans and Greeks, means "land of palms". Some of the ancient coins of Tyre and Sidon bear the image of the date palm, as does a Jewish coin issued at the time of Judas Maccabeus, about 175 B.C. To commemorate the conquest of the Jews and the destruction of Jerusalem by Titus in 70 A.D., the Roman emperor Vespasian issued a coin showing a weeping woman sitting beneath a palm tree.

Flavius Josephus, a Jewish historian, reported that during his time (First Century A.D.) there were still groves of date palms near Jericho, around the lake of Galilee, on the Mount of Olives, and in and around Jerusalem. In passing, it may be said here that the Hebrew word for the date palm is "tamar". It became the Jewish symbol of grace and elegance and was often bestowed by them on women, as for instance, the sister of Absalom, in allusion to their graceful, upright carriage. Even today, in Israel and other countries "Tamar," "Tamara," and "Tamarah" are often used as girls' names.

The legend is, that the date palm (not the apple tree) was the tree of knowledge of good and evil, and that the date (not the apple) was the fruit Eve so generously offered to Adam in the Garden of Eden (Figure 17b). If the date palm was the tree of knowledge, Gabriel would not have suggested to Adam that he taste and eat the dates.

Where the date palm originated is not known. Although widely cultivated, no truly wild plant has ever been found. Its progenitor is believed to be *Phoenix reclinata* Jacq from tropical Africa, or *Phoenix sylvestris* (L). Roxb. from India, or a hybrid between these two. Both these species have palatable, although inferior fruits.

The spreading of the date palm and its cultivation occurred during the past centuries following two distinct directions:

- One starting from Mesopatamia to Iran, to reach the Valley of the Indus and Pakistan;
- The other starting from Egypt towards Libya, the Maghreb and Sahel countries (Figure 18).

The original establishment of date palm in these countries was initially localised: Tunisia/Djerid; Algeria/Souf, Oued Rhir, Tidikelt and Saoura; Morocco/Tafilalet and Draa Valleys; and Mauritania/Adrar.

To the south, it was introduced into Mali/Tassili, Hoggar and Adrar of Iforas; Niger/Djado-Kaouar; and Chad/Borkou-Tibesti.

The above date propagation in Africa was realised using the same itineraries as those of the Neolithic civilisation but with some delays. It is illustrated by the presence of Sudan date plantations around the Neolithic sites.

The establishment of date plantations and oases was made possible because of the development of irrigation techniques. This establishment in the Sahara was initiated during the last centuries before our era. The optimum development was only reached during the Fifth and Sixth centuries with Botros and Zenets when commercial camel traffic through the Sahara was made possible.

The old world of date palm stretches from east to west (± 8,000 km) and from north to south (± 2,000 km). According to Dowson (1982), date palm covers 3 % of the world's cultivated surface.

In the early years of the Nineteenth Century (1912), the date palm was introduced into the western part of North America (Colorado Desert, Atacama Desert and other regions).

2. Geographical distribution of date palm

Date palm is found in both the Old World (Near East and North Africa) and the New World (American continent) where dates are grown commercially in large quantities (Figure 19). The date belt stretches from the Indus Valley in the east to the Atlantic Ocean in the west. In order to have a clear picture on the geographical distribution of date palm, it is worth looking at it from the following aspects: (i) Distribution according to latitude, (ii) Distribution according to altitude, and (iii) Number of date palms in the world.

(i) Distribution according to latitude

The distribution according to latitude for both northern and southern hemispheres is illustrated in Tables 6 and 7. In Asia, 32° north, in the Indus Valley, is the northern limit of date palm cultivation. It follows the southern edge of the Perso-Afghan mountain mass, till it reaches the 35° north in Iraq and turns south west to the Mediterranean sea at the Gulf of Gaza. Date palm then follows the Mediterranean coast as far as Tunisia and skirts the southern edge of Morocco to the Atlantic Ocean.

The 17° north parallel is the southern limit of the date palm in the Sahara. From the 15° north in Sudan, it follows the coast of the Red Sea and the Gulf of Aden, till it drops to 10° north to cover the northern part of Somalia. This southern line continues till it reaches the coasts of Arabia and Pakistan till the limit of Indus.

At about 33° north in the American continent, date palm plantations were newly introduced in Southern California. Seven degrees (7°) further south, less important and older introductions are found in the lower California Peninsula of Mexico. Other few, small and recent

TABLE 6
Latitude limits of date palm cultivation in the Northern Hemisphere of the Old World

Limits	Country	Region/District	Parallel
Northern	Pakistan	N.W.F. Province - Bannu Makran - Siahan Mountain Range	33° N 27° N
	Iran	Hajabad Aliabad Fasa Baluchistan Qasr-i-Shirin Kazarum Shiraz Darab	28° 18' N 28°36' N 28°57' N 29°07' N 34°31' N 29°37' N 29°36' N 28°46' N
	Turkmenistan	Kizyl Arvat Bam	39° N 29°07' N
	Iraq	Basra Fao Along the Tigris-Samara Along the Euphrates - Rawa	30°34' N 34°53' N 34°12' N 34°30' N
	Syria	Abukemal Taza Khurmatu Kirkuk	34°27' N 35°18' N 35°27' N
	Palestine, Israel and Lebanon	Jericho, Jerusalem Araba desert Capernaum South of Tripoli-Rift Valley	32° 30° to 31° 32°53' N 34°26' N
	Cyprus and Turkey	Nicosia Antalya	36°10' N 36°34' N
	Algeria	Touggourt El-Kantara	33°09' N 35°14' N
	Spain	Elche	38°17' N
	Egypt	Cairo	30°02' N
	Tunisia	Gabes	33°57' N
	Morocco	Erfoud	31°26' N
	USA	Indio/Ca	33°43' N
	Mauritania	Atar Nema	20°38' N 16°50' N
Southern	India	Turbat Gujarat	25°59' N 23° N
	Pakistan	Sind-Kotri	25°22' N
	Arabian Peninsula	Muscat West of Aden	23°37' N 12°36' N
	Somalia	Genale/Mogadishu	1°47' N
	Djibouti	Hambali/Djibouti City	11°30' N
	Ethiopia	Dirre Dawa	10°15' N
	Sudan	Kamlin/Nile	15°02' N
	Cameroon	Rei Buba/Garua	8°40' N
	Chad	Lettire	13°40' N
	Niger	Guidimouni/Zinder Bilma	13°45' N 18°50' N
	Burkina Faso	Dori	14°10' N
	Mali	Kolokani Kidal Kayes	13°20' N 18°27' N 14°26' N
	Senegal	Bakel	14°51' N

To summarise, the extreme limits of date palm distribution are between 10°N (Somalia) and 39°N (Elche/Spain or Turkmenistan). Favourable areas are located between 24° and 34°N (Morocco, Algeria, Tunisia, Libya, Israel, Egypt, Iraq, Iran, etc.). In USA, date palm is found between 33° and 35°N. Because of climatic factors, the date palm will grow, but will not fruit properly outside the above defined geographical limits.

TABLE 7
Latitude limits of date palm cultivation in the southern hemisphere

Country	Region/District	Parallel
Tanzania R.S.A.	Tabora Henkries Fontein Kakamas Klein Pella	5° S 29° S 27° S 27° S
Australia	Coward Springs	29°29' S

	Lake Hairy Petra Bore Gasgoyne Hergott Springs (Now Marree) Oodanadatta	29°25' S 33°51' S 25°03' S 29°39' S 27°33' S
Namibia	Naute/Keetmanshoop Hardap/Mariental Aussenkehr/Karasburg Eersbegin/Kunene	26°57' S 24°33' S 28°24' S 20°09' S

(ii) Distribution according to altitude

Altitude is very important since it imposes the availability of water and the temperature limits which largely determine the distribution of date palm in the world. In fact, date palm grows and flourishes from 392 m below sea level to 1,500 m above with an altitude range of 1,892 m. Table 8 summarises this distribution based on altitude.

(iii) Number of date palms in the world

The world total number of date palms is about 100 million, distributed in 30 countries, and producing between 2.5 and 4 million tons of fruit per year.(Further details on world date production are to be found in Chapter III).

However, it is worth mentioning that accurate statistics on the number of date palms are not always available and not easy to collect. Even when some numbers are available, it is not clear to which category they belong: are they adult producing, young palms, total or both,?

If we look at the distribution region by region we find that Asia is in the first position with 60 million date palms (Saudi Arabia, Bahrain, UAE, Iran, Iraq, Kuwait, Oman, Pakistan, Turkmenistan, Yemen, etc.); while Africa is in the second position with 32.5 million date palms (Algeria, Egypt, Libya, Mali, Morocco, Mauritania, Niger, Somalia, Sudan, Chad, Tunisia, etc.).

TABLE 8
Date palm distribution in the world with regard to altitude

Country/Region	Area/District	Altitude
Pakistan	Rawalpindi Makran Rukshan	527 m 600 m 900 m
Iran	Kazarum Shiraz Fasa Darab Baluchistan Hajabad Aliabad Qasr-i-shirin Bam and Jahrus	808 m 1,530 m 1,200 m 1,189 m 1,069 m 933 m 1,380 m < 500 m 1,067 m
Iraq	Most commercial plantations (Fao) Kirkuk	< 400 m < 500 m
Eritrea	South Denkala and Diredawa	1,000 to 1,500 m
Saudi Arabia	Hijaz Hasa Teima (Medina)	1,630 m < 500 m 1,300 m
Oman	Oman Wadi Hadhramout Hadhramout valley	500 - 1,000 m 625 m 700 - 800 m
Egypt	North of Egypt South of Egypt	< 100 m < 200 m
Libya	Coast Mizda Ghat	little above sea level 510 m 760 m
Tunisia	Tibssa Gafsa Biskra Boussaada	900 m 345 m 538 m 87 m
Algeria	El Kantara Tebessa Aflou Oued Rhir Touggourt Djanet Tin Guellet	538 m 900 m 1,426 m ± sea level 69 m 1,094 m 1,365 m
Morocco	BouDenib Errachidia Taourirt	935 m 1,061 m 1,146 m
Chad	Tibesti-Aozou Bardai Dazinga and Goubone	880 m 960 m 1,500 m
USA	California - Indio - Mecca - Coachella Valley Arizona-Phoenix	- 6 m - 60 m - 22 m 335 m
Mexico	San Ignacio	900 m
Spain	Elche	± sea level

Palestine/Israel/Jordan	Dead Sea	- 392 m
RSA	Henkries Fontein Kakamas Klein Pella	300 to 600 m 600 to 900 m 100 to 200 m
Australia	most of plantations Queensland district, Coward Springs, Hergott Springs and Oodanatta	< 300 m < 150 m
Namibia	Naute (Keetmanshoop) Hardap (Mariental) Aussenkehr (Karasburg) Eersbegin (Kunene)	700 m 1,100 to 1,120 m 130 to 140 m 640 m
Mauritania	Atar Nema	229 m 266 m
Mali	Kidal Kayes	479 m below 200 m
Niger	Bilma	305 m

Mexico and the USA have 600,000 palms followed, by Europe (Spain) with 32,000 and Australia with 30,000. Table 4 illustrates this geographic distribution of date palm in different countries. Iraq is leading with 22 million palms, followed by Iran 21 million and Saudi Arabia with 12 million, Algeria 9 million, Egypt and Libya 7 million each, Pakistan and Morocco 4 million each. The remaining date growing countries have less than 1 million palms each.

Date growing countries located in the southern area of the Mediterranean Sea have approximately 35 million palms (35% of world total). Based on 200 palms/ha, they have a date palm superficies of about 175,000 ha.

Table 9 also illustrates the date palm cultivated area per country and shows that Iran has the largest superficies with 180,000 ha, followed by Iraq, 125,000 ha. Morocco has 84,500 ha while Saudi Arabia, Algeria and Egypt each have approximately 45,000 ha. In the remaining date growing countries it varies from 2,500 to 22,000 ha.

Regarding planting density, there is again a controversy about the cultural system used. Is it a modern plantation with fixed spacing (case of Israel and Tunisia), or is it the traditional planting system which is similar to a forest (case of Morocco, Pakistan, Somalia, for example). In each case, the planting density varies tremendously from 50 palms/ha (Morocco and Bahrein), up to 577 palms/ha (Somalia). Between these two extremes, there are Algeria, Libya and Tunisia with a density value of 200, 254 and 133, respectively.

Table 10 illustrates the increase in the number and percentage of the date palm culture in four North African countries. Morocco, because of the damage caused by Bayoud disease and in order to rehabilitate its plantations, is programming the production by tissue culture techniques and the plantation of approximately 2.5 million palms by the year 2007. Once implemented it will ensure an increase of 58.88%. If we look at the annual percentage increase, Morocco and Egypt are the leaders with 3.93 and 2.63, respectively. Tunisia and Algeria follow with an annual percentage increase of 1.84 and 1.10, respectively.

TABLE 9
Superficies and total number of date palms around the world

Country	Number of palms (in 1,000)	Part of the world's total (%)	Superficies (in 1,000 ha)	Density of planting (number of palms/ha)
Iraq	22,300	22.30	125	178
Iran	21,000	21.00	180	116
Saudi Arabia	12,000	12.00	45	148
Algeria	9,000	09.00	45	200
Egypt	7,000	07.00	45	155
Libya	7,000	07.00	27.5	254
Pakistan	4,375	04.37	-	-
Morocco	4,250	04.25	84.5	50
Tunisia	3,000	03.00	22.5	133
Sudan	1,333	01.33	-	-
Mauritania	1,000	01.00	-	-
Oman	1,000	01.00	-	-
Yemen	800	00.80	6.4	125
U.A.E.	359	00.35	3.44	105
Somalia	204	00.20	0.35	577
Bahrein	200	00.20	3.70	50
Israel	200	00.20	1.6	125
Palestine	60	00.06	0.25	200
Kuwait	38	00.03	-	-
Syria	12	00.01	-	-
Other countries	4,929	04.92	-	-
WORLD TOTAL	100,000	100	770	173

Source: Djerbi, 1995; "Options Mediterranéennes", 1996.

TABLE 10
Increase in number and percentage of date palm in Algeria, Egypt, Morocco and Tunisia

Country	Years	Increase (in 1,000 palms)	Total increase (%)	Annual increase (%)
Algeria	1970- 1994	1,488	16.53	1.10
Egypt	1990-1994	920	13.14	2.63

Morocco	1992-2007 (*)	2,500	58.88	3.93
Tunisia	1970-1991	1,161	38.70	1.84

(*): Through a national programme to rehabilitate Moroccan date plantations that have been destroyed by Bayoud disease.

Source: "Options Mediterranéennes", 1996.

Looking at the areas where date palm have been harvested (ha), it is clear from Table 11 that the area harvested in the world has increased more than threefold (from 238,522 ha in 1961 to 770,795 ha in 1996) during a period of 35 years yielding an average annual increase of about 8.6 %.

The same table illustrates that during 1996, the top 10 producing countries with regard to harvested areas are in the following order: Iran (153,000 ha), Iraq (116,000 ha), Saudi Arabia (95,000 ha), Algeria (87,000 ha), Pakistan (73,915 ha), Morocco (44,400 ha), United Arab. Emirates (31,005 ha), Tunisia (29,480 ha), Oman (28,000 ha), and Egypt (26,000 ha). These 10 countries, on their own, make up approximately 88 % of the world's total harvested area.

The above-mentioned 10 countries had a different increase in harvested area for the period between 1961 and 1996. The United Arab Emirates is the leader with an increase of about 62 %, followed by Pakistan with 8.30 %, and Saudi Arabia with 4.32 %, while the remaining countries had an increase of between 2 to 3 % (Tunisia, 2.95 %, Morocco, 2.47 %, Algeria, 2.29 %; and Oman, 2.15 %). Egypt, Iran and Iraq had an increase of less than 2 %.

Table 11 also illustrates the evolution of harvested areas in other countries other than the top ten listed above. As an example, we can cite Israel with an increase of 2,286 % during the period between 1961 and 1996, with 70 ha and 1,600 ha, respectively.

TABLE 11
Area harvested in date palm growing countries (hectares) - (from 1961 till 1996)

Country	1961	1968	1975	1982	1989	1996
Algeria	38,000F(*)	59,000F	61,000F	68,000F	78,000	87,000F
Bahrein	1.600F	1,600F	2,300F	1,200F	1,600F	2,200
Cameroon	-	-	-	-	60F	90F
China	1.000F	1,150F	1,150F	1,800F	3,200F	4,800F
Egypt	20,000F	20,000F	20,000F	21,000F	25,000F	26,000F
Gaza Strip	-	600F	650F	200	210F	220F
Iran	78,000F	79,000F	80,000	120,919	120,913	153,000
Iraq	92,000C(*)	92,000C	140,000C	-	119,970F	116,00F
Israel	70F	200F	290F	530	1,050	1,600F
Jordan	150F	70F	92	13	24	230
Kenya	-	-	-	-	345F	345F
Kuwait	-	-	-	-	250F	250F
Libya	-	-	-	-	15,000F	15,000F
Mauritania	4,500F	4,700F	3,500F	3,500F	5,000F	12,000F
Mexico	811	750	527	482	606	500F
Morocco	18,000F	20,000F	23,000F	21,900	20,900	44,400
Niger	-	-	-	-	2,200F	2,200F
Pakistan	8,900	20,200	22,471	30,525	41,795	73,915
Peru	110F	95F	120	141	270	80
Qatar	-	-	-	677	967	1,800F
Saudi Arabia	22,000F	28,000F	53,121	68,583	68,305	95,000F
Somalia	-	-	-	-	2,400F	2,300F
Spain	405	620	751	542	516	500F
Sudan	8,800F	11,700F	14,000F	13,637	15,000F	18,000F
Oman	13,000F	13,000F	14,000F	20,194	25,000F	28,000F
Tunisia	10,000F	17,000F	12,000	18,000	20,000	29,480
Turkey	520F	590	850	950	2,710	3,300F
U.A. Emirates	500F	580F	2,200F	7,146	22,156	31,005
USA	1,700	1,724	1,660	1,660	2,020	2,226
West Bank	-	-	-	30	-	-
Yemen	10,456	10,100F	13,593	12,569	16,479	19,354
World	238,522C	290,679C	327,275C	414,198C	611,946C	770,795C

(*) **F** stands for FAO estimate and **C** for calculated figure.
Source: FAO Trade Stat. 1997.

3. Date nutritional value

Dates are very nutritious, assimilative and energy producing.

With the present uncertainty in the world food supply and the expected increase in demand, the date palm could be a good source of food of high nutritional value. In fact, date fruit is rich in nutrients, and due to its dietetic values it has always been held in high esteem by people. Compared to other fruits and foods (apricot: 520 calories/kg; banana: 970 calories/kg; orange: 480 calories/kg; cooked rice: 1,800 calories/kg; wheat bread: 2,295 calories/kg; meat (without fat): 2,245 calories/kg, dates give more than 3,000 calories per kilogram.

Furthermore, the date palm is one of the greatest producers of food per hectare, and world date production is well over 3 million tons.

The date fruit consists of 70 % carbohydrates (mostly sugars), making it one of the most nourishing natural foods available to man. The water content is between 15 to 30 % depending on the variety and on the maturity stage of the fruit.

In most varieties, the sugar content of a date fruit is almost entirely of the inverted form (namely glucose and fructose), important for persons who cannot tolerate sucrose (cf. table 12). The invert sugar in dates is immediately absorbed by the human body without being subjected to the digestion that ordinary sugar undergoes. The flesh of dates contains 60 to 65 % sugar, about 2.5 % fibre, 2 % protein and less than 2 % each of fat, minerals, and pectin substances. Date fruits are also a good source of iron, potassium and calcium, with a very low sodium and fat content. In addition, moderate quantities of chlorine, phosphorous, copper, magnesium, silicon and sulphur are also found in the date fruit (cf. table 13).

TABLE 12
Sugar contents, in percentages, of 51 date varieties grown in the USA (Cook and Furr, 1953)

Constituent	Type of date Number of varieties analysed	Percentage dry weight		
		Soft	**Semidry**	**Dry**
		34	**9**	**8**
Total Sugars	Average	78	77	77
	Maximum	85	82	82
	Minimum	67	71	73
Reducing Sugars	Average	78	60	41
	Maximum	85	81	76
	Minimum	61	45	17
Sucrose	Average	1	17	36
	Maximum	20	38	59
	Minimum	0	0.1	1

TABLE 13
Mineral constituents of the ash of date fruits

Element	Percentage of the ash (*)
Potassium	50
Chlorine	15
Phosphorus	8
Calcium	5
Iron	0.25
Magnesium	12
Sulphur	10

(*) The ash of dates amounts to about 2 % of cured dates (wet weight).

Date fruit is called a mine in itself because it is very rich in minerals. Its phosphorous content is similar to that found in the same quantity of apricots, pears and grapes put together.

Its high content of magnesium (±600 mg/1kg of dates) could also be very beneficial. Date consumers in Saharan areas are known to have the lowest rate of cancer diseases, a fact attributed to the magnesium found in dates.

With only 1 mg of sodium per 100 g, dates are good food for those on a low sodium diet. The iron content of 3 mg per 100g is almost a third of the Recommended Dietary Allowance for an adult male. Note that fibre, even though it is not a nutrient for humans, is of much value in a diet as an aid to digestion and evacuation. There is ample evidence that for most persons a diet fairly high in fibre is healthier than one low in fibre.

Furthermore, dates are a good source of vitamins A, B1 (thiamine), B2 (riboflavin), and B7 (nicotinic acid also called niacin). The following contents per kilogram are an average for all date varieties: vitamin A, 484 international units; B1, 0.77 milligram (mg); B2, 0.84 mg; and B7, 18.9 mg.

Protein is also of particular interest; it is variety dependent and also varies according to the stage of maturity. An average of 1.7 % of protein of the wet weight of the flesh is roughly obtained.

According to Genske and Weers, (1973), one kilogram of the flesh of ripe Deglet Noor dates contains the following: water (220g), sugar (730g; 2740 calories), proteins (22g), Fats (2g) and minerals (19g,) K 6480mg), P (630mg), Ca (590mg), Mg (580mg), Fe (30mg) and Na (10mg)), vitamin A (500 units), vitamin B1 (0.9mg), vitamin B2 (1mg) and vitamin B7 (22mg).

4. Date products

Dates are especially delicious as a fresh fruit. When used in baking they provide superb taste to the final product. Dates are also used as a component in food preparations like sweets, snacks, confectionery, baking products, institutional feeding and health foods.

Listed below is a brief summary of the main date products:

- Home-made delicatessen

    * Pastry, bakery, confectionery products, and beverages
    * Sandwich spreads
    * Party snacks, salads and appetisers

- Semi-finished date products

    * Whole pitted dates
    * Macerated chips
    * Date paste and date paste mixtures
    * Extruded date pieces and diced dates

* Dehydrated dates, date flour (dietetic baby foods)
* Breakfast foods (dates with other dried fruits, cereals, almonds and nuts)

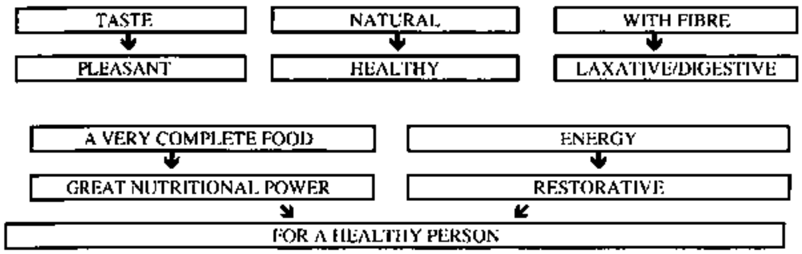
- Ready for use date products

  * Sweets and snacks (date nut roll)
  * Chocolate-coated and stuffed dates (with nuts)
  * Date jams, date butter or cream
  * Date preserves and cardiments, caramel products
  * Date desserts (with juice, ice-cream, whipped cream, etc.)

- Derived date fruit products

  * Date juice and syrup
  * Liquid sugar (Saccharin as a low calorie sweetener for soft drinks), protein yeast and vinegar
  * Fermentation products (wine, alcohol, organic acids, etc.)

In conclusion, dates have many strong points such as nutritional value, laxative power, exoticism, originality and a source of energy (EMER/GIK, February 1996). Their energy is in the form of invert sugars except for the Deglet Noor and Theory varieties in which about half the sugar content is cane sugar or sucrose.



In addition to the dates' high nutritive value, the date palm could play an important role in the ecology of various desert and semi-desert environments. Date palm, which is an irreplaceable tree in irrigable desert lands, provides protection to under-crops from the harshness of the climate (heat, wind and even cold weather), reduces damage caused by sand storms and wind erosion. Furthermore, with the micro climate created by date palm plantations, the cultivation of some fruit palms and annual crops will be possible.

Figure 17. Sumerian grafting:

A - Sacred date palm in Sumerian and Babylonian era. **(Soussa, 1969)**

B - Adam and Eve with a date palm between them **(Soussa, 1969)**

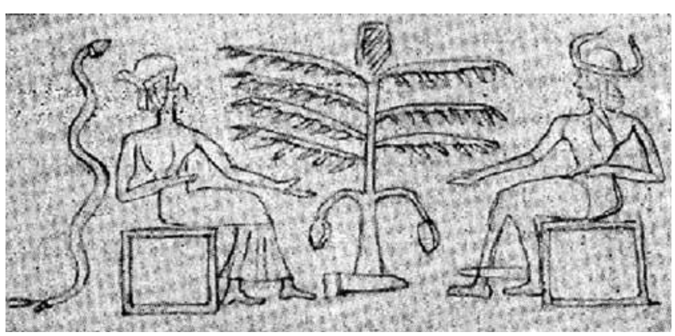
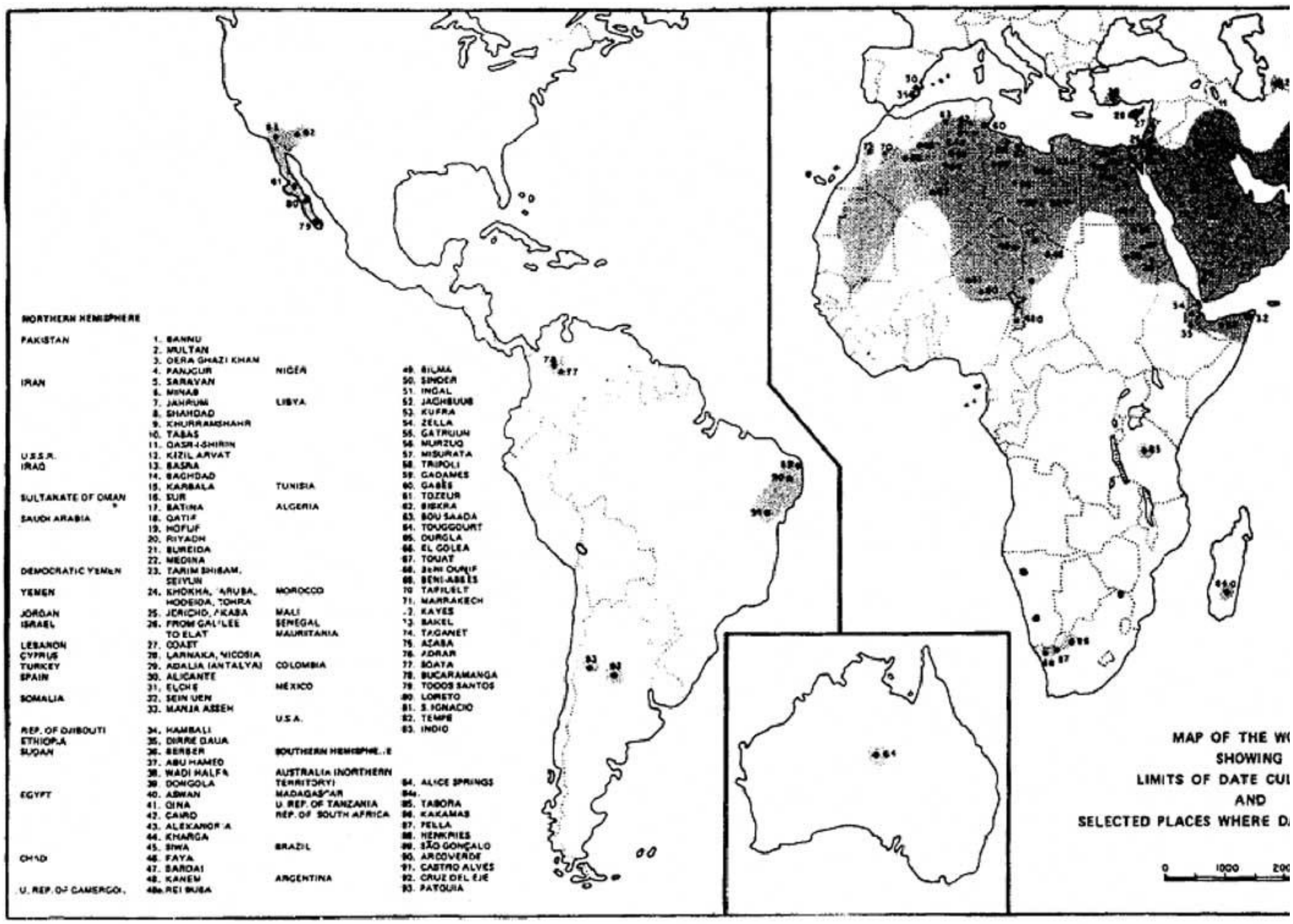


Figure 18. Place of origin and distribution of date fruit in the world.

Figure 19. Geographical distribution of date palm in the world



CHAPTER III: THE ECONOMIC IMPORTANCE OF DATE PRODUCTION AND INTERNATIONAL TRADE

By André Botes and A. Zaid
Date Production Support Programme
Updated by Pascal Liu, FAO

1. World production and trade

Date production is a world agricultural industry producing about 5.4 million metric tonnes (Mt) of fruit. The date fruit, which is produced largely in the hot arid regions of South West Asia and North Africa, is marketed all over the world as a high-value confectionery and fruit crop and remains an extremely important subsistence crop in most of the desert regions.

The world production of dates has increased from about 1.8 million tonnes in 1961 to 2.8 million in 1985 and 5.4 million in 2001 (Figure 20). The increase of 2.6 million tonnes since 1985 represents an annual expansion of about 5 percent.

The major date producers in the world are situated in the Middle East and North Africa. Figure 21 reflects the distribution of date palms by country for the major date producing countries. On average over the period 1999-2001, Iran, Saudi Arabia and Iraq had almost half of the harvested area of the world. Trade figures indicate that about 93 percent of the date harvest is consumed locally and that by far the majority of these palms are not of the well-known export varieties.

History shows the date palm is a traditional crop in the old world. It is only in recent years that the date palm has been introduced as modern plantations in USA, Israel and in the southern hemisphere.

In 2001 the top five date producing countries (Table 14) were Egypt, Iran, Saudi Arabia Pakistan and Iraq, accounting for about 69 percent of total production. If the next five most important countries are included, i.e. Algeria, United Arab Emirates, Sudan, Oman and Morocco, then this percentage rises to 90 percent. This clearly indicates that most of the world's date production is concentrated in a few countries in the same region.

TABLE 14
Main countries producing dates

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	% of world	% change 1991-2001
	thousand tonnes												
World	3 717	3 664	4 387	4 568	4 849	5 015	4 953	5 425	5 354	5 307	5 353		43
Egypt	603	604	631	646	678	738	741	840	906	1 007	1 102	20.6	67
Iran, Islamic Rep. of	634	578	716	774	780	855	877	918	908	900	900	16.8	42
Saudi Arabia	528	552	563	568	589	617	649	648	712	712	712	13.3	35
Pakistan	293	275	577	579	533	534	537	722	580	550	550	10.3	88
Iraq	566	448	613	676	881	797	625	630	438	400	400	7.5	-29
Algeria	209	261	262	317	285	361	303	387	428	366	370	6.9	75
United Arab Emirates	173	230	236	236	237	245	288	290	305	318	318	5.9	84
Oman	135	150	163	170	173	180	185	236	282	260	260	4.9	93

Sudan	140	142	130	138	160	168	174	175	176	176	177	3.3	26
Morocco	107	82	111	62	98	80	110	85	73	74	32	0.6	-31

Source: FAOSTAT

Most of the major date producing countries have steadily expanded production over the last 10 years, representing a 43 percent increase over the period 1994 to 2001. Over the same period, date exports increased by only 25 percent. Increase has been rapid in Oman, the United Arab Emirates, Egypt and Pakistan. Conversely, output decreased in Iraq (due to the trade embargo) and Morocco (due to phytosanitary problems).

2. Date exports

In 1998-2000, an average of almost 500 000 tonnes of dates were exported annually with a total value of about US$258 million. When this figure is compared with total production, it is clear that the bulk of the dates produced are consumed within the producing countries. Of the 500 000 tonnes exported, 225 000 tonnes were imported by India, 150 000 tonnes by the United Arab Emirates (UAE) and about 60 000 tonnes by the EC.

The international trade in dates can be volatile. Changes are often associated with political and economic instability in the main producing countries. Unseasonable weather can also lead to production and storage losses.

There was a steady increase in world export, from about 260 000 tonnes in 1961 to 400 000 tonnes in 1970 (Fig 22), followed by a slight decrease until 1980. A sharp decline in exports was experienced from 1981 to 1984 after which exports increased again to over 400 000 tonnes in 1989 and 1990. During 1991 there was a sharp fall in exports again, resulting in a net export of only 243 000 tonnes. This fall is due to the fact that Iraq exported only 20 000 tonnes compared to 248 000 tonnes in 1989 as a result of the trade embargo imposed on it following its invasion of Kuwait in 1990. It is interesting to note that exports from Iran increased from 13 000 tonnes in 1989 to 120 000 tonnes in 1994, partly compensating Iraq's reduced exports.

Fig. 23 shows that the UAE is the leading exporting country in terms of gross exports. However, if imports are deducted from gross exports, the five leading net exporting countries since 1991 have been: Iran, Pakistan, Tunisia, Algeria and Saudi Arabia. Of these five countries, only two, i.e. Tunisia and Algeria achieve high export prices. Their price of US$1 700 and 1 400 per tonne respectively in 2000, is due to their strategy of targeting the high value European markets while Iran, which exports much lower quality dates, only achieved US$240 per tonne in 2000.

Figure 23 shows clearly the dominance of the UAE and Iran in the export market regarding volumes. Figure 24 reflects the export market share during 1998-2000 in terms of volume exported and foreign exchange earned per region. Asia dominates the export market by far in terms of volume, but further analyses show that North Africa has 26 percent of the market in terms of value, while it represents only 8 percent in terms of quantity. This is a clear reflection of North Africa's strategy to target the high value markets of Europe. Asia on the other hand is exporting lower quality dates at much lower prices, mainly to India. Europe, predominantly France - a non-producing region - has 5 percent of the market share through its re-exports of dates originating from North Africa.

Knowledge of prices, of pricing patterns and the capacity to analyse the economic forces that cause and change those prices will be a necessary condition to help make effective marketing decisions.

There is a wide variation in the average export prices achieved by different countries (see Table 15). Higher export prices are achieved by Israel, Tunisia, United States and Algeria, which have developed a specific export strategy, to grow top quality varieties and target the higher priced European markets. These high prices are achieved by growing varieties such

TABLE 15
Export prices achieved by leading exporting countries

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	US dollars/tonne										
Israel	2 685	2 894	3 314	2 493	2 932	2 882	5 498	5 571	5 452	4 583	4 556
United States of America	2 051	2 326	2 352	2 568	2 484	2 524	3 036	2 939	2 967	3 396	3 609
France	3 316	3 363	3 745	2 198	3 664	3 456	3 103	2 549	2 794	2 262	1 958
Tunisia	2 836	2 721	2 884	2 568	2 705	2 954	2 630	2 210	2 251	2 042	1 722

Algeria	2 052	2 012	2 826	2 790	3 351	3 621	3 214	1 803	1 836	1 462	1 368
Saudi Arabia	688	584	807	1 387	818	635	684	835	767	767	767
Egypt	536	502	527	457	471	422	356	666	723	546	662
Oman	718	771	692	630	644	555	455	704	633	600	600
Pakistan	592	446	418	579	425	349	468	411	436	477	377
Iran, Islamic Rep of	326	602	481	500	463	430	415	248	221	226	240
World Average	**571**	**942**	**977**	**960**	**731**	**891**	**630**	**540**	**556**	**529**	**495**

Source: FAOSTAT

It is interesting to note the price that France achieves on its re-exports mainly to other European countries. France's strategy is to import good quality fruit in bulk and then repack in Marseilles into "glove boxes" for the higher income market.

The major exporting countries in terms of volume, i.e. Iran and Pakistan, achieved much lower prices, US$240 and 377 respectively in 2000. The majority of their fruit that is exported is sold in bulk for the market in India.

3. Date imports

World date imports varied greatly over the period 1961 to 2000. In 1961 world date imports were at 285 000 tonnes and reached a high of about 440 000 in 1973. The world market then experienced a decline and only 180 000 tonnes were imported in 1984. Thereafter imports increased gradually to reach 400 000 tonnes in 1989 and continued to rise to reach approximately 500 000 tonnes per year in 1998-2000.

Table 16 reflects five-year averages of date imports (gross) for selected countries since 1961. The main importers are India, the United Arab Emirates (UAE) and Europe. The top five countries to import dates during 1996-2000 were India, Pakistan, Malaysia, the United Arab Emirates and the European Community. For the five-year period 1996 to 2000 India imported on average 213 000 tonnes while the UAE imported 139 000 tonnes, accounting for 28 percent of the import market. However, the UAE also increased its exports in the late 1990s. While the UAE was a net importer until 1996, it was a net exporter of dates in 1997, 1998 and 1999 (net exports of 15 000 tonnes in 1999).

TABLE 16
Date imports for selected countries: 5 year averages since 1961

		1961-65	**1966-70**	**1971-75**	**1976-80**	**1981-85**	**1986-90**	**1991-95**	**1996-00**
France	Volume: Tonne	20 049	18 326	15 253	17 195	14212	15 802	18 586	21 227
	Value: thous. US $	6417	7 094	11 880	18 270	22 085	33 863	43 923	42 332
India	Volume: Tonne	53 869	60 158	41 226	32 692	33 066	74 526	73 793	213 199
	Value: thous. US $	5 332	5 238	5 993	10 037	13 934	21 624	19 979	48 654
United Arab Emirates	Volume: Tonne	-	577	2 876	3 140	13 298	87 577	82013	139 000
	Value: thous. US $	-	66	369	*111*	3 805	28 275	23 535	41 271
United Kingdom	Volume: Tonne	13 654	11 976	13 009	9 707	9 421	9 455	11 630	10 666
	Value: thous. US $	4 921	5 020	7 204	10 767	13 666	15 207	16 355	16 846
World	Volume: Tonne	329 612	343 763	364 723	290 835	205 455	360 471	324 043	602 957

	Value: thous. US $	48 781	52 853	78 168	136 602	162 573	224 588	270 311	310 868

The European Community imports an average 60 000 tonnes annually. The total value of imports for European countries is in the order of US$110 to 130 million annually. France alone pays between US$40 and 45 million per year for its imports. The total value of European imports does, however, not reach the producing countries. It is estimated that about one third of all the dates imported into France are re-exported at a value of about US$20 million annually to other European countries.

Figures 25 and 26 illustrate the import market share of the major importing countries during 1998-2000 in terms of volume and value of date imports. Although India's imports were 36 percent of the total volume traded, it represented only 15 percent of the market in terms of US dollars paid for date imports. France and the UK contributed 20 percent to world trade in value while they imported only 6 percent of the total volume traded.

European countries like France, Germany, the UK and Italy import much more expensive and, hence, higher quality dates. In contrast, countries such as India, the UAE and Malaysia import much cheaper and lower quality dates.

In the SADC Region it is mainly South Africa and Kenya that import dates. Preliminary investigations showed that dates being imported into South Africa are of a lower quality, imported in bulk, and are mainly being processed for the baking industry. Figure 27 shows a definite decline in volumes being imported into the SADC Region during the period 1961 to 1996, and a stagnation at the level of 1 500 tonnes per year since then.

Figure 28 gives the general trend in world export prices (using the unit value of exports as a proxy for prices). It reflects the effect on prices of an increase in bulk exports of lower quality dates.

According to the TradStat Trend Report, the average export price per tonne in 1996 was in the order of US$3 100 in the case of France (re-export) while Algeria and Tunisia achieved US$3 500 and US$2 600 per tonne respectively.

To confirm these statistics, prices were obtained from a number of markets and agents in Israel, and are summarised in Table 17.

TABLE 17
Farm gate prices for export quality dates in Israel in 1996 (US$/kg)

Variety	Export price at farm gate
Medjool	3.5
Barhee	1.5
Deglet Nour	2.5
Hayany	0.6
Iraqi Varieties	0.7

Source: Study Tour Report; 1996

Prices varied greatly according to the variety, quality, season, type of packaging and market destination.

According to Israeli farmers in 1996 dates were the best crop and financially outperformed any other farming activity, especially under harsh climatic conditions. In the case of an Israeli farmer, 1 ha of dates of the Medjool variety ensured in 1996 an average income of US$37 800 per annum, based on farm gate-price of US$3 500 per tonne and an expandable quantity of 10.8 tonnes/ha.

4. European markets

The EC is by far the largest date importer in value (over US$100 million in 2000) and the third largest in volume. Within the European Community, France and the UK were the major markets, importing 21 000 tonnes and 10 600 tonnes, respectively.

France

The biggest market for top quality and high-priced dates is France, importing mainly from Tunisia and Algeria. France mainly imports the Deglet Nour variety and all imports are categorised as fresh. As with most of Europe, the main season for date sales is October to December and during Ramadan (see Table 18). The physical quality standards for dates imported into France are comparable to most other European countries. However, the French do tend to rely more on subjective criteria such as texture, flavour and colour than other European countries.

TABLE 18
France's date imports: top 4 supplying countries

	Algeria			Israel			Tunisia			USA			TOTAL		
	tonnes	'000$	$/tonne	tonnes	'000$	$/tonne	tonnes	'000$	$/tonne	tonnes	'000$	$/tonne	tonnes	'000$	$/tonne
1990	5 440	11 222	2 063	1 177	2 930	2 490	7914	23 946	3 026	2 053	3 869	1 884	16 584	41 967	2 531
1991	4 788	8 569	1 790	1 003	2 760	2 752	8 899	24 826	2 790	2 736	5 387	1 969	17 426	41 542	2 384
1992	7 782	15 996	2 056	758	2 304	3 040	7 035	22 557	3 206	2 561	5712	2 230	18 136	46 569	2 568
1993	7 606	13710	803	583	1 826	3 131	7 058	20 247	2 869	1 872	4 323	2 309	17 119	40 106	2 343
1994	6 001	11 607	934	498	1 468	2 949	8 608	23 522	2 733	1 645	4001	2 432	16 752	40 598	2 423
1995	6 507	14010	2 153	805	2 658	3 302	7 176	22 130	3 084	1 709	3 522	2 061	16 197	42 320	2613
1996	11 086	21 506	940	1 253	4 673	3 729	5 089	14 185	2 787	809	2 088	2 581	18 237	42 453	2 328
1997	8 522	14 740	730	876	3 396	3 877	8 606	19 860	2 308	133	623	4681	18 137	38 618	2 129
1998	9 326	15 992	715	890	3 373	3 790	11 536	26 980	2 339	195	1 151	5 904	21 947	47 497	2 164
1999	9 573	14 345	499	1 034	3 499	3 384	8 648	17 544	2 029	217	1 211	5 580	19 472	36 599	1 880
2000	9 320	13 323	430	1 411	3616	2 563	11 671	21 247	1 820	129	756	5 859	22 531	38 942	1 728

The USA has found a new market in France and now competes with the traditional sources like Tunisia and Algeria. It is interesting to note that France's imports during the months of March to August originate virtually all from the USA. The lower price indicates that the dates stored for such a long period are regarded as of a lower quality, or are a direct indication of prices responding to lower demand.

Low volumes of dates are being imported during the months March to August. Date imports reach their lowest mark in July and peak in November. The date market is highly seasonal.

Most of the dates imported into France are packed loose into cartons and transported in containers. Tunisian cartons, the bench-mark for the trade, contain 5 or 10 kg and are repacked into "glove boxes" in Marseilles, one of the main importing centres in France.

In 2000, France imported some 22 500 Mt of dates with a total value of US$39 million. Deglet Nour on the branch is imported from Tunisia for FF. 14/kg in 5 kg, 3 kg, 1 kg and smaller packages. Pre-packed Medjool dates, imported from Israel, were sold in supermarkets (Marks & Spencers) for FF. 75/kg in 1996. Barhee (khalaal) was sold for FF. 45/kg at the fruit stalls in Paris and for FF. 25-30/kg in Marseilles.

United Kingdom

The United Kingdom imports and consumes over 10 000 tonnes annually and it is believed that there are good prospects for future expansion in the date market. Pitted dried dates for processing and home baking account for about 45 percent of the market. The market for dessert dates, either fresh, chilled or frozen, is the fastest growing segment.

During 1993, the dessert segment was estimated at 1 000 tonnes while the rest is sold as dried dates. Dates imported into the UK originate mainly from Iran (6 000 tonnes), Tunisia (1 700 tonnes), Pakistan (1 000 tonnes), France (re-exports - 1 000 tonnes) and the USA (1 100 tonnes). Most of the dates imported are from a range of varieties and the market is more concerned with quality in terms of infestation, appearance and moisture levels than with a specific variety.

According to a Commonwealth Report, traditionally most of the dates consumed in the UK originated from North Africa and most were packed in Marseilles in "glove boxes". Importers are, however, now starting to import directly from other countries, particularly the USA. The reason for this change is due to the fact that the level of infestation and use of agro-chemicals in North Africa is too high.

In 2000, the United Kingdom imported about 10,400 tonnes of dates, valued at US$16,6 million. The following retail prices were noted in London:

Fruit stalls:	Barhee	£2/lb
Marks & Spencer:	Medjool (USA)	£2.5/250g
Covenant Fresh Produce Market:		
Gilgrove Ltd (Agent)	Medjool (Israel)	£3/lb
Louis Reece (Agent)	Medjool (Israel)	£33/5kg
	Medjool (USA)	£45/15lbs

Figure 20. World date production in metric tons

Figure 21. Area distribution for date palm

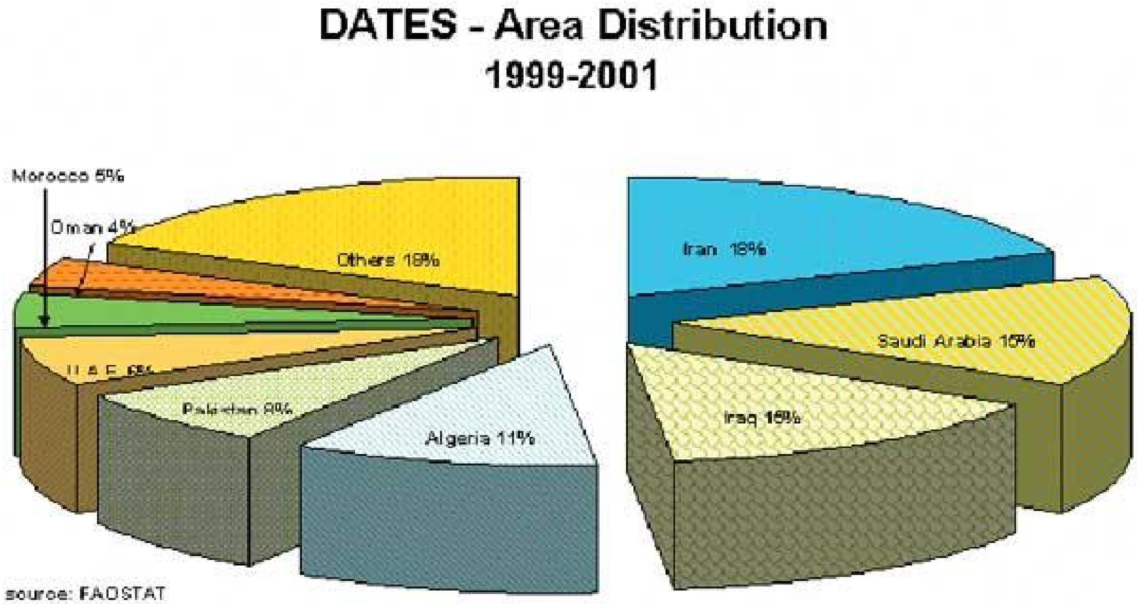


Figure 22. World date exports for the period 1970 to 2000

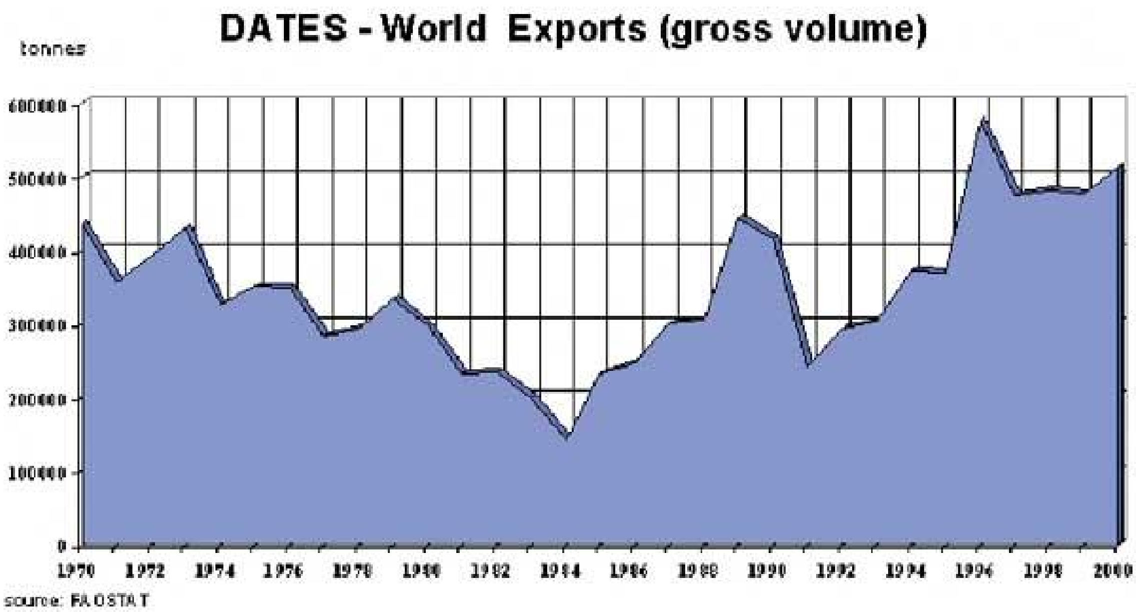


Figure 23. Export market share (volume) of the major producing countries

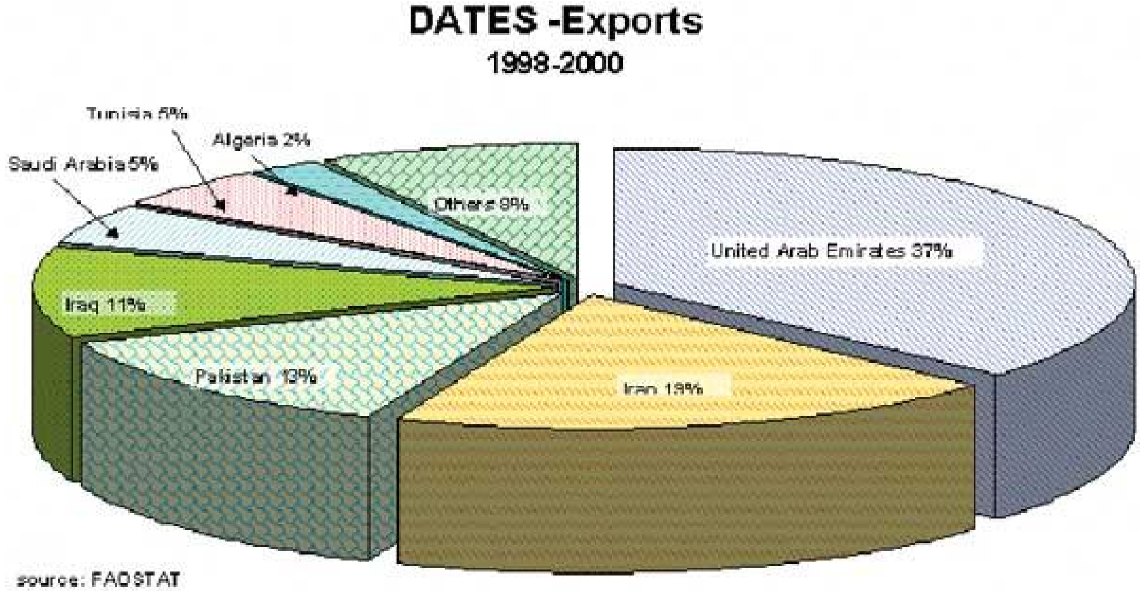


Figure 24. Export market share by region

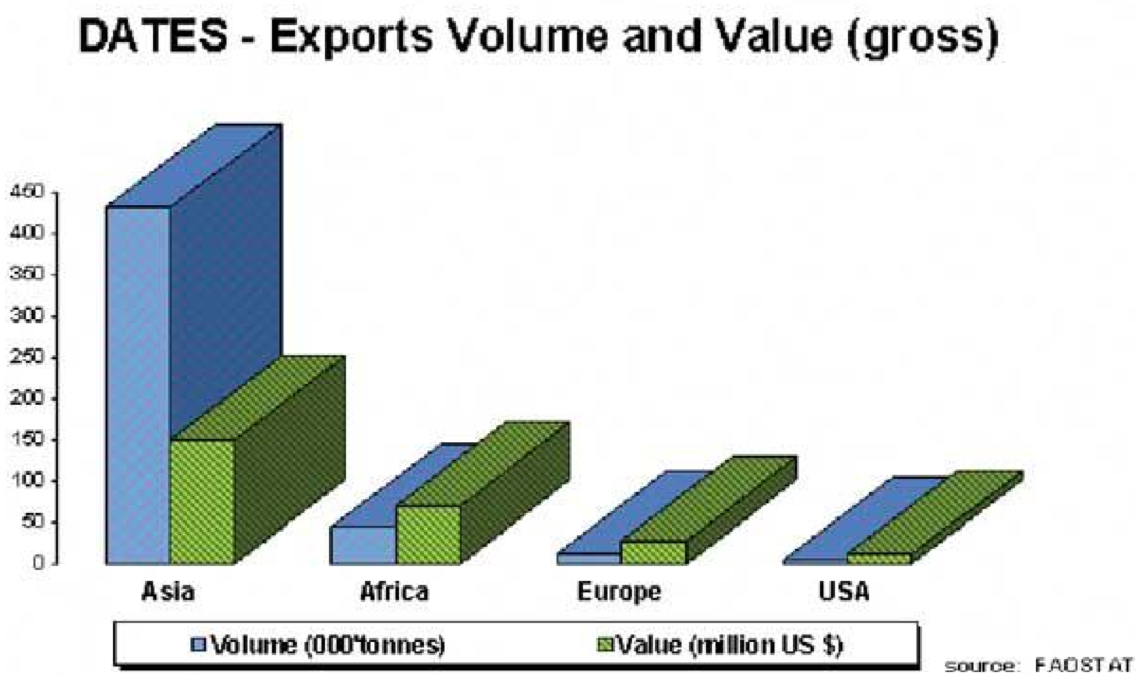


Figure 25. Import market share for selected countries (1998 - 2000) in terms of quantity

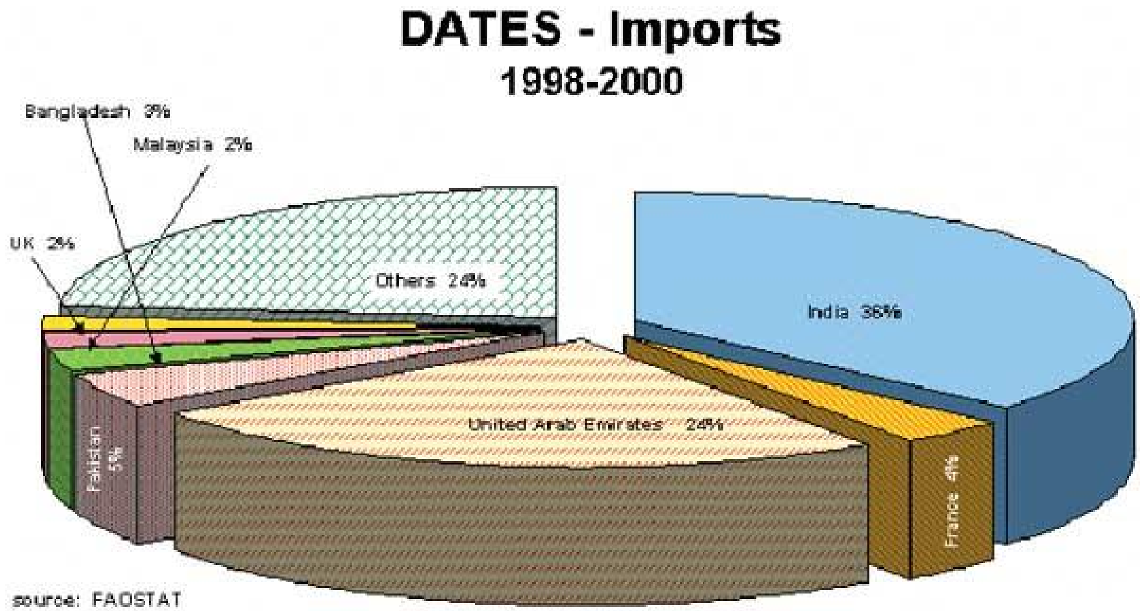


Figure 26. Import market share for selected countries (1998 - 2000) in terms of value

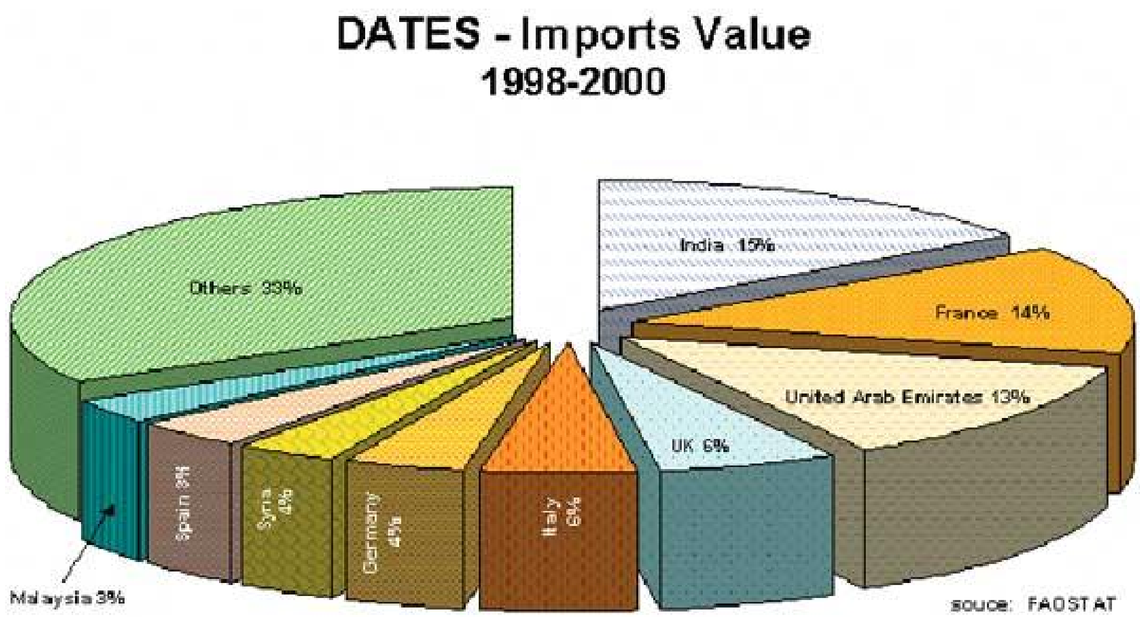


Figure 27. Date imports (metric tons) of SADC countries for the period 1970 to 2000

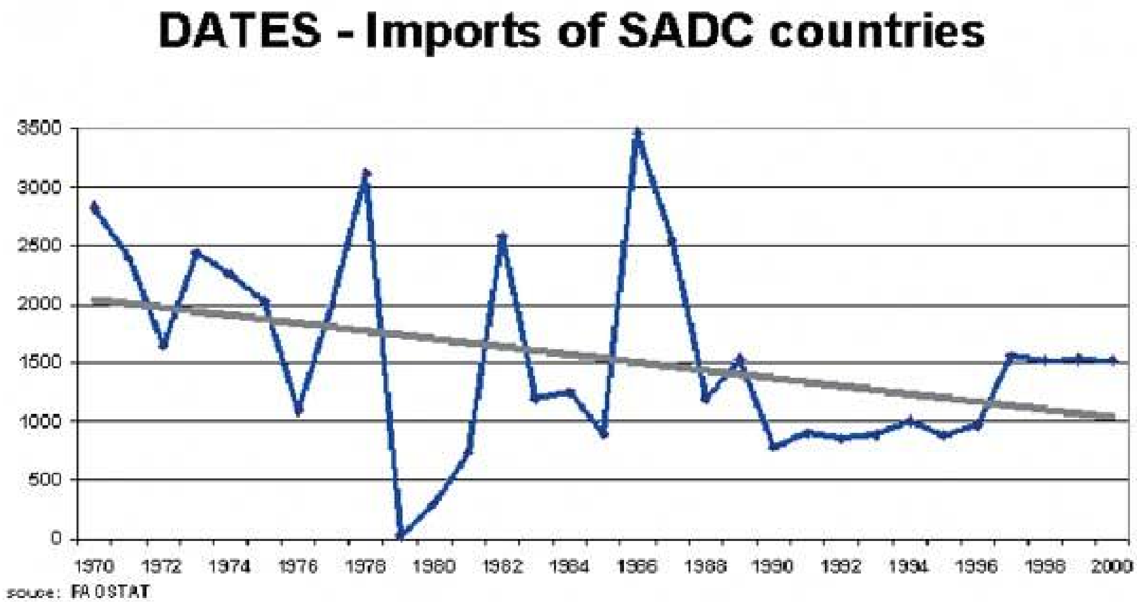
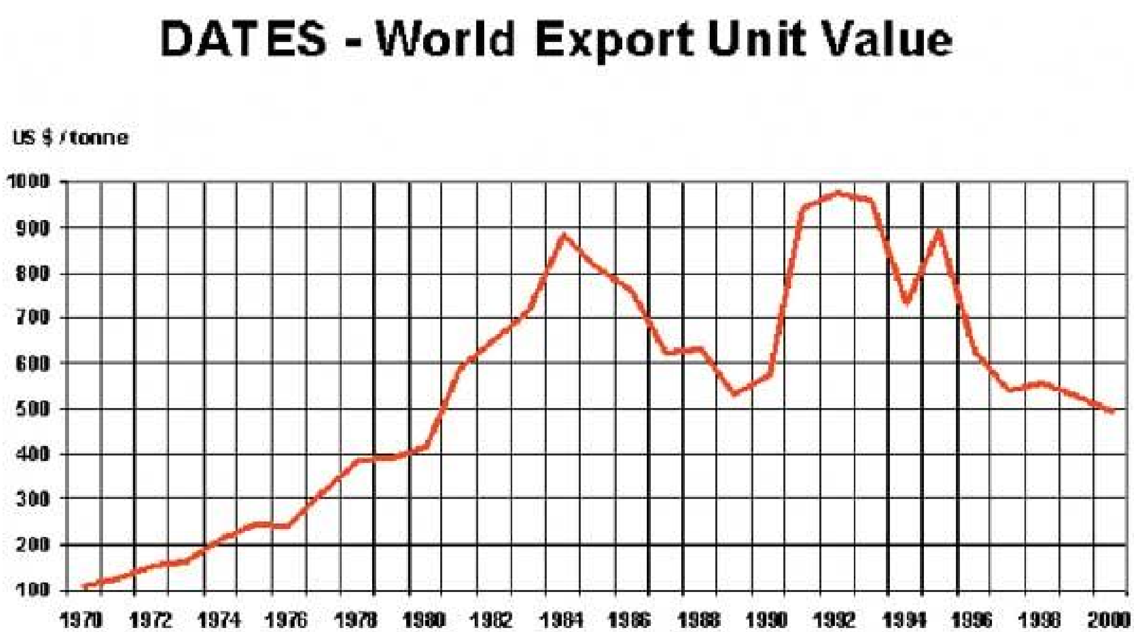


Figure 28. World export unit value. (Source: FAO Agrostat Database)



CHAPTER IV: CLIMATIC REQUIREMENTS OF DATE PALM

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Date Production Support Programme

The climatic factors influencing date growth and production are discussed in this chapter. Temperature, rain, humidity, light and wind are the most important climatic factors which determine the suitability of a specific site for growing date palm.

1. Temperature requirements

The highest maximum temperatures found in the date growing areas of the world are the result of low humidity, great insolation and long days in summer.

There are several ways to record temperature, and the analysis of its effect will be conducted accordingly. First, there is the average daily temperature with a daily maximum and a daily minimum (Table 19), then the values of average annual temperatures are also used (Table 20). The average of a larger number of daily records translated into monthly values will, however, give a more accurate result (Table 21).

TABLE 19
Average maximum and minimum daily temperatures of various date growing areas (°C)

Station/Country	Length of record (years)	Maximum May to Oct. incl.	Minimum (Jan.)
Turbat/Pakistan		41	6.7
Basra/Iraq	19	37.4	6.4
Muscat/Saudi Arabia		38.5	15.9
Cairo/Egypt		33.7	7.6
Gabes/Tunisia	30	29.3	6
Touggourt/Algeria	15	35.9	3.4
Erfoud/Morocco	12	36.4	1.3
Elche/Spain		28.2	6.9
Indio/California; USA	25	37.6	3.7
Bahrein/Bahrein	12	34.3	13.3
Oued Haifa/Sudan	30	40.2	1.1
Keetmanshoop/Namibia	37	35.1 (Jan)	6.2 (July)

Source: Saeed, 1972; Al Bakr, 1972.

TABLE 20
Average annual temperatures for various date growing areas

Place/Country	Length of record (years)	Temperatures (°C)
Basra/Iraq	4	24.2
Baghdad/Iraq	9	22.5
Tozeur/Tunisia	49	21.3
Touggourt/Algeria	25	21.4
Biskra/Algeria	25	21.8
Niamey/Niger	-	31.5
Kidal/Mali	-	27.7
Keetmanshoop/Namibia	37	20.7

Source: Dowson, 1982.

To compare the climates of different places with regard to their suitability for date cultivation, it is appropriate to use the average of the two extremes. However, in order to differentiate between places which may grow dates and those that are not suitable, it is recommended that use be made of the annual average of the daily averages.

Date palm is cultivated in arid and semi-arid regions which are characterised by long and hot summers, no (or at most low) rainfall, and very low relative humidity level during the ripening period. Exceptional high temperatures (± 56°C) are well endured by a date palm for several days under irrigation. During winters, temperatures below 0°C are also endured. The zero vegetation point of a date palm is 7°C, above this level growth is active and reaches its optimum at about 32°C; the growth will continue at a stable rate until the temperature reaches 38°C/40°C when it will start decreasing.

Even though date palm is a thermopile species, it withstands large temperature fluctuations. Below 7°C growth stops and this stage is called a resting period. When the temperature decreases for a certain period to below 0°C, it causes metabolic disorders which lead to partial or total damage of leaves. At -6°C pinnae margins turn yellow and dry out (Figures 29a and 29b). Inflorescences are also heavily damaged by frost (Figure 30). When frost periods are suspected, inflorescences should be protected with craft paper bags immediately after pollination (Figure 31). From -9 to -15°C, leaves of medium and outside canopy will be damaged and dry out. If these low temperatures are maintained for a long period (12 hours to 5 days) all leaves will show frost damage and the palm will look as if it was burnt (cases of Morocco date plantations in 1952, and 1965; Iran, 1964; USA, 1913, 1937, 1949 and 1959 (Mason, 1925a; Nixon, 1937). The more leaves damaged, the greater the possibilities of poor fruit quality that year. Poor flowering could also be expected the

TABLE 21
Average daily and annual maximum air temperatures at various date plantations in northern and southern hemispheres

Station/Country	Length of record (years)	Average daily maximum temperature (°C)												Average annual maximum temperature
Northern Hemisphere		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	
Touggourt/Algeria	15	17	19.5	22.7	28	32.3	37.2	41.3	40.1	36	29	21.8	17.4	28.6
Biskra/Algeria	27	16.1	18.3	21.7	26.1	30.6	36.1	41.1	40.6	34.4	27.8	21.1	16.7	27.2
Tozeur/Tunisia	9	15.2	18.6	22.5	27.4	31.7	37.6	41.7	40.3	34.3	28.4	21.4	15.7	27.9
Basra/Iraq	19	15.6	18.4	23.2	28.9	34.6	38.1	40.2	40.5	38.5	32.6	25	17.8	29.4
Indio/Ca, USA	25	20.9	23.8	26.4	30.1	33.7	38.9	41.4	40.8	38.1	32.6	26.9	21.5	31.3
Southern Hemisphere		**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	
Alice Springs/Australia	46	19.4	22.2	26.5	30.5	33.4	35.3	35.9	34.9	32.4	27.9	22.8	19.8	28.4
Finke P.O./Australia	24	20.2	22.3	26.6	31.1	34.4	36.4	37.8	36.6	34.0	29.2	23.5	20.7	29.4
Kakamas/RSA	15	21	24	27	31	33	36	36	35	32	29	24	22	29.2
Goodhouse/RSA	15	23	26	29	33	35	38	39	38	36	32	27	23	32
Keetmanshoop/Namibia	37	21.2	23.4	27.4	29.9	32.6	34.4	35.1	33.7	31.8	28.1	24.1	21.2	28.6
Hardap/Namibia	20	22.9	25.1	28.7	31.4	34.4	36.4	35.6	33.6	31.8	28.9	25.7	22.7	29.7

It is worth mentioning that owing to the fibrillium, the meristematic area of a date palm (growth centre) is well protected against frost. After frost occurrence and during early spring, the damaged palm restarts its normal growth. Nixon (1937) noted that date gardens that were irrigated during frost periods were less damaged than the ones that were not irrigated.

The Zahidi variety (Iraq) was found to be the least damaged by frost while Khalas (also Iraq) is the most sensitive.

According to Mason (1925), the growth of a date palm does not cease if:

(i) minimum daily temperature does not fall below freezing point, and
(ii) maximum daily temperature at the growth centre does not fall below 9 to 10°C.

The temperature requirements presented below are those of normal growth, flowering and fruit maturation. Date palm flowering is initiated after a cold period, when the temperature becomes high enough and reaches a level known as the flowering zero (0). This temperature level varies according to varieties and to local climatic conditions. Table 22 indicates the flowering time of several date growing regions.

TABLE 22
Flowering time and related average daily temperatures of various date plantations around the world

Plantations/Country	Flowering Period	Temperatures (°C)
Tafilalet/Morocco	March - April	21
Touggourt/Algeria	Mid March - Mid April	18
Atar/Mauritania	February	22
Basra/Iraq	March	18
Aswan/Egypt	March	20
Kakamas/RSA	July - August	22
Keetmanshoop/Namibia	July - August	21
Alice Springs/Australia	August - September	17

Source: Dowson, 1982.

Flowering temperatures represent the average daily temperatures from initiation till the end of the flowering period, while the fruiting period of date palm starts at fruit set and ends at fruit maturation; its length (of about 120 to 200 days) varies from one date variety to another and depends on environmental conditions (Table 23).

TABLE 23
Average fruiting periods of various date growing areas

Plantation/Country	Fruiting period (days)	Months
Touggourt, Bechar, Laghouat and Alkantara/Algeria	180	May - October
Kankossa and Atar/Mauritania	135 to 150	March - July
Nema/Mauritania	135	Mid February - June
Bilma/Niger	150	Mid March - Mid August
Kidal/Niger	135	March - Mid July
Kayes/Mali	150	January - End May
Basra/Iraq	165	March - August
Turba/West Pakistan	200	February - Mid August
Cairo/Egypt	239	End February - End October
Alice Springs/Australia	185	August/Sept. - March/April
Keetmanshoop/Namibia	195	September - March
Kakamas/RSA	200	September - April

Source: Djerbi, 1995; McColl, 1992.

The above two criteria (flowering temperature and fruiting period) allow the calculation of the heat units, which correspond to the sum of the average daily temperatures from flowering time till fruit maturation, that are necessary for a given variety under a given environment. Different methods of calculating this heat unit value were used by the following authors:

- In 1879, Cosson estimated the sum of heat units necessary for Algerian date varieties as 6,000 °C. Similar results were obtained by Fisher (1883) while working with Egyptian varieties (6,136°C). Those authors' techniques were based on using the earliest date in each place when the temperature first reached 18°C in the year, and the last date of the year when the temperature dropped below that value.

- De Candolle (1883) considered 10°C as the growth's zero value. By subtracting it from the average daily temperature and then adding all the obtained values together, he found that 5100°C was the required heat units to ripen fruits of some date varieties completely.

- Swingle (1904) added the daily temperature maxima for a period of 184 days. The growth zero value used was 18°C (since the flowering process does not commence below 18°C) and consequently the value of heat units for several date plantations are shown in Table 24.

- Munier (1973) used the same technique as Swingle but differentiated between varieties such as Gharas, Degla Beida with 180 days and a heat unit value of 1,800°C, and Deglet Nour with 200 days and a heat unit value of 1,890°C. His results, presented below (Table 25), concluded that the value of 1,000 °C is the minimum limit for growing a productive date palm.

TABLE 24
Value of heat units at various date growing areas in Algeria and Iraq

Plantation/Country	Heat Units (°C)
Laghouat/Algeria	2,327
Biskra/Algeria	3,049
Ayata/Algeria	3,295
Touggourt/Algeria	3,666
El Golea/Algeria	3,990
Baghdad/Iraq	3,898

Source: Swingle, 1904.

TABLE 25
Heat units at various date growing countries

Plantations/Country	Heat Units (°C)
Elche/Spain	792
Laghouat/Algeria	990
El-Kantara/Algeria	1,170
Touggourt/Algeria	1,854
Bechar/Algeria	1,620
Atar/Mauritania	1,860
Kankossa/Mauritania	1,836
Nema/Mauritania	1,903
Basra/Iraq	1,872
Kidal/Mali	1,841
Kayes/Mali	1,980
Agadez/Niger	1,827
Bilma/Niger	1,860
Largeau/Chad	1,860

In conclusion, the value of the heat unit is of great importance for defining the suitability of a site in which to grow a productive date palm, to eliminate areas that cannot grow date palm, and also to help in variety selection. Furthermore, the temperatures shown in the above table can be regarded as optimum for date cultivation.

2. Rain effect

Date palm culture has mostly been developed in areas with winter rainfall which does not cause harm to the date fruits, but benefits the soils of the plantations by lessivating the deposited surface salt and avoiding the upward movement of salt from lower layers. Table 26 shows that the main date-growing regions are almost rainless until November. In these countries harvest begins mid August until the end of October. Rain during the flowering and harvest season is likely to cause some damage to the fruits.

TABLE 26
Rainfall in the main date growing regions

Grove/Country	Length of record (years)	Rainfall (mm)				
Northern Hemisphere		**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**
Multan/Pakistan	-	60	50	8	0	2

Maskat/Oman	37	0	0	0	2	10
Bushire/Iran	52	0	0	0	2	40
Bahrein/Bahrein	21	0	0	0	0	10
Basra/Iraq	24	0	0	0	2	22
Cairo/Egypt	25	0	0	0	1	3
Tozeur/Tunisia	49	1	2	7	9	12
El Oued/Algeria	25	0	0	3	7	13
Biskra/Algeria	25	1	2	7	9	12
Indio, Ca/USA	33	0	1	1	1	1
Yuma, Ariz/USA	60	1	2	1	1	1
Southern Hemisphere		**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**
Alice Springs/Australia	17	43	41	33	16	13
Finke/Australia	26	22	40	17	14	11
Keetmanshoop/Namibia	37	25.2	43.4	41.3	16.3	4.4
Mariental/Namibia	50	35.9	54.5	47.2	15.7	3.1

Source: Nixon and Carpenter, 1978; Dowson, 1982; and McColl, 1992.

There is controversy about the effect of rain on pollination and fruit set**.** Rain that occurs just after pollination is considered as a washing agent that takes away most of the applied pollen. Another negative effect of rain on fruit set also results from low temperatures that accompany or follow rain. A third factor is the reduction of the flower's receptivity when in contact with water.

Date growers must assume that the rain will affect pollination/fruit set, and any pollination operation immediately preceded or followed by rain (4 to 6 hours) must be repeated.

Rain is also responsible for increasing the relative air humidity creating favourable conditions for cryptogamic diseases that result in the rotting of inflorescences. A light spring shower with ahigh relative humidity followed by warm temperature just before pollination causes the Khamedj disease (*Mauginiella schaettae*). This high relative humidity is also associated with the pollen's explosion (Further details on this subject are to be found in the Chapter "Pollination and Bunch Management").

The major damage caused by rain occurs when either the rain is early, or the dates are late in ripening. In fact, rain does not seriously damage the dates when they are still at the early Khalal stage, but rather has a beneficial effect by washing away all dust and sand particles from the fruits. Rain can however cause severe checking and cracking in the Kimri and late Khalal stages. In some areas of California (USA), where rain damage is frequent, date growers commonly use craft paper to protect fruit bunches (Figure 32). Rutab and Tamar stages are the most sensitive since rain and associated humidity cause severe damage including rotting and fall-off of the fruit. Rain or cool weather occurring near harvesting is also inclined to delay ripening.

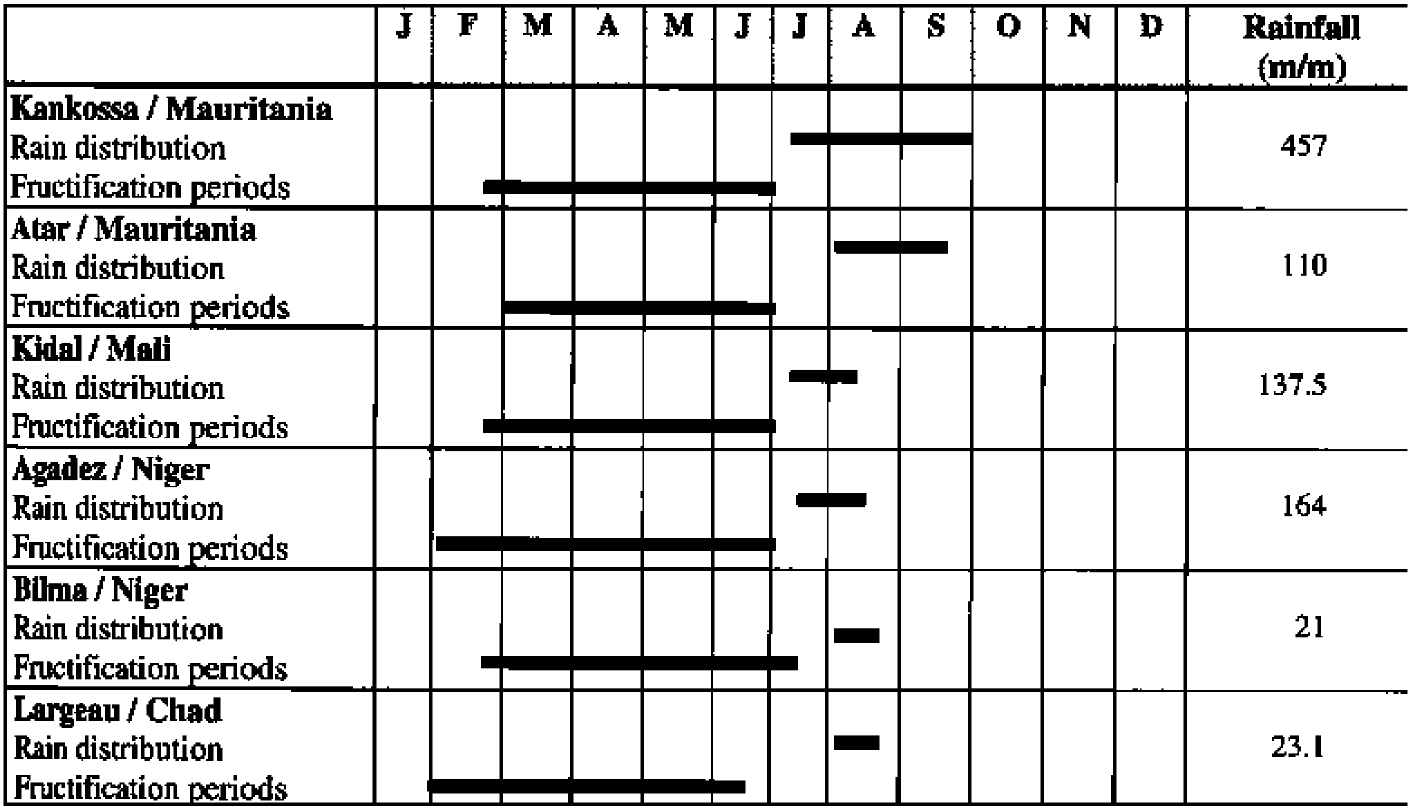
It is worth mentioning that the amount of any particular rain is of less importance than the conditions under which it occurs (Nixon and Carpenter, 1978). A light shower accompanied by prolonged periods of cloudy weather and high relative humidity may cause more damage than heavy rain followed by clear weather and dry winds.

Varieties of dates differ in their susceptibility to rain and humidity. Dayri, Khastawi, Thoory, Khadraoui, and Sair, under Coachella Valley conditions, were found to be the least damaged of sixteen varieties (Nixon, 1950). Zahidi, Khalas and Barhee varieties had average damage, while Deglet Nour, Yatima, Hayani and Ghars were the most sensitive. Both very early (Al Mehtari/Iran) and late varieties (Khissab and Hilali/Iraq) escape the rain and consequently their fruits are not affected.

The chances of damaging rain (in August, September and October for Northern Hemisphere and January, February and March for the Southern Hemisphere) in any given season is more important from a practical point of view. Hence, a season could be considered: Good to average, if less than 50 mm of rain fell in each of the three months; average to poor, if more than 50 mm of rain fell in one of the three months, poor, if more than 50 mm of rain fell in two of the three months; and very poor, if more than 50 mm of rain fell in each of the three months.

The extension of date palm culture to the southern part of the Sahara Desert (Sahel) came as an exception to the above with heavy rain in July, August and September, and a dry period during October, November, and December (Table 27).

TABLE 27
Rain distribution and fructification periods in the Sahel date growing countries



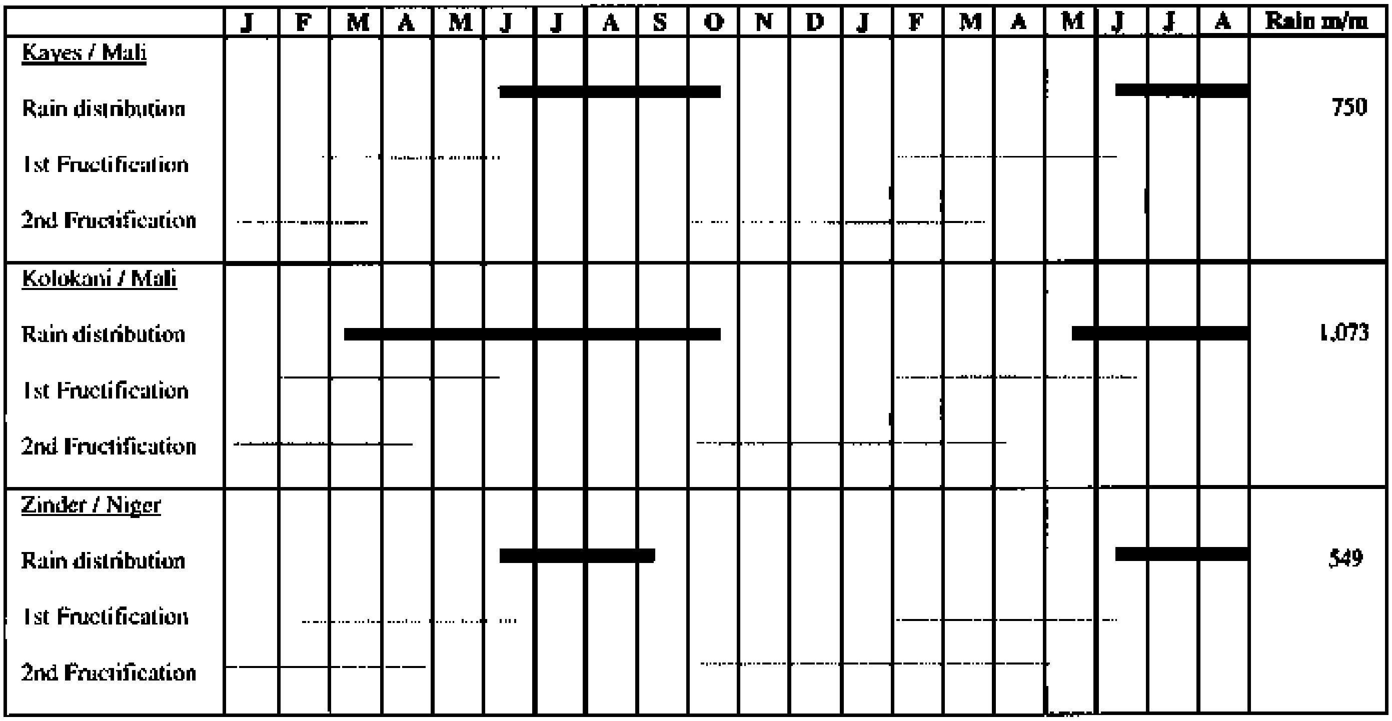
Source: Djerbi, 1995.

Table 27 illustrates the case of Mali, Mauritania and Chad where there is a perturbance of the date production cycle resulting in two periods of fructification:

i) One first short cycle, of about 130 to 150 days, characterised by flowering during the dry season and fruit maturation at early rainy season with an abundant yield but of a low quality.

ii) A second long cycle, of about 180 to 200 days, where flowering occurs during the rainy period and the fruit maturation at the dry season; the yield is less abundant but of a high quality. Table 28 illustrates the above two cycles in both Mali and Niger.

TABLE 28
Fructification cycles and rain distribution in two Sahel growing countries



Source: Djerbi, 1995.

3. Air relative humidity

Depending on air humidity at the locality of a date palm plantation, various advantages and/or disadvantages are found. In fact, the date palm eco-system is mostly of an arid nature where air relative humidity has a large influence.

In the presence of high air humidity, some leaf diseases, such as Graphiola leaf spot (*Graphiola phoenicis* Moug. Poit.), are becoming more prevalent, while others, such as the Date mite (Bou-Faroua), become rare or absent. On the other hand, when air humidity is low, fungal diseases are absent, while pest and mite attacks are dominant.

Air humidity also affects the date quality during the maturation process. At high humidity, fruits become soft and sticky, while at low humidity they become very dry (case of Northern Sudan and in-land plantations). This phenomenon is strengthened when low humidity is coupled with hot and dry winds (called Chili in Tunisia, Chergui in Morocco, N-W in Iraq, etc.).

Dry and hot winds cause a rapid maturation process leading to fruit desiccation and the appearance of a yellow or white ring at the fruit base.

When air humidity is high during maturation (date plantations in Bahrein, Minab/Iran), the skin of the date fruit shows several cuts or breaks with an edge-blackening (Blacknose), the soft fruits fall to the ground and consequently lose their commercial value.

The number of these breaks and the manner in which they occur (longitudinal, transverse, or irregular) varies between varieties. Deglet Nour's checking occurs mainly near the tip of the fruit.

The above effect occurs only when high humidity is experienced immediately before the Khalal stage. After the fruit acquires the Khalal colour, checking no longer occurs. After the flesh softens in the Rutab stage, the skin does not break readily upon contact with moisture, but the fruit absorbs moisture and tends to become sticky and more difficult to handle. After the Tamar stage is reached, air humidity causes little damage to the fruit unless it is neglected.

Most commercial date plantations in USA and Israel are not intercropped with any other plants/fruit tree species (citrus, lucerne, etc.) because of the increasing effect of these on the humidity level of the date plantation.

The following table illustrates the high relative humidity of four Middle East date plantations and at one place in Namibia.

TABLE 29
Examples of relative humidity of various date plantations (at 08:00 am)

Place/Country	Length of record (years)	Averages of Relative Humidity (%)

		July	**August**	**September**	**October**
Baghdad/Iraq	80	37	40	42	51
Basra/Iraq	18	51	51	55	60
Bahrein/Bahrein	15	68	74	74	77
D.I. Khan/Iran	10	72	75	75	76
		Jan.	**Feb.**	**March**	**April**
Keetmanshoop/Namibia	37	43	52	57	58

Source: Dowson, 1982.

4. Wind

Compared to other plant species, the date palm shows no damage under windy conditions. In fact, date palm can withstand strong, hot and dusty summer wind and consequently protects the other cultures by breaking the force of the wind and sheltering more susceptible vegetation (Dowson, 1982).

Wind is, however, a carrier of dust and sand that adheres to the date fruits in their soft stage (Rutab and Tamar). When the fruits are at their early development stage (green/Habakouk), nearly black-indurated patches are sometimes seen on the fruit because of the wind beating the tender fruits against the hard fronds. Recently planted small offshoots can, however, easily be uprooted by strong winds.

In most date growing areas the latter part of the pollination season is usually characterised by severe hot and dry winds which dries out the stigmas of the female flowers. Cold winds disturb the pollen germination. It seems, therefore, that dry wind storms lead to a faster drying of the styles which shortens the time for the pollen to reach the ovule (Reuveni et al., 1986). The speed of the wind could also have an effect on the pollination efficiency; light winds are beneficial and favour pollination while high speed winds will blow away a great deal of the pollen, especially on palms found at the edges of the plantation. In some cases severe wind could also break the inflorescence's fruit stalk (rachis), blocking the movement of nutrients and finally causing the death of the bunch. It has also been suggested that mites are carried from palm to palm by wind.

The falling down of an old date palm may be caused by strong wind but only in the following cases:

- If the palm is very tall with a large crown and grows in shallow soil;

- If a large number of offshoots are removed form the trunk of a palm at one time, leaving the palm without basal support; and

- If rats have gnawed away the roots on one side of the palm.

It is highly recommended that wind breaks be planted one to two years before the establishment of any commercial date palm plantation. Beefwood (*Casaurina cunninghummiana*, or *C. glauca*) is the most appropriate wind break for the protection of a date palm plantation (Figure 33) since they are both drought and salt tolerant.

5. Light

According to Mason (1925b), the growth of a date palm is inhibited by light rays at the violet and yellow end of the spectrum, but enhanced by rays at the other end of the spectrum i.e. red light. These latter rays are most active in promoting photosynthesis.

Clouds could reduce light intensity, but unfortunately, the sky is un-clouded in the date growing countries during the ripening period (July to October in Northern Hemisphere and February to May in Southern Hemisphere). Table 30 gives the average number of cloudless days in three famous date growing areas of Algeria (Lasserre, 1922), while Table 31 shows the sunshine and radiation values obtained in Keetmanshoop area (Namibia) for a period length of 37 years (1948-1985).

TABLE 30
Average number of cloudless days in Algeria

Place	Length of records (Years)	Number of cloudless days from July to October
Biskra		52

Touggourt	5	38
Eloued		75

TABLE 31
Sunshine and radiation (calories per square cm) in Keetmanshoop in Namibia

Month	Mean total of sunshine in hours	Mean solar radiation/day	
		Global	Diffuse
January	351.4	767.1	129.5
February	296.4	697.2	121.3
March	301.7	542.4	142.7
April	305.9	521.4	67.3
May	304.5	428.6	62.2
June	286.9	372.5	64.9
July	305.6	375.3	67.9
August	320.5	465.6	78.6
September	315.1	542.8	110.2
October	337.7	696.3	103.0
November	348.2	741.0	132.6
December	370.9	765.4	125.6
Mean	320.4		

In conclusion, the five important factors which determine the suitability of a site for date palm culture, are temperature, rain, humidity, light and wind. The effect of these factors on the growth and productivity of date palm is to be considered as a combination of all the factors and not each one separately.

Furthermore, because of the nature of date palm, its growth is not as easy as some other plant species and attention should be given to the following characteristics:

- Date palm cannot be classed as arenaceous, nor aquatic. Although frequently found growing in sand, its roots are characterised by air spaces similar to the ones in Banana roots, but it also grows well where the subsoil water is close to the surface.

- It is not a true halophyte despite its healthy growth in exceedingly salty places, as it grows better when the soil and water are sweet.

- It is not a xerophyte; although it has a thick waxy cuticle, leaflets with the two halves of their upper surfaces to the sun, reduced leaf surface, efficient insulation of the growing point and its trunk's vascular bundles; it requires a copious water supply.

Figure 29. Effect of low temperatures on:

A - Five years old Barhee palm; Note the yellowing and drying out of pinnae margins (-6°C);

B - Eight months tissue culture Medjool plants: Note the destruction of large part of the leaflet (-3°C)

Figure 30. Frost damage on date palm female inflorescence

Figure 31. Protection of female inflorescences with craft paper bags at Hardap Research Station (Namibia)

Figure 32. Protection unit made of craft paper to avoid rain damage to date fruit bunches (USA)

Figure 33. Wind breaks (*Casaurina cunninghummiana*) used for the protection of a commercial date plantation (Naute, Namibia)

CHAPTER V: DATE PALM PROPAGATION

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Date Production Support Programme

1. Introduction

Although economically important, palms are a much neglected plant group in terms of understanding development and propagation potential thereof. Furthermore, progress in the field of breeding, genetics, crop improvement, and expansion of commercial plantings for palm has been restricted by the habit and long-lived nature of these monocotyledonous trees. Most palms can only be propagated by seeds, i.e., Coconut and Oil palm.

There are three techniques to propagate date palm: Seed propagation, offshoot propagation (traditional methods), and the recently developed tissue culture techniques. This chapter will highlight each of these techniques.

2. Seed propagation

Seed propagation, also called sexual propagation, although useful for breeding purposes, is not a proper method of date palm vegetative propagation, and should be discouraged. Reasons in favour of discouraging seed propagation, are the following:

> * Date palm is a dioecious species and consequently half of the progeny will be males and half will be females, with no certain way to determine at an early stage the sex of the progeny, nor fruit or pollen quality prior to flowering (often only seven years later);
>
> * Female plants originating from seedlings usually produce late maturing fruits of variable and generally inferior quality compared to established clonal palms. In a seedling plantation it is rare that more than 10 percent of the palms produce fruit of satisfactory quality;
>
> * Date palms are heterozygous, and thus there will be much variation within the progeny, and desirable characteristics of the parent palm may be lost. In other words, it is not true to type propagation and no two seedling palms are alike;
>
> * Seedlings differ considerably with regard to production potential, fruit quality and harvesting time, making them very difficult to market as one harvest;
>
> * The above reasons result in waste of time, space and money.

Thus, seed propagation is by far the easiest and quickest method of propagation. However, it is not a true to type propagation technique and no two seedlings will be alike. Because of its diversity, the seed approach could only be useful for breeding purposes. When conditions are known to be unfavourable for date fruit production (case of marginal areas), the planting of date seeds, for future selection on fruit quality, is the most economical way of selecting clones that have some desirable characters such as rain and/or salt tolerance (Figure 34).

Taking the above into consideration, and also because of the many reasons listed below, date growers are encouraged to use tissue culture-derived material of known varieties with high date quality and marketing potential.

3. Offshoot propagation

Offshoot propagation, also called asexual or vegetative propagation, offers the following advantages:

(i) 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 and ensures uniformity of produce.

(ii) 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. From the time that the axillary bud of a leaf has differentiated into an offshoot until the time it grows outwards, takes up to three years (18 to 36 months), with another three to four years before it reaches the desired size for its separation and planting (Hilgeman, 1954).

Offshoots are mainly produced in a limited number (20 to 30 at most) during the early life of the palm (10 to 15 years from the date of its planting) depending on the variety and on prior fertilisation treatment, irrigation and earthing up around the trunks, (Nixon and Carpenter, 1978). Although 20 to 30 offshoots are produced by a palm, only three or four offshoots are suitable for planting out in one year and must still go into the nursery for 1 to 2 years before field planting. Zahidi, Berim and Hayani varieties are known to produce large numbers of offshoots, while Mektoum and Barhee varieties produce relatively low numbers of offshoots.

Offshoots are recognised by their curved form while seedlings have a straight form. Another way to differentiate between the two is that seedlings have roots all around their base with no connecting point to the palm, while an offshoot does not have any roots on the side where it was connected to the mother plant. Furthermore, an offshoot always has a mark on one side which is a result of detachment from its parent palm.

To obtain a high survival rate of transplanted offshoots, the following steps are recommended:

Offshoot selection

The offshoot selected for removal must be disease and pest free and at least three to five years old with a base diameter between 20 and 35 cm (Table 32), weighing over 10 kg but not more than 25 kg because of handling difficulties. Signs of mature offshoots are the availability of theirown roots, first fructification and the production of a second generation of offshoots (Nixon and Carpenter, 1978).

Small offshoots weighing 5 kg and less, if needed, could also be used, but their survival potential will be much lower than that of larger offshoots. They should initially be looked after, for at least two years, in a nursery, or mist bed in a greenhouse or a shade net structure (Reuveni et al., 1972). Fungi are usually a serious problem in a mist bed, and the offshoots must be treated twice a month with a large spectrum fungicide.

TABLE 32
Relationship between diameter and weight of the offshoot

Base diameter of the offshoot (cm)	Approximate weight (Kg)
12 - 15	4-8
15 - 20	8 - 15
25 - 35	22 - 35

The best time for the removal of offshoots and transplanting into the nursery for rooting (**never directly into the field**) is after the soil begins to warm up in the late spring and early summer (September/October in Southern hemisphere and March/April in the Northern hemisphere). February/March and September/October are then the most suitable period for field planting, respectively.

Offshoot rooting

Two types of offshoots occur on a date palm tree: the lower and older ones, and the upper and younger ones. It is believed that low offshoots are more active physiologically than high ones; they probably grow faster (the number of leaves produced increases with age). In fact, the high offshoots have less carbohydrates than low offshoots, resulting in low roots production and consequently low survival rate. It is also suspected that high offshoots develop when no fruit is on the palm.

Early offshoot removal is desirable because:

(1) removal allows easy access to the palm,

(2) removal improves the development and fruit production of the parent tree, and

(3) planting young offshoots is advantageous as they will in turn produce a greater number of offshoots than older ones.

Numerous factors to consider when rooting offshoots include: the size of an 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 an 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 twelve months before removal. Production of high offshoots is primarily of a varietal character but also in some cases related to a damp climate. For these high offshoots, boxes or plastic bags/Hessian material could be fastened around the base of the offshoot. Another technique is to leave them on the mother palm until they mature. They are then removed and rooted in a nursery (Figure 35a and 35b).

Offshoot pruning

When the aim is the production of offshoots, no green leaves should be removed from an offshoot until it is cut from the mother palm, since the growth of an offshoot is in proportion to its leaf area. When larger offshoots are selected for the following year's cutting, all their leaves must be retained until the offshoots are removed. When leaves interfere with cultivation, they may be tied together.

When a date palm is crowded with offshoots, only 5 to 6 larger offshoots could be left, considering the tree's equilibrium, and the other smaller ones could either be totally removed if not needed in the future, or have their leaves cut back close to the bud to retard their growth.

Offshoots removal

After 3 to 5 years of attachment to the parent palm, depending on the variety, offshoots will form their own roots and start producing a second generation of offshoots. Only at this stage are they ready to be removed (Nixon, 1966; Nixon and Carpenter, 1978).

Care and skill, acquired only by experience, is important in order to cut and remove an offshoot properly from its mother palm. The operation, usually carried out by two skilled labourers, starts by irrigation several days before cutting. Soil is then dug away from the offshoot(s) using a sharp, straight-blade shovel (a ball of earth, 5 to 8 cm thick, must be left attached to the roots of the offshoot, with the connection exposed on each side). Roots should at no time be cut closer than necessary, since most of the cut roots die and new roots just emerging are susceptible to injuries (Nixon and Carpenter, 1978).

A specially designed chisel is recommended to cut offshoots. It is a rectangular cutting blade made of tempered steel, which is welded to a solid iron handle. One side of the blade is fl at and the other bevelled so as to form a sharp cutting edge. The following chisel dimensions could be suggested: Blade: 11 cm wide, 22 cm long and 2,5 cm thick; Handle: 120 cm long and 3 cm thick (Figure 36).

Lower leaves must be cut off and the remaining ones tied together in order to facilitate handling. Once the loose fibre and old leaf bases are cut away and the connection between the offshoot and the mother-palm is located, the first cut is made to the side of the base of the offshoot close to the main trunk. The fl at side of the chisel is put towards the weak point of the offshoot and the bevelled side towards the mother palm. Injury must be avoided at all times, the offshoot's tender heart should never be damaged and the cutting operation must be only from one side to obtain a smooth cut surface.

After completion of the removal of the offshoot, the old leaf stubs and lower leaves are cut off close to the fi bre and the basal part left bare of leaves. Ten or twelve leaves around the bud are retained and tied close together 6 to 8 cm above the bud with heavy twine or wire. The terminal parts of these leaves extending beyond the tie (20 cm above the tip - centre of the offshoot) are also cut off (Figure 37). It is advised that the cut surfaces of both the offshoot and the mother palm be covered with a copper sulphate product in order to avoid infection by Diplodia and other parasites.

Survival of cut-offshoots depends to a large extent on the variety. Medjool's offshoot is far more difficult to establish than Deglet Nour or Zahidi.

In places such as Fezzan (Libya), some areas of Iraq and Saudi Arabia, and Hadramaout (Yemen), offshoots are not at all removed and continue to grow outwards from the original mother palm, producing large clumps consisting of hundreds of shoots, none of which produces a trunk and of course with no significant yield (Dowson, 1982).

Planting offshoots

It is advisable that an offshoot never be planted into the field directly after removal from the mother plant. A rooting period of one to two years in a nursery is essential in order to ensure an optimum survival rate and to avoid uneven development of the plantation.

In most soils, the early and rapid growth of the offshoot is better when the holes are prepared one to two months before planting. The size of the hole should be one m^3 and the holes should be filled with a mixture of topsoil and 10 to 15 kg of manure of high quality (with very little unmatured matter) and NPK fertilisers. The filled holes should be irrigated several times to promote the decomposition of the manure and also to allow the mixed soil to settle in the hole. Well-rotted manure can be used in holes prepared and irrigated shortly before planting, but extreme care must be taken to put the manure (and fertilisers) deep enough to form a layer of soil of at least 15 to 20 cm thick between the manure and the base of the offshoot.

The leaf base of the offshoot should be clearly above the soil level. It is important to plant the offshoot to the depth of its greatest diameter in order to avoid the rotting of the base (if it is too low) and to prevent the water reaching the loose fibre near the bud which causes its desiccation (if it is too high). The plant water basin, of 1.5 to 1.8 m in diameter and 20 to 30 cm deep, should be prepared around the offshoot (Figure 41).

The soil near the newly planted offshoots should be kept moist at all times by light and frequent irrigation. The irrigation frequency is dependent on the type of soil. Very sandy soils require daily irrigation during the first summer. Heavy soils require irrigation only once a week; while in most soils irrigation is required every second or third day. During the first six weeks (or till the appearance of new growth) the date grower should always inspect his/her planted offshoots to make sure that the surface soil does not dry and shrink away from the offshoot. A mulch of hay or straw around the offshoot will enhance moisture contention, weed control and finally improve humus in the basin (Figure 38).

Young offshoots and tissue culture-derived plants should be protected from harsh climatic conditions (sun and wind during the first summer and cold the following winter) and against some animals (rabbits, etc.). The use of shade net/hessian wrapping or a tent of date leaves is recommended (Figure 39). The top is to be left open so that new growth may push through.

Under Namibian conditions (Southern hemisphere), there are two appropriate periods for planting: February/March and September/October. The first period is preferable since it allows a longer time for the offshoot to establish itself before the arrival of the next year's hot summer temperatures, although it passes through the cold months of winter (June, July and August) while the plant is still in its initial establishment phase. The second period (September/October) avoids the cold temperatures and later receives warm temperatures that allow an active growth followed by the hot summer (December, January).

To summarise, offshoot propagation is true to type but it is not very practical from a mass propagation point of view, and consequently does not satisfy the large needs of plant material. The following reasons illustrate this handicap:

- Offshoot production is limited to a certain period in the palm's life span (a short vegetative phase of about 10 to 15 years);

- During this short phase, only a limited number of offshoots are produced (20 to 30 offshoots, at most, depending on the variety);

- Some varieties produce more than others (some do not produce offshoots at all);

- A mature specimen with no offshoots will be lost if not propagated through another technique;

- Depending on the care given, a low planting survival rate is frequently obtained when using offshoots;

- The use of offshoots will enhance the spread of date palm diseases and pests;

- Offshoot propagation is difficult, laborious, and therefore expensive.

In comparison to the seed propagation technique, offshoots which are axillary vegetative buds, will offer the following two advantages:

- The fruits produced will be of the same quality as the mother palm and ensure uniformity of produce (true to type).

- The offshoot will bear fruit earlier than seedlings (by 2-3 years).

4. Tissue culture propagation

Palms are a much neglected plant group in terms of understanding their development and vegetative propagation potential. Yet, they are economically important in tropical and subtropical regions. The rapid propagation of date palm as well as propagation from a mature specimen, is impossible due to the limited number of offshoots produced and the fact that offshoot production is limited to a certain period in the palm's life span. As mentioned above, seed propagation of date clones and cultivars is impractical.

The application of tissue culture techniques for date palm, also called *in vitro* propagation, has many advantages (in comparison to the above two techniques) and enables the following:

- Propagation of healthy selected female cultivars (disease and pest-free), Bayoud resistant cultivars, or males having superior pollen with useful metaxenia characteristics which can easily and rapidly be propagated;

- Large scale multiplication;

- No seasonal effect on plants because they can be multiplied under controlled conditions in the laboratory throughout the year;

- Production of genetically uniform plants;

- Clones to be propagated from elite cultivars already in existence, or from the F1 hybrids of previous selections, and seed-only originated palms;

- Ensure an easy and fast exchange of plant material between different regions of a country or between countries without any risk of the spread of diseases and pests; and

- Economically reliable when large production is required.

The success of propagating monocotyledons *in vitro* has been limited to relatively few herbaceous species. Similarly, most dicotyledons, successfully tissue cultured, have also been the herbaceous types. It has been postulated that in woody plants, the ability to regenerate plantlets using tissue culture techniques was lower in comparison to herbaceous plants. In palms, until twenty years ago, little success was achieved in inducing and maintaining good callus. Plant tissue culture techniques have been employed to clone a wide range of plants and economically important palms e.g., coconut, oil and date palms (Cheikh et al., 1989).

In reviewing date palm tissue culture, the classification followed will be that of behaviour and relevant techniques of tissue culture as a whole from a perspective of their eventual applications to date palm (Zaid and Djerbi, 1984; Zaid, 1985; 1986a; 1986b).

This review also explains the background to the cloning methods applied to the date palm and explores the wide range of results obtained with embryo culture, meristematic tissues (shoot tips and buds) and highly differentiated somatic tissues (leaf, stem, inflorescence and root sections).

4.1 Embryo culture

Embryo culture involves excising an embryo-aseptically from the seed and planting it in a sterile nutrient medium (Hoded, 1977). Embryo culture is suggested to have several potential applications in plant research. It is used to save embryos that fail to develop naturally in the fruit or seed, or grow out embryos from interspecifi c hybridisation where defective endosperms are common (Johnston and Stern, 1957). Embryo culture may also be used to reduce lengthy dormancy periods due to physical and/or chemical inhibitors present in the fruit or seed (Hoded, 1977). Excised embryos cultured *in vitro*, free from these inhibitors, usually germinate immediately. Isolated embryos were also chosen as explant material in metabolic studies (Raghavan, 1976). The culture of isolated embryo segments may be useful to study the development of the primary meristems, organogenesis and the interactions between different organs (Rabéchault and Gas, 1974). The culture of embryo outside the seed was first performed with crucifers (Haning, 1904). It has since become a routine procedure.

With regard to date and other palms, callus initiation and embryoid induction was first observed by Rabéchault (1962) working with oil palm embryos. Reuveni (1979) reported that callus and roots developed from the date palm embryo cotyledonary sheath tissue in media containing naphthalene acetic acid (NAA). This callus continued to proliferate and to differentiate roots when subcultured if a piece of the cotyledonary sheath was present. Ammar and Benbadis (1977) established organogenic callus from date palm cotyledonary sheath of zygotic embryo germinated *in vitro*.

Reynolds and Murashige (1979) cultured embryo explants of *Chamaedores costaricana* Oerst, *Howeia forsteriana* Becc., and *Phoenix dactylifera* L. *in vitro*. Green date palm fruits, harvested two to three months after pollination were planted in a medium enriched with 2,4-dichlorophenoxy acetic acid (2,4-D), and a creamy-coloured grainy callus was subsequently developed. Transfer of this callus to an auxin-free medium resulted in the development of numerous asexual embryos. Mature zygotic embryos cultured in nutrient media containing charcoal with high auxins levels, 10 and 100 mg/1NAA, also produced nodular callus (Tisserat, 1979). Repeated culture resulted in the formation of plantlets. Tisserat and DeMason (1980), described plantlet formation from date palm tissue cultures. The morphological development of asexual embryos from callus closely paralleled excised zygotic embryo germination *in vitro* (Figure 40).

Zaid and Tisserat (1984) performed a survey study to determine excised embryo callus production. In the Arecaceae, embryo excised from mature seeds of 38 species were cultured on modified Murashige and Skoog (MS) medium containing 3g/L^{-1} activated charcoal; with 100 mg L^{-1}, 2,4-D and 3 mg L^{-1} N6- (2 - isopentyl) adenine (2-iP). Embryo cultures from 18 of these species produced prolific callus after repeated reculturing for six months. Zaid (1987) also cultured embryos of date palm to follow up their development. The sequence of germination is shown in Figure 41.

4.2 Culture of date palm meristematic tissues

When comparing shoot-tips and lateral buds *in vitro* versus culturing other explant sources, the following advantages become apparent:

1. Shoot-tips and lateral buds are protected by bud scales and leaves, and are usually easier to surface-sterilise than root or stem explants (Morel, 1960).

2. By culturing shoot-tips or buds, an entire shoot is already present, thus only root induction is required to produce a whole plantlet (Morel, 1965; Williams, 1974).

3. The cells of the shoot-tips and buds are more uniformly diploid than those derived from less meristematic regions (Murashige, 1975). Presumably, plantlets derived from naturally meristematic regions are likely to be clonal and generate faster than other explant sources.

A distinction is made between bud and apical meristem cultures. Lateral bud culture involves the growth of an entire rudimentary vegetative shoot. Apical meristem culture, ideally involves only the excision and growth of apical dome of the shoot usually less than 0.1 mm in diameter and 0.25 mm in length, sometimes with, though preferably without, a few leaf primordia attached (Cutter, 1965). In contrast to culturing herbaceous angiosperm shoot apices, few woody angiosperm shoot-tips have been established *in vitro* (De Fossard, 1976).

4.2.1 In vitro culture of date palm shoot-tips

Schroeder (1970) and Staritsky (1970) employing date and oil palms respectively, cultured shoot-tips *in vitro* with some success. However, most of excised shoot-tips either failed to grow or showed no root differentiation.

Reuveni et al.(1972) found that growing tip cultures of date palm responded irregularly to growth regulators, but optimal leaf development occurred when media contained 0.1 mg/1 NAA and 0.01 mg/1 kinetin. Callus occasionally formed at the cut surface of the tip, particularly in dim light, when low concentrations of auxin and/or cytokinin were present.

Generally this callus was very short lived and its subculture was unsuccessful (Reuveni and Kipnis, 1974).

El Hannawy and Wally (1978) observed some bud differentiation in date palm cultures. They reported that by adding 200 mg/1 "fermentol" to MS medium containing 1.0 mg/1 auxin and kinetin, and using an incubation temperature of 25°C, 60 % bud differentiation occurred. Scharma et al. (1980), using date palm shoot-tips, reported limited success in their development due to the browning of the tissue and media. Tisserat (1979), culturing date palm shoot-tips,found that a high auxin concentration of 10 and 100 mg/1 NAA and 2,4-D caused a reduction in the culture weight, and inhibition of shoot growth, but promoted the formation of yellow-white nodular callus. These nodules were precursors to asexual embryos. Transfer of callus to nutrient medium containing lower levels of auxins such a 0.1 mg/1 NAA or 2,4-D allows shoot development from tips to occur. Male and female shoot-tips were found to grow equally well. Root initiation was infrequent and did not appear to be related to the nutrient medium composition.

Zaid and Tisserat (1983a) cultured date palm shoot tip explants from adult palms, offshoots, seedlings and asexual plantlets on modified MS nutrient media containing 10 mg/1 NAA. Differential morphogenetic responses were obtained dependent on the explant type and parent source (Table 33). The same authors also determined the action of several auxins and cytokinins on development of date seedling shoot-tips and apical meristems (Table 34). Shoot-tip explants consisted of the apical dome with two to four leaf primordia, and varied in size from 0.5 to 1 mm^2. Meristems and tips were cultured on modified MS medium containing 3 mg L^{-1} activated charcoal, 0.1-300 mg L^{-1} NAA, 2.4 - D, indoleacetic acid (IAA), indolebutyric acid (IBA), 4 - chorophenoxyacetic acid and 2iP. Best consistent shoot regeneration occurred on nutrient media containing 10 mg L^{-1} NAA. These shoots were recultured on nutrient media, devoid of charcoal, containing 10 mg L^{-1} NAA or kinetin to obtain rooting and enhanced shoot development. Best rooting was achieved with 0.1 mg L^{-1} NAA with 63% of the shoots initiating adventitious roots after the first culture passage. Axillary bud outgrowths were occasionally obtained from shoots cultured on media containing 0.01 and 0.1 mg L^{-1}NAA only.

TABLE 33
Morphogenesis obtained from shoot tip cultures derived from various date explant sources

Explant sources (*)	Survival/ treatment (%)	Shoot growth/ culture (%)	Shoot length/ culture (%)	Leaves/ culture	Rooting/ culture (%)
Adult palm	70	85	2.12 ±.71	1.5 ±.5	0
Juvenille offshoot	78	80	2.75 ±.69	2.5 ±.6	0
Seedling	85	100	2.35 ±.65	2.0 ± 0.0	60
Asexual plantlet	95	100	1.67 ±.39	2.2 ±.4	80

(*) 15-20 cultures employed per treatment; results taken 8 weeks after planting.

TABLE 34
Influence of growth regulators on the growth of date palm shoot tips

Test levels (mg/l)	Shoot growth (%) Growth Regulator Type					

	NAA	2,4-D	IAA	Kinetin	BA	2iP
0.0	58	50	42	80	58	80
0.1	58	-	-	60	67	60
0.3	67	47	33	40	58	40
1.0	58	53	42	53	50	53
3.0	67	53	33	66	58	66
10.0	75	53	33	73	33	73
30.0	-	67	50	-	33	-
100.0	75	13	-	60	42	60
300.0	58	6	25	53	42	53

4.2.2 In vitro culture of date palm buds

Most buds of date palm were reported to die within the first 30-50 days after planting *in vitro* (Reuveni and Kipnis, 1972; Schroeder, 1970). Only the largest and most distinctly differentiated buds grew. These buds exhibited leaf expansion and produced additional leaves. Tisserat (1979) and Zaid (1981) also investigated the conditions for bud development, and found that in nutrient medium shoot-tips and lateral buds grew equally well on the same medium. Callus cultures have been initiated from axillary buds of 2 to 4 year old date palm offshoots. Zaid and Tisserat (1983b) found that subcultured lateral buds callus on nutrient media devoid of charcoal and supplemented with 0.1 mg/1 NAA, produced adventitious plantlets. Tisserat and DeMason (1980) found that on a medium devoid of 2,4-D and 2-iP, sectioned buds callus consisted of two distinct types of tissues; a loose friable tissue and compact aggregates. The friable portion of the callus was composed of large non-meristematic cells and disorganised clumps which were highly vaculated and ranged in diameter from 20-40 µm. This tissue was not involved in embryo formation and was generally found surrounding the aggregate clumps which consisted of densely cytoplamic cells containing few vacuoles and usually were 8-20 µm in diameter. The formation of vascular bundles within the asexual plantlet at the 8- week old stage corresponded to that found in the zygotic seedling.

Starting from the bottom of young leaves, soft tissues, shoot tips or axillary buds of date palm offshoots (Figure 42),and using MS half strength or Beauchesne medium supplemented by various auxins at a low concentration, buds were obtained after six months of *in vitro* culture (Beauchesne et al., 1986) (Figure 43).

Early rooting of date palm tissues reduce bud multiplication and is, occasionally, responsible for the inhibition of bud initiation. In order to solve this problem, the bottom of young leaves of date palm offshoots were cultured on eight different nutrient media with different levels of growth regulators (Anjarne and Zaid, 1993). High level of auxins, especially NAA, allowed root initiation. These roots showed a rapid growth after subculturing on a medium containing a lower level of auxins. Furthermore, organogenesis was inhibited on media with a low concentration of auxins.

Vitrification phenomenon of date palm tissues is a handicap for the successful *in vitro* multiplication of some date varieties and selected clones. In order to overcome such a problem, four culture media with different ammonium/total nitrogen ratio were tested, and bottom young leaves from offshoots of AGUELLID variety were used (Bougerfaoui and Zaid, 1993). It was found that ammonium plays an important role in the vitrification process. High levels of ammonium nitrate were found to enhance rapid growth and consequently tissue vitrification (46 to 53 % of cultures); while this phenomenon is reduced to 14 - 19 % in media with low levels of ammonium nitrate.

4.3 Culture of highly differentiated date somatic tissues in vitro

4.3.1 Leaf cultures

Callus developed from a seedling date palm leaf (Schroeder, 1970), and gave rise to roots several months later. Similar results were obtained by Reuveni and Kipnis (1974). In their study, primordial leaves survived in culture and expanded, especially in the presence of light. The addition of plant growth regulators at concentrations of 0.1 mg/l and above was injurious to cultured leaves.

Eeuwens and Blake (1977) working with date palm leaf found development of root initials to be enhanced by the presence of a low level of gas and auxins, and by a reduction in either the level of minerals or sucrose. *Phoenix* leaf petiol explant has initiated roots within 6 weeks when subcultured onto a medium with high levels of auxin (Eeuwens, 1978). Root initiation was not prevented by the presence of high cytokinin or low sucrose levels, but occurred more frequently in media containing high sucrose and reduced cytokinin levels. Poulain et al (1979) obtained some callus at the base of young date palm leaves. Buds developed at the insertion zone between young leaves and rachis. Roots were obtained on MS supplemented with a combination of low auxin levels such as 1.2 and 3 mg/l NAA, IBA, and IAA, respectively. Scharma et al (1980) noted callus from leaf petioles of date palm initiated in media employed by Staritsky (1970) or using Eeuwens Y/3 mineral formulation (Eeuwens, 1976).

Zaid (1981), working with date palm leaf explants from adult trees, offshoots, seedlings and asexual plantlets, found that only subcultured leaf callus from seedling and asexual plantlets produced roots.

4.3.2 Stem culture

Staritsky (1970) and Smith and Thomas (1973), both working with oil palms, and Eeuwens (1978) with coconut and date palms, obtained a white callus on a few stem cultures. Further attempts to subculture this callus failed.

Phoenix stem explants reportedly enlarged considerably in size during the first few weeks of culture (Tisserat, 1979). Repeated culture to fresh media resulted in the formation of non-friable nodular callus. Plantlets were developed from this callus. Poulain et al. (1979) working with date palm stem tissues also successfully initiated callus.

4.3.3 Inflorescence culture

Inflorescences of several species have been cultured *in vitro* (Nitsh, 1963). Since 1973, several workers attempted to culture palm inflorescences. Explants of female and male oil palm inflorescences were cultured on a variety of media and usually developed somewhat normally, but callus was not obtained (Smith and Thomas, 1973). A high auxin level was speculated to be necessary to disrupt normal development. This has subsequently been confirmed in date palm (Eeuwens and Blake, 1977).

Date palm ovules, carpel tissue, parthenogenetic endosperm, and the fruit stalk blackened within 24 hours after culturing on nutrient media, and subsequently died (Reuveni and Kipnis, 1974). Also cultures of date palm floral bud reproductive tissues and especially male anthers, usually turned brown and died after a few weeks in culture (Tisserat et al., 1974). De Mason and Tisserat (1980) found that *in vitro* applications of auxins to media increase the frequency of visible expanded carpels developing from supposedly date palm male fl owers.

Vestigial female date carpels on surviving male flowers enlarged and became quite prominent (Tisserat, 1979). White friable callus usually initiated from the floral bud strand (Tisseral et al., 1979). In some cases, roots and embryoids were initiated from explants of *Cocos* inflorescences rachillae (Eeuwens, 1978) and from date palm (Tisserat, 1979). Roots have not been initiated on inflorescence rachis explants which lack leaf or meristem tissue.

Date palm inflorescence culture was also largely investigated by Drira (1981). Morphogenetic responses were found dependent on the origin and physiological stage of the explant.

4.3.4 Root culture

Staristsky (1970) and Schroder (1970) were the first to investigate root cultures in palms *in vitro*. Oil palm root and root primordia failed to develop. Schroder (1970) observed that date palm root pieces in turn developed secondary rootlets but did not produce shoots. Eeuwens (1978) found that isolated roots excised from cultured explants of date and coconut palms continue growth and produce laterals when subcultured on liquid static media. Callus was also reported to form at the root tip region of young date palm seedlings (Smith, 1975; Smith and Thomas, 1973). This callus had produced leaves and shoots. Other investigators (Scharma et al., 1980) reported no growth for cultured date palm roots. Usually, severe browning and death of root explants occurred within the first few weeks of culture. However, Zaid and Tisserat (1983a; 1983b), obtained some callus from seedlings and asexual plantlets roots when callus failed to exhibit any morphogenic response.

4.4 Browning of tissues and media in date palm tissue culture

During the course of *in vitro* growth and development, plant tissues not only deplete the nutrients that are furnished in the medium, but also release substances that can accumulate in the cultures. These substances, such as phenols, may have profound physiological effects on the cultured tissues. Date palm tissue cultures, like those of many other plants, have been commonly observed to release discolouring substances into the medium which inhibit their own growth. For date, injury through cutting of tissue is accompanied by secretion of the substance(s) into the medium. The intact organ, as exemplified by embryos or whole leaves on tips do not brown and thus grow well in culture (Reuveni and Kipnis, 1974). Browning of the tissue and the adjacent medium is assumed to be due to the oxidation of polyphenols and formation of guinones which are toxic to the tissues (Maier and Metzlier, 1965; Zaid, 1987).

To minimise browning, Murashige (1974) has suggested the pre-soaking of explants in ascorbic and citric acid solutions and adding them to the culture medium. Zaid and Tisserat (1983a; 1983b) soaked their date palm explants in an anti-oxidant solution (150 mg/l citric acid and 100 mg/l ascorbic acid) prior to the surface sterilisation treatments. Addition of a combination of adsorbents including citrate, adenine and glutamine, retarded browning in date palm explants (Rhiss et al., 1979).

Addition of other adsorbents to nutrient media, such as dihydroxynaphtalene, dimethylsulfoxide, were ineffective against browning in date palm explants (Zaid, 1984). Apavatjrut and Blake (1977) suggested that browning could be eliminated by a nutritionally balanced medium. Excision of browning explant parts during culture was also advocated to prevent this problem (Zaid, 1984).

The use of charcoal is preferred over cysteine and other adsorbents because the latter are often toxic to the plant tissues at higher concentrations (Zaid, 1984, 1990). Addition of 3 % charcoal has caused substantial root and shoot growth of date embryos. Constantin et al. (1977) suggested that the growth regulators required for callus growth and shoot development for tobacco are adsorbed by charcoal addition. Similarly, Fridborg and Erikson (1975), postulated that the addition of charcoal to a culture medium drastically alters the properties of the medium. Hence, growth regulator substances are tested at high levels (e.g. 10 and 100 mg/l) with charcoal included in the nutrient media to obtain beneficial effects on tissues (Zaid, 1990; Zaid et al., 1989).

4.5 Cryopreservation of date palm shoot tips

Studies on the cryopreservation of date palm for germplasm collections were initiated by Towill et al., (1989). Shoot-tips were excised from 2 month-old seedlings derived from the cultivar "Medjool", precultured for 2 days and then cooled to liquid nitrogen (LN) temperatures using procedures described for potato and mint species. Viability of treated shoot-tips was assessed by growth *in vitro*. Dimethylsulfoxide (DMSO) in concentrations up to 10 % was not toxic, although growth was slower than untreated shoot-tips. Several combinations of DMSO and sucrose were effective in obtaining survival after LN exposure. In most cases, the LN-treated shoot tips developed directly into a shoot without callus formation (Towill et al., 1989).

4.6 Organogenesis and asexual embryogenesis

Date palm plantlets may be produced through either; asexual embryogenesis, i.e. initiation and germination of somatic embryos from callus; or organogenesis, i.e. rooting and division of shoot tips and lateral buds.

Organogenesis technique, based on meristematic tissues potentiality, avoids callus formation and does not use 2,4-D. Growth substances included in the media are used as low as possible.

Organogenesis technique consists of 4 steps: Initiation of meristematic buds (also called the starting step), multiplication (Figure 42), elongation and rooting (+ swelling step). The success of such a technique is tremendously dependent on the success of the first step (initiation); Furthermore, various problems met at other levels have their origin at the initiation phase. These technical problems could be summarised as follows:

* <u>At the initiation phase</u>

  - Physiological stage of the offshoot, weight, age, signifi cation degree, period of introduction.

  - Initiation: too long.

- Bacterial contamination.

- Browning phenomenon.

- Varietal response to the technique/Lack of reactions of some clones and varieties.

- Yield of the technique/offshoot.

- Precocious root development.

- Lack of results repetition.

* At the multiplication phase

- Low and irregular multiplication rate.
- Decrease of regeneration capacity (precocious rooting).
- Loss of totipotency for some varieties.

* Rooting and elongation

- Low effi cient rooting.

* At the acclimatisation phase

- Low rate of survival.

Asexual (also called somatic) embryogenesis, is based on the callus production and multiplication, followed by the germination and elongation of somatic embryos. Up to now, this technique had shown to be genotype independent with a high rate of multiplication and a high survival rate upon transfer to soil.

4.7 True-to-Typeness

There is always a dispute amongst date growers, technicians and scientists about the true-to-typeness of plants produced *in vitro*. It is worth mentioning that tissue culture-derived plants of many species are subject to somaclonal variation in particular, and to genetic variations in general. Unlike epigenetic variations, which are at physiological level with non-heritable effect, genetic variations are affecting the genome and consequently are heritable (Pierik, 1987; Zaid, 1987; 1990).

According to these authors, factors causing variations in plant tissue culture are:

- Technique used for propagation;
- Nature of plant mother (chimera);
- Type of growth regulators used;
- Type of explant used (ploidy gradients: apex to root);
- Age of culture (> one year);
- Medium composition; and
- Incubation conditions.

Most of the commercial laboratories are doing their best to ensure the true to typeness of the produced date plant material. Various techniques are used to produce and certify the conformity of the plants (Histo-cytology:Figure 44), iso-enzyme, RFLP (Figure 45), RAPD techniques). In most cases, fi nger printing is the technique actually used, but according to our experience we feel that the fi eld response is the only reliable way to confi rm if the palms derived from tissue culture are true to type to the plant mother.

Up to now, only two cases of variation with Medjool and Barhee have come to our attention. Out of 2000 Barhee palms derived from asexual embryogenesis, only 2 are showing an abnormal vegetative growth (a ration of 0.1 %). These palms are marked and their fruits will be compared to the mother variety (Figures 46, 47 and 48).

4.8 Commercial production

Various laboratories in the world have made attempts to propagate date palm by tissue culture techniques. According to the knowledge of the authors, success has been achieved at only a few international laboratories (Table 35).

Some of these laboratories are recent (2 to 3 years), while others have been functioning for approximately 15 years. There are 9 functional laboratories known to the authors. These are found in England (1), France (2), Israel (1), Morocco (1), Namibia (1), UAE (1), Oman (1), and India (1). Information about the last two laboratories is not available.

The commercial laboratory of the "Domaine Agricole El Bassatine" (Morocco), which since its start had produced ± 500,000 plants, is reserving all its production for national use. No signifi cant sale outside Morocco has been implemented because all the production is destined to rehabilitate the Moroccan Date plantations destroyed by the Bayoud disease.

The remaining laboratories (England, France, Israel and Namibia) are potential sources of date plant material. Most of these laboratories' efforts were focused on the Medjool (and Barhee recently) variety with an average sale price (FOB) of about 20 to 23 US$ per plant. Delivered plants have only juvenile leaves and still need to be hardened-off by the buyer before fi eld planting (Figure 49). Note that the selling price depends on the variety, the number of plants ordered and the growth stage at delivery.

TABLE 35
List of international date palm commercial laboratories(*)

Country	Company	Address
UNITED KINGDOM	- DATE PALM DEVELOPMENTS	Baltonsborough, Somerset BA6. 8QG, United Kingdom Tel: (+44) 1458 850576 Fax: (+44) 1458 851104
France	- MARIONNET G.F.A.	21 Rue de Courmemin 41230 Soings - France Tel: (+33) 254 987 103 Fax: (+33) 254 987 523
	- PALMDAT - France	"Laboratoire de Physiologie Végétale" "Recherche et Développement" Marolles 37460, Genille, France Tel: (+33) 247 5952 52 Fax: (+33) 247 59 59 18
ISRAEL	- RAHAN MERISTEM	Propagation Nurseries Kibbutz Rosh Hanikra Western Galilee 22825, Israel Tel: (+972) 4 985 7100 Fax: (+972) 4 982 4333
MOROCCO	- DOMAINE AGRICOLE EL BASSATINE	B.P. 299 Meknes, Morocco Tel: (+212) 5 50 0493 Fax: (+212) 5 50 0730
NAMIBIA	- PALMDAT NAMIBIA	P.O. Box 20519 Windhoek, Namibia Tel: (+26461) 230480 Fax: (+26461) 250889

UNITED ARAB EMIRATES	UNITED ARAB EMIRATES UNIVERSITY - DATE PALM DEVELOPMENT RESEARCHUNIT	P.O. Box 81908-Al-Ain Tel: (+9713) 8732334 Fax: (+9713) 7832472
Others in Middle East (Oman) and in India	- No information available	
Total Laboratories	**9**	

(*) There is no order of importance in the list, which should also not be considered as exhaustive. Countries were classifi ed in an alphabetical order.

5. Acclimatisation and hardening-off of tissue culture-produced date plants

5.1 Introduction

Although *in vitro* mass plant propagation has become commercially feasible, many problems hinder its application to economically important crops.

One of the major obstacles concerning the practical application of plant tissue culture to mass propagation has been the diffi culty of successful transfer of plantlets from *in vitro* conditions to a soil medium. Losses from 50 to 90 % of *in vitro* propagated plantlets of many species have been encountered at the time of transfer to soil (Zaid and Hughes, 1989a; 1989b). This isunfortunate because the ultimate success of plant tissue culture as a commercial means of plant propagation depends on the ability to transfer plantlets out of culture, on a large scale, at low cost and with a high survival rate.

It is appropriate at this level to differentiate between the acclimatisation of date palm *vitro* plants at the laboratory's glasshouse and their hardening-off at the farmer's nursery.

5.2 Acclimatisation

Acclimatisation presents challenges at least equal to those posed by the initiation of cultures because it marks the end of artifi cial control and the beginning of autonomous plant growth. Approximately 20 years ago it was stated that research concerning the preparation of *in vitro* plantlets for transfer to soil had been neglected (Murashige, 1974). Since that time many scientists have become interested in the effects that the transfer process has on tissue cultured plantlets (Zaid and Hughes, 1995a; 1995b).

The culture of date tissue *in vitro* with almost 100 % relative humidity within the culture vessel can lead to various abnormalities in the plant structure (Zaid and Hughes, 1989c). Plants of many species produced *in vitro* often show morphological, structural, physiological and biochemical differences from those produced conventionally. These include reduced epicuticular wax deposits (Figure 50), altered leaf anatomy (Figure 51), excessive water loss and stomatal abnormalities compared to greenhouse grown plants (Zaid, 1995; Zaid and Hughes, 1995c).

It is worth mentioning that loss of viability is attributed to poor control of water loss from the date plants and their heterotrophic nature.

Stomatal development and frequency can be affected by water availability, light intensity, temperature, humidity and osmotic concentration of the culture medium (Zaid and Hughes, 1995b).

Even when gradual hardening off has been used, poor survival and slow growth of date plantlets have commonly been reported. Such a low survival rate (that sometimes reaches below 50 %) is caused by several factors which are mainly young physiological stage of plantlets to transfer, inadequate root system, unsatisfactory irrigation schedule, and lack of technical care at the *in vitro* laboratory stage.

Several techniques have been used to acclimatise date plantlets and improve their survival during establishment under greenhouse conditions. The effectiveness of these methods depended upon ambient conditions, and most methods have involved environmental modifications. Mentioned below are the three most important factors to be taken into account by the manager of a date palm propagation laboratory in order to ensure a high survival rate and fast growing situation of date palm tissue culture-derived plantlets:

5.2.1 Physiological stage

Date palm plantlets are ready for transplanting only when they gain the following characteristics:

- Two to three healthy and enlarged leaves with no curling phenomenon;

- A shoot length of at least 10 to 15 cm from stem base to the highest point of the leaves;

- A shoot base with an onion bulb-like form (also called pear-shaped crown);

- A well developed root system with an average of 5 cm in length. Adventitious rooting is obtained by trimming the primary roots to 1 - 1.5cm in length and reculturing the plant to an agar nutrient medium containing 0.01/0.1 mg/l NAA without charcoal; and

- Well acclimatised plant as a fi nal product (Figure 52).

Plants are then rinsed in distilled water to remove adhering agar and residual sucrose. A spray with Benlate solution at 0.5 % (or any wide spectrum fungicide) is important since it protects the plant from fungal attack.

In order to achieve the above, and consequently produce a well pre-acclimatised date plant that will survive the transplanting stress, it is recommended that the following be ensured:

- Do not transplant any plant until it gains the previously mentioned characteristics;
- Enhance a root-elongation process by using auxins at the last *in vitro* stage;
- Increase the light intensity during the last 4 to 6 weeks; and
- Create an artifi cial osmotic stress (at the nutrient medium level).

5.2.2 Transplanting to soil medium

The transplanting operation should be done as quickly as possible to avoid plant dehydration and avoid root damage as far as possible. The soil medium must always be sterile and usually consisting of 1 peat: 1 vermiculite (v/v) mixture. Sterile sand with a large grain size could also be added to improve drainage. Bark is to be avoided because it dries out rapidly and causes a water stress situation. To summarise, the substrate should be a well drained one, yet with good water retention capacity. The adequate pH to work with should be about 6.5.

Plastic pots (7.5 - 12.5 cm), jiffy peat pots or trays (25 plants; in case of commercial production) are often used for date palm transplanting.

5.2.3 Environmental conditions

Plants are immediately irrigated with 50 % Hoagland's solution or 10 % MS solution before their incubation into a micro tunnel located in an environmentally controlled glasshouse (or a large plastic tunnel).

These environmental conditions will ensure a high relative humidity (90 - 95 %) and a constant temperature ± 25 - 26°C day time and 21 - 22°C during the night. Bottom heating of the micro tunnel (± 23°C) was found to be very helpful.

To ensure a high survival rate, date palm tissue culture-derived plants should be adapted to gradually decreasing humidity and gradually increasing light. The light intensity is important during the first 3 to 4 weeks in the glasshouse (around 10,000 lux) with a 16 hr photo period. Benlate is to be applied to the foliage once a week, and irrigation using 10% MS solution (or 50 % Hoagland) every 3rd or 4th day depending on the hygrometry level of the micro tunnel.

Four to six weeks later, the plastic of the micro tunnel is gradually opened in order to decrease humidity and prepare the plants to adapt to the large glasshouse (or tunnel) conditions which preferably should have a fog system. Plantlets are now ready to be transplanted to larger plastic bags.

It is worth mentioning that at all stages, water should never be sprayed form the top of the plant. Plants could stay in the glass house (or a tunnel) for a period between 3 to 4 months before their transfer to a less environmentally controlled nursery, which is usually at the farmer's level, for their further hardening-off process.

5.3 Hardening-off

Plantlets received from a laboratory are usually about 35 to 45 cm long with 4 to 5 leaves among which are 0 to 2 pinnae leaves (called also permanent leaves). The plant must have a thick shoot system and the base must be similar instate to that of a large onion bulb (pear-shaped). As stated above, the plant must have a well developed root system.

Transportation of these plants must be realised in a proper manner and plants must preferably not be stacked on top of each other to avoid stem breakage and/or leaf damage. Transport must preferably also be in one stage and if plants/truck are to stay over somewhere, it must be in a shaded area; watering should not be neglected if transport takes up several days.

It is recommended that, upon reception of this material by the date grower, plants are transferred to larger bags (7 to 10 litres capacity) with an adequate substrate,usually sand (soil), vermiculite and gravel at a ratio of 1:1:1, respectively. Transplanting should be done properly with no disturbance to the root system. Original substrate around the roots should stay intact. Plants are then left in the nursery for approximately 8 to 12 months depending on surrounding conditions and care given, till most of them reach the 4 pinnae leaf stage. The date grower is advised to co-ordinate the purchasing and the hardening-off period, to ensure that planting can betimely implemented (during February/March for Southern hemisphere and September/October for Northern Hemisphere).

The nursery size and type are related to the number of plants to be hardened-off. An average size of 150 m² will be adequate for 1,000 plants. An ultra-violet resistant shade net of 80 % is recommended during the first 6 months (Figure 53). During the summer time, the top of the nursery should have a double layer of the shade net for insulation purposes. The nursery should be well located (close to several trees to benefi t from their shade) but also in a protected area to avoid sand storms and severe wind. A water tap should be installed inside the unit for easy irrigation and the unit must be enclosed to avoid animals getting in and eating the plants.

Irrigation is an important factor and must be implemented once a week in winter time and at least twice a week during summer. Water should never be sprayed on top of the plant; soil is to be mounted around the base of the plant so water can not get into its heart.

Fertilisation is to be applied once per month: apply 5 g of ammonium sulphate/plant bag (5 % nutrient solution; thus 15 kg deluded per 63 litres water for 650 plants). Apply 120 ml of solution per plant bag.

Control of diseases and pests is also recommended and the use of Benlate (or any other large spectrum fungicide) has proven to be highly efficient. Foliar spray of Benlate is to be applied every 3 to 4 weeks.

Close monitoring is advised as mistakes could be disastrous; It is from our own experience, that we recommend a close follow-up by the date grower. If all above recommendations and advicse are respected, the date grower could expect a survival rate between 90 and 95 % (Figure 54).

In Namibia, a total of 10,007 plants of various date palm varieties were hardened during 1996 and 1997 in both Naute and Eersbegin project sites (Table No. 36).

The results obtained are satisfactory and after 8 to 12 months (depending on the variety and the source), a final survival rate of 92% was obtained (9,177 plants survived and successfully passed the hardening-off operation out of 10,007 plants).

TABLE 36
Hardening-off of date palm tissue culture plant lets: Survival rate (16/06/1997)

VARIETIES	ORIGINAL NUMBER OF PLANTS ORDERED	ORIGIN OF PLANT MATERIAL	TOTAL SURVIVAL	RATE OF SURVIVAL (%)

Medjool du Roi	2,922	RSA	2,723	93.10
Medjool Marionnet	2,650	France	2,411	90.90
Kush Zabad	120	UK	106	88.30
Khalas	90	UK	84	93.30
Hilali	90	UK	88	97.70
Nabutsaif	120	UK	116	96.60
Khenezi	135	UK	35	25.90
Barhee	1,965	UK	1,854	94.30
Bou Feggouss	1,225	France	1,225	100
Deglet Nour	120	France	117	97.50
Khadrawy	45	France	01	02.20
Anbara	50	UK	35	70.00
Sukkari	175	UK	162	92.50
Khissab	90	UK	87	96.60
AbuNaringa	120	UK	105	87.70
Lulu	90	France	28	31.10
Total	**10,007**		**9,177**	**91.70**

- Immediately after transplanting, an average percentage a loss of 3.2% occurred.

- After 8 to 12 months in the nursery, the final survival rate was about 92% (9,177 out of 10,007 plants).

(Source: Date Production Support Programme in Namibia; FAO-UTF/NAM/004/NAM; 1997)

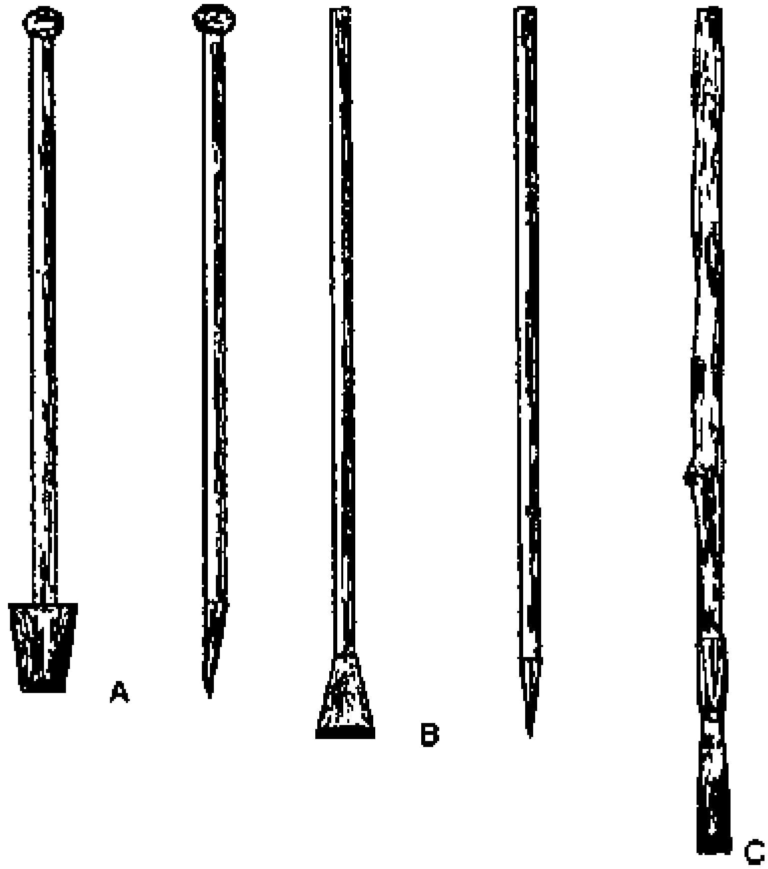
Figure 34. Date palm seedling plantation to select salt tolerant clones at Guanikontes (Swako-pmund, Namibia)

Figure 35. **Rooting of off-shoots:**

A - Normal axillary offshoots after their separation from the mother palm.

B - High offshoots on the palm using plastic bags fi lled with saw-dust.

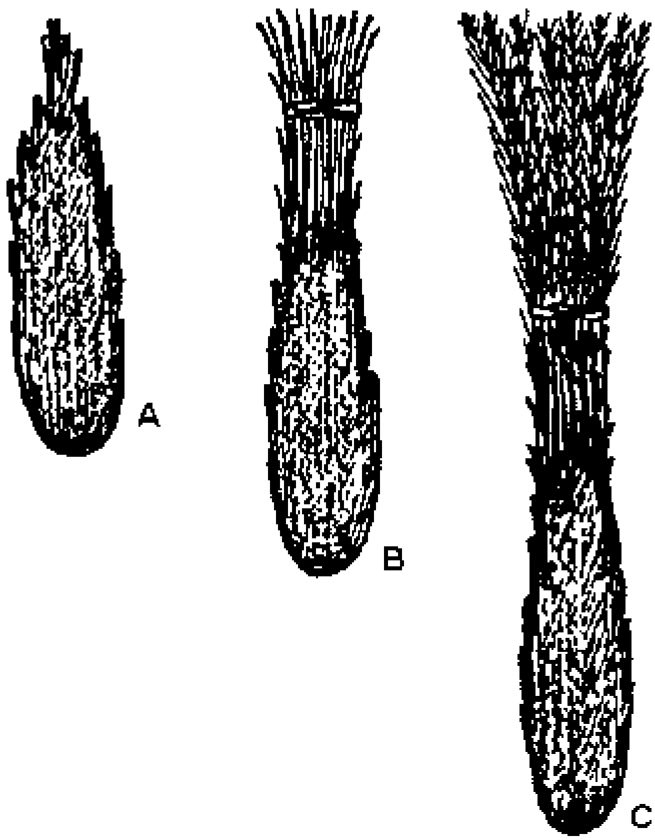
Figure 36. Various types of chisel used around the world



A - American type **B** - normal and most common **C** - traditional type

(Source: Munier, 1973).

Figure 37. **Offshoots pruning methods:**



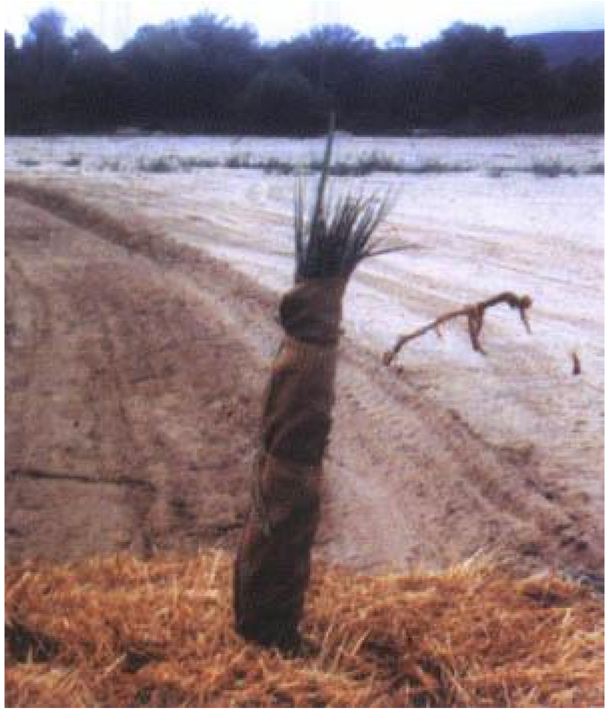
A - as an onion-bulb **B** - average pruning **C** - short pruning

Figure 38. Basin around a young date palm (1.5 to 1.8 m diameter and 20 to 30 cm deep) with wheat straw as a mulching.

Figure 40. **Comparison of asexual embryo (right) with excised zygotic embryo (left)** at the cotylegon elongation stage

Figure 39. **After planting protection against harsh climatic conditions:**

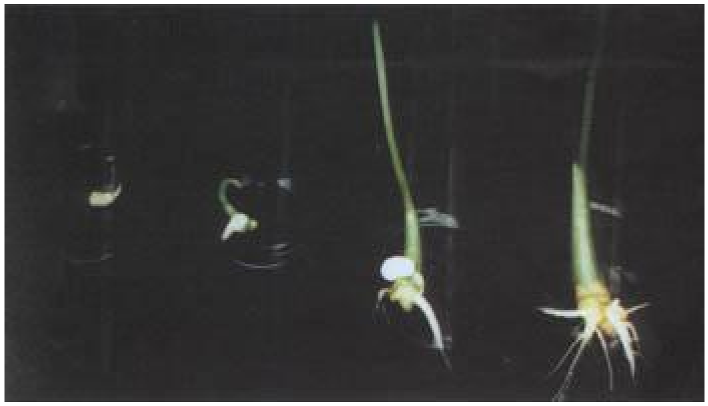
A - Use of hessian wrap for offshoots



B - Protection unit made of wire and shade net for tissue culture plants

C - Protection tent made of date leaves.

Figure 41. **Sequence of germination for *Phoenix dactylifera* cultivar Sayer excised embryos cultured on a modifi ed Murashige and Skoog medium containing 0.3 activated charcoal.**



From left to right: early cotyledon elongation stage (1 week old); emergence of first foliar leaf (3 week old); and established seedling *in vitro* (6 week old).

Note that the cotyledon haustorium is much reduced in size in all stages of seedling develop-

Figure 42. Various types of date palm explants used in organogenesis technique (mostly the bottom of young meristematic leaves)

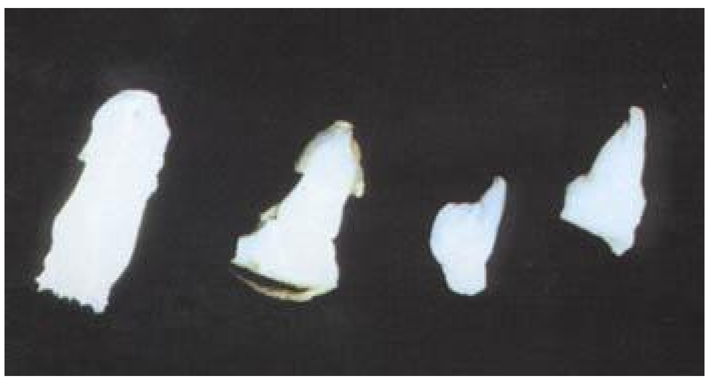


Figure 43. Multiple shoot formation of date palm "Tademant" variety

Figure 44. Cross section of date palm shoot tip

Figure 45. Zymogram of date palm "Black Bousthami" variety

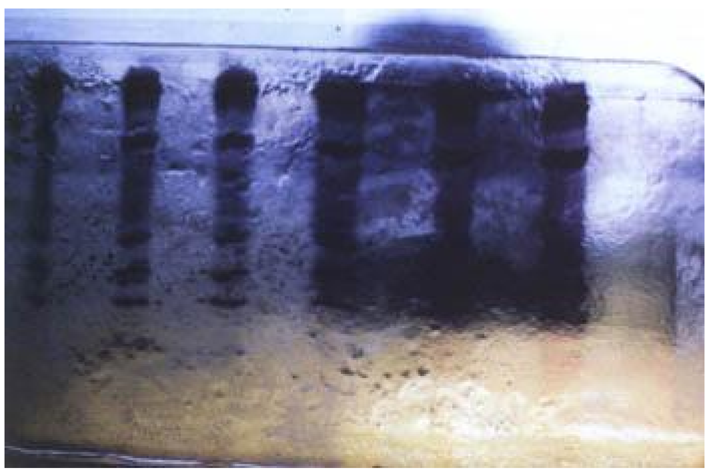


Figure 46. Medjool palm derived from asexual embryogenesis showing abnormalities (Eden Expt. Station, Israel, 1996); It looks like Black Scorch attack

Figure 47. Barhee palm derived from asexual embryogenesis showing morphological abnormality (Ref. G12-Block2, Naute project, Namibia)

Figure 48. Large leaf size as an abnormality (Right: Variant Barhee; left: normal Bar-hee leaf); (Ref B14-Block 2, Naute Project, Namibia).

Figure 49. Boufegouss variety plants after hardening at the laboratory's glasshouse

Figure 50. Comparison of leaf epicuticular wax between greenhouse- grown, tissue culture- derived (Polyethylene glycol-treated and non treated plants); Note five varieties were tested

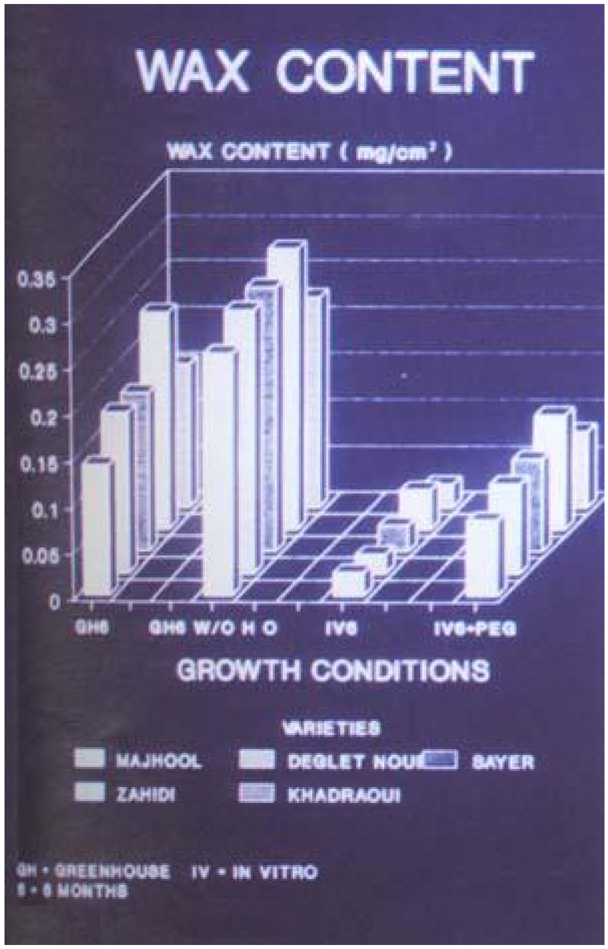


Figure 51. Leaf anatomy of a Med-jool date palm. Note the size of the bulliform cells.

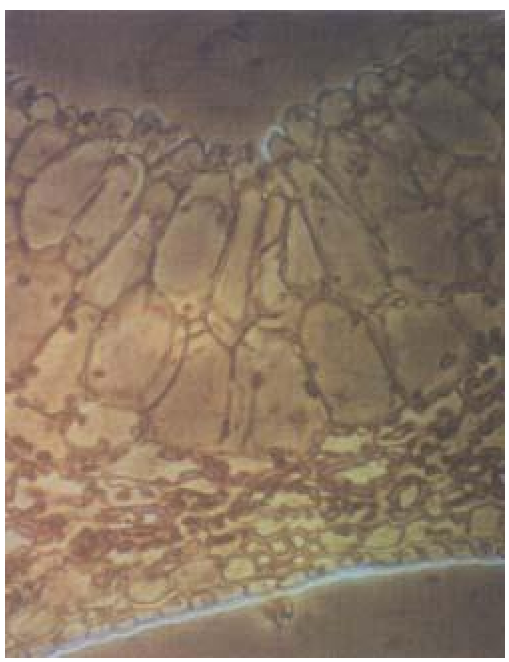


Figure 52. Well acclimatized plants ready to go through the hardening-off process.

Figure 53. An ultra violet resistant shade net of 80% is commonly used for date palm nursery (hardening-off at the date grower's level).

Figure 54. Various stages of growth and development of date palm tissue culture plants during the hardening-off process.

From right to left: 3 months, 6, 9 and 12 months old.

CHAPTER VI: LAND PREPARATION, PLANTING OPERATION AND FERTILISATION REQUIREMENTS

by P. Klein and A. Zaid Date
Production Support Programme

I. Land preparation

When establishing a new date plantation, certain actions need to be implemented to ensure the long term success of the plantation. One of these actions involve the initial land preparation which should be done prior to transplanting of the plant material (offshoots or tissue culture-derived plants).

The purpose of land preparation is to provide the necessary soil conditions which will enhance the successful establishment of the young offshoots or the tissue culture plants received from the nursery. Considering the nature of the date palm, one can not "save" on this operation and hope for long term sustainability of the plantation.

The aim is to enable the date grower to plan and structure the implementation process in advance, ensuring the successful establishment of the date plantation. Planning forms part of the initial preparation and will help to limiting unnecessary stoppages during the implementation phase.

Critical factors to consider during this planning exercise are summarised as follows:

- Availability and quality of irrigation water;
- Field selection;
- Mechanical actions to be implemented;
- Chemical needs for pre-plant soil improvement;
- Tools and equipment needed for date cultivation;
- Labour needs;
- Irrigation design and installation;
- Leaching schedule;
- Hole preparation;
- Financial requirements and
- Time schedule.

1. Field selection

The area selected for the establishment of the date plantation can infl uence the cost of land preparation to the extent that it may not be viable to proceed with the development at all. The authors' aim is to highlight the critical areas to be considered when selecting the land for the establishment of a new date plantation.

1.1 Availability of water

Although not always realised, the date palm requires a rather large quantity of water for sustainable growth. Critical factors regarding water for irrigation purposes are:

(i) the sustainability of the water source,
(ii) the quantity of water available for irrigation,
(iii) the distance to the fi eld, and
(iv) the quality of the water.

1.2 Soil depth

In time date palms grow very tall and become top heavy especially during the fruit bearing stage. They therefore need sufficient room for proper root development to support the palms. Besides the importance of root development, soil depth also infl uences drainage and leaching possibilities. Any obstructive layers must be evaluated to determine whether they will infl uence root development and whether they can be corrected.

1.3 Soil quality

Date palms can grow and produce in different types of soil in both hot arid and semi-arid regions. Adaptation could go from a very sandy to a heavy clay soil. The soil quality is related to its drainage capacity mainly when soils are salty or the irrigation water is characterised with a high salt content. Sandy soils are common in most date plantations of the old world. Rare cases of clay soils (i.e. Basra-Iraq) with drainage systems are found allowing the culture of date palms. The optimum soil conditions are found where water can penetrate to at least 2 m deep.

When evaluating the soil quality, attention must be given to:

(i) the soil texture which will infl uence the water retention capacity, and
(ii) the nutrient content to determine the corrective measures necessary for soil improvement.

1.4 Soil salinity or acidity

Plant growth is influenced by either saline or acid soil conditions which, in the end, will result in a loss of potential yield.

Saline and alcaline soils are common in date plantations and are characterised by a high concentration of soluble salts, and exchangeable sodium, respectively. Soluble salts present in these soils belong to cations: sodium, calcium and magnesium and to chloride and sulphate anions.

Saline soils have an electric conductivity (EC) of their saturated extract higher than 4 mmhos/cm at 25°C, with a sodium absorption rate less than 15 and a pH generally less than 8.5. Saline soils can be recognised by the presence of a white layer on the surface of the soil resulting from the high salt concentration which may harm the growth and development of date palm.

Alcaline soils are characterised by an EC of their saturated extract less than 4 mmhos/cm at 25°C with a sodium absorption rate higher than 15, and a pH higher than 8.5. Alcaline soils do contain harmful quantities of alkalis with the hydroxyl group - OH, especially NaOH. These types of soil are usually diffi cult to correct coupled with a low production resulting from low content of calcium and nitrogen. However, it is recommended to eliminate the excess of sodium by the addition of acidifying agents (gypsum, sulphate of iron or sulphur).

Saline and alkaline soils are usually the result of:

(i) an increase of the underground level caused by excessive drought situations (high evaporation);

(ii) the use of high salt content water, and

(iii) very poor drainage system.

Where date palm grows in climates of little rain, but great heat and much evaporation, irrigation or flood water evaporates quickly, and its salts are left on the surface of the soil.

The negative infl uence of saline conditions are:

(i) high concentration of soluble salts;
(ii) high soil pH;
(iii) poor drainage and aeration; and
(iv) the negative effect of sodium on the plant metabolism.

Table 37 shows the relationship between crop responses and soil salinity expressed in terms of the conductivity of the saturation extract (Richards et al (1954)).

TABLE 37
Relationship between crop response and soil salinity

Crop Response	Scale of Conductivity (Millimhos/cm at 25°C)
Salinity effects mostly negligible	0 - 2
Yields of very sensitive crops may be restricted (Radish 4*)	2 - 4
Yield of many crops restricted (Castor 6*)	-
Only tolerant crops yield satisfactorily (Alfalfa 9*) (Tomato 10*) (Garden beet 12*)	8 - 16
Only a few very tolerant crops yield satisfactorily (Barley 16*)	17 +

Source: Richards et al., 1954.

* The electrical conductivity values of the saturation extract in millimhos per cm at 25°C associated with a 50 % decrease in yield.

Compared to other fruit crops, the date palm is considered to have a high tolerance for salts. Table 38 illustrates this high tolerance.

TABLE 38
Relative salt tolerance of fruit crops [(1)]

High salt tolerance ($EC_e \times 10^3 = 18$[(2)])	**Medium salt tolerance ($EC_e \times 10^3 = 10$)**	**Low salt tolerance ($EC_e \times 10^3 = 5$)**	
Date Palm	Pomegranate	Pear	Almond
	Fig	Apple	Apricot
	Olive	Orange	Peach
	Grape	Grapefruit	Strawberry
	Cantaloupe	Prune	Lemon
		Plum	Avocado

[(1)] (Source: Richard *et. al.*, 1954).

[(2)] The numbers following $EC_e \times 10^3$ are the electrical conductivity values of the saturation extracts in millimhos per cm at 25°C associated with a 50 % decrease in yield.

According to Arar (1975), the date palm is more salt tolerant than any other fruit crop. It will survive in soils containing 3 % soluble salts; when this content goes above 6 %, the date palm will not grow. This author also studied the crop tolerance and leaching requirements of some important crops, including date palms (Table 39). It is clear from these results, that it is possible to irrigate date palms with water of a salinity of up to 3.5 mmhos/cm with no reduction in yield, provided that a leaching requirement of 7 % is provided for. A ten (10) % reduction in yield is obtained when irrigation water is of 5.3 mmhos/cm salt content and with a leaching requirement of 11 %.

TABLE 39
Crop tolerance and leaching requirements

Yield Decrement to be Expected for Certain Crops due to Salinity of Irrigation Water when Common Surface Irrigation Methods are Used.

	0%			**10%**			**25%**			**50%**			**Maximum**

Crop	ECe 1	ECw 2	LR 3	ECe	ECw	LR	ECe	ECw	LR	ECe	ECw	LR	Ecdw 4
1. Barley	8	5.3	12%	12	8	18%	16	10.7	24%	18	12	27%	44
2. Sugar Beet	6.7	4.5	11 %	10	6.7	16%	13	8.7	21 %	16	10.7	26%	42
3. Cotton	6.7	4.5	11 %	10	6.7	16%	12	8	19%	16	10.7	26%	42
4. Wheat	4.7	3.1	8%	7	4.7	12%	10	6.7	17%	14	9.3	23%	40
5. Rice	3.3	2.2	12%	5	3.3	18%	6	4	22%	7	4.7	26%	18
6. Beans	1	0.7	6%	1.5	1	8%	2	1.3	11 %	3.5	2.3	19%	12
7. Figs, Olives	3.3	2	8%	5	3.5	12%	-	-	-	9	6	21 %	28
8. Citrus	1.7	1.1	7%	2.5	1.7	11 %	-	-	-	5	3.3	33%	16
9. Strawberries	1.0	0.7	7%	1.5	1.0	10%	-	-	-	3	2	20%	10
10. Date Palm	5.3	3.5	7%	8	5.3	11 %	-	-	-	16	10	21%	48

1 ECe - Electrical Conductivity of soil saturation extract in milliohms per centimeter (mmohs/cm)

2 ECw - Electrical Conductivity of irrigation water in mmhos/cm

3 LR - Leaching Requirement

4 ECdw - maximum concentration of salts that can occur in drainage water under crops due to ET

N.B. For conversion to TDS as PPM multiply mmhos/cm by 640.
(Source: Arar, 1975).

Soil acidity contributes towards negative plant growth and is mainly due to:

(i) the toxic levels of certain elements (aluminium, manganese);
(ii) the defi ciency of certain elements (calcium, magnesium, molybdenum);
(iii) the low availability of phosphorous; and
(iv) a drop in the efficiency of fertiliser and water usage because of poor root development.

2. Physical land preparation

Once a suitable area for establishing the plantation is selected and the planning operation is fi nalised, the actual preparation can be activated. These activities are divided to structure and pace the implementation process in order to be ready for planting at the most suitable time, according to the specifi c regional climatic conditions.

2.1 Mechanical fi eld preparation

The mechanical or initial soil preparation concerns mainly the preparation of a fi eld for further detailed preparation such as irrigation system installation, hole preparation, etc. Actions, if applicable to the area, include:

(i) debushing/bush clearing;
(ii) removal of stones and rocks;
(iii) ripping; and
(iv) levelling of the soil.

2.2 Irrigation system installation

The type of irrigation system to be used will be determined by the availability of water, topographical and soil conditions. When the initial soil preparation is completed, the installation of the required irrigation system will be implemented according to the prescribed design (Figure 55).

2.3 Soil improvement

The scheduling of the soil improvement programme will depend on the date grower, as certain applications could be combined with the initial actions of soil preparation. Due to the long waiting period, planting to first production, it is a trend to establish date plantations on new soils, with the exception of areas where date palm is used for intercropping.

If new soils are considered, the soil improvement programme will mostly deal with:

(i) the application of organic matter; and/or
(ii) the elimination of soil salinity.

2.3.1 Organic material

In general, most soils are poor in organic matter content and the improvement of this situation plays an important role in soil fertility. Some of the advantages of a higher humus content in the soil are summarised as follows:

- Enhances crumb formation which improves the respiration of the roots;
- Increases the water infi ltration rate;
- Increases the water holding capacity;
- Lowers soil compaction and crust formation; and
- Limits the harmful effects of alkalinity and improves the leaching of salts.

2.3.2 Salinity

In an attempt to reclaim salt affected soil, consideration should be given to:

(i) the type of salinity/alkalinity,
(ii) the drainage possibilities of the soil profi le,
(iii) the origin or the source of salts,
(iv) the quality of irrigation water and
(v) the leaching of salts from the soil.

If the source of salts is identifi ed as drainage water from higher lying areas, a cut-off canal may be suffi cient to eliminate this source of "salt" supply.

Poor drainage normally goes hand in hand with soil salinity problems and therefore the improvement of the drainage potential should be addressed before any leaching programme is implemented. A soil cover (mulching) and the application of organic material will improve the water infiltration resulting in improved drainage (excluding soils with obstructive layers).

In saline soils (soluble salts present as chlorides, sulphates and/or carbonates of calcium, sodium or magnesium), only leaching will be necessary to drain the excess salts. In the case of alkaline and/or saline-alkaline soils, sodium can be replaced through the application of gypsum or acidifying agents like sulphur. Once the sodium has been replaced, a programme should be followed to leach it out.

When the irrigation water is of poor quality, proper drainage and over irrigation, without the development of a water table, is very important.

2.4 Hole preparation

The actual digging of the hole is one of the last actions before planting takes place, but it must be emphasised that this is not the fi nal preparation for the planting operation itself. This is the point where the required inputs such as gypsum and organic materials are worked into the soil and a start is made with the leaching programme. The reason why the leaching is only applied at this stage is because of the relatively small area that is occupied by the date palm. If the total area had to be leached, it would become very costly with little or no benefi t in the long run.

It is recommended that a hole of 1 m^3 be prepared and that the soil from the hole be mixed with the organic material and gypsum (Figures 56 and 57). The soil mix is then put back into the hole, whereafter the site is clearly marked for positioning of the small date palm plants.

At this stage, once the hole has been prepared and closed, it is irrigated and a leaching programme implemented. The water supply will then enhance the leaching of excessive salts and contribute to the fermentation process of the organic material. Subsequent irrigation, several times (2 to 3) before planting, will also allow the mixed soil to settle in the hole.

In most soils, the early and rapid growth of the date plant is better when the holes are prepared one to two months before planting. Well-rotted manure can also be used in holes prepared and irrigated shortly before planting, but extreme care must be taken to put the manure (and fertilisers) deep enough to allow a layer of soil at least 15 to 20 cm thick to be placed between the manure and the roots of the date plant.

II. Planting operation

This is probably the most critical phase in the establishment of a new date plantation. Mistakes at this point may lead to a poor survival rate of offshoots or tissue culture-derived plants, regardless of the efforts put in during the preparation phases. The aim is to assist the date grower to execute the planting operation in a way that will ensure a high transplanting survival rate in the newly established plantation. The planting operation is divided into different activities which will be discussed separately.

1. Plant spacing

It is diffi cult to prescribe a defi nite plant spacing but there are specifi c factors infl uencing the spacing such as:

- to allow for suffi cient sunlight when palms are tall;
- to allow for suffi cient working space within the plantation; and
- to provide suffi cient space for root development.

Previously, the general assumption for a commercial date plantation was to use a plant spacing of 10 m × 10 m (100 palms/ha). It has, however, changed over time and a plant spacing of 9 m × 9 m (121 palms/ha; Israel) or 10 m × 8 m (125 palms/ha; Namibia), is used in modern plantations.

As an example of different spacing used with date palm, Table 40 illustrates the distance apart, the square unit to each palm and the number of palms in each spacing.

TABLE 40
Comparative table of spacing distances (Palms planted at the corners of squares)

Distance Apart (m)	Square Units to each palm (m)	No of Palms in Each (Hectare)
10.06	101	100
9.14	84	119
8.83	78	129
8.53	73	137
8.23	68	148
7.92	63	159
7.62	58	172
7.32	54	185
7.01	49	204
6.71	45	222
6.40	41	244
6.10	37	270
5.79	34	294
5.49	30	333

Source: Dowson, 1982.

The planting density also depends on ecological factors (mainly humidity) and on varieties. In general, commercial plantations use 10 m × 10 m, 9 m × 9 m or 10 m × 8 m, for all varieties except for Khadrawy (dwarf variety with a small canopy) which could be planted at a higher density. The tendency to plant more closely is found when the prevailing wind is dry and extremely hot and strong. The 10 × 10 is desired in areas where humidity during the date ripening period (Coachella valley-USA, Elche-Spain and Coast of Libya (Zliten)) is high (Dowson, 1982); This wider spacing is to allow sun and wind to counteract the humidity's infl uence. According to Nixon (1933), wide spacing is also recommended whenever there is considerable danger of rain damage to dates during the ripening season.

2. Time of planting

The critical factor is to transplant the young tissue culture date palms or offshoots at that time of the year that will ensure a good survival rate and proper establishment before the beginning of a "hard" season.

In most of the date regions in the northern hemisphere, spring and autumn are preferred for the planting out of tissue culture-derived date plants or offshoots. Spring avoids the cold of winter and takes advantage of the warm weather that encourages rapid growth, while autumn gives the young shoot a longer time to establish itself before the heat of summer. Each of the two seasons, however, has its corresponding disadvantage; spring, the early approach of the great heat, and autumn, the early approach of the cold.

In the southern hemisphere the best time of establishment is during autumn (February/March) because of the following reasons:

- Winters are relatively frost free,
- Very high summer temperatures,
- Strong, dry winds during August-January, and
- Sand storms during the summer.

In areas without extreme dry, hot summers and with severe frost during winter it is recommended to plant during August/September or at a time safe from the occurrence of frost.

3. Transplanting stage

Research has shown that the best fi eld survival rate, as well as early plant development, is obtained when the date tissue culture plantlets are transplanted at the four (4) plus pinnae leaf stage. Plants received from a tissue culture laboratory normally only have juvenile leaves or one pinnae leaf at the most. These plants are thus too small to be transplanted into the field. It is therefore necessary to include a hardening-off phase for plant development which also allows some time for plants to adapt to local climatic conditions. This results in the young plants being kept in the farm nursery for a period (approximately 8-12 months), until the suffi cient number of pinnae leaves have developed before transplanting takes place.

In a fi eld test at the Eersbegin project (Namibia), tissue culture plants with 4-6 pinnae leaves were transplanted and the results indicated that the initial plant development, after transplanting, was better when the plants were transplanted at the 4-pinnae leaf stage than at the 5-6 pinnae leaf stage. Regarding offshoots, it is highly recommended to ensure their rooting in the nursery after separation from the plant mother (at least 10 to 12 months). It is not recommended to plant an offshoot directly after its separation.

4. Planting time and depth

Planting should always be initiated early in the morning to limit stress on the date plantlets and also to allow suffi cient time for adaptation (from the plastic bag to the soil). Bags are to be removed with care and the plant, with most of its surrounding substrate, to be planted carefully.

Planting is probably the area where most people make the vital mistake of planting the plant too deep. The planting depth is critical because the "heart" of the plant should never be covered with water. Once the plant is covered with water the growing point rots and the plant dies off. If a date plant is planted too shallow, its roots will desiccate and die.

The golden rule is to ensure that the greater 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.

5. Basin preparation

Immediately after transplanting, a basin is prepared around the palm to prevent run-off and to ensure a suffi cient supply of water to the plant. When using a micro irrigation system, it is recommended to have a basin of approximately 3 m in diameter and 20 to 30 cm deep. The basin should have a slight downward slope towards the plant to allow the water to reach the root system of the young plant.

6. Mulching

The benefi ts of organic material were highlighted when land preparation, as part of the plantation development, was discussed. The mulching is done by putting a layer of organic material (e.g. wheat straw) around the base of the palm. Mulching of the basin has the following advantages:

- Limits water loss from the soil through evaporation;
- Prevents crust formation;
- Allows better water penetration into the soil:
- Limits weed growth around the plant; and
- Improves the humus content of the soil.

7. Irrigation

Immediately after transplanting, the palm should be irrigated to limit transplant stress. Once the plantation is established, a frequent irrigation schedule is to be followed to allow suffi cient water supply to the young date palm.

The irrigation frequency, is soil type dependant, but on very sandy soils it requires daily irrigation during the first summer. Heavy soils will require irrigation once a week, while in most soils, irrigation is required every second or third day. During the first six weeks, the date growers should inspect their planted date palms to verify that the surface soil does not dry and shrink away from the plant.

8. Protection

Tissue culture-derived plants and young offshoots should be protected from harsh climatic conditions (sun and wind during the first summer and cold the following winter) and against some animals (rabbits, etc.). The use of a hessian wrapping, a shade net cover, or a tent of date leaves is recommended. The top is to be left open so that new growth may push out.

9. Aftercare

Beside irrigation applications, the annual fertilisation schedule, weeding and mulching, the date grower should, for at least the first 10 to 12 months, keep an eye on the plantation in order to detect and consequently correct any adverse situations.

III. Fertilisation requirements

1. Introduction

The initial land and orchard preparation aims at preparing the soil for establishment of the young tissue culture date palm or offshoots, but does not ensure proper establishment and growth after transplanting. A fertilisation programme should be included in the date plantation establishment phase for optimum growth.

In general, farmers do not realise the importance of following a date palm fertilisation programme. This behaviour is normally caused by one or more of the following factors:

- Information, regarding date palm fertilisation requirements, is not readily available.

- Information may confuse farmers, because of the differences between literature/studies conducted by various scientists. This example will be discussed later in the document.

- Farmers tend to assume that date palms do not require any nutrients, because of the general view that date palms can survive the toughest conditions.

The importance of a fertilisation programme at and after transplanting is to provide in the nutrient needs of the young tissue culture plants or the offshoots, to ensure rapid growth in preparation for the first production season. An under-developed plant will not have the capacity to reach its production potential at an early stage.

The purpose of this chapter is to serve as a basic reference guide for fertilisation planning in date plantations.

2. Functions of nutrient elements and their availability in relation to soil conditions

Date palm has similar fertiliser requirements to other cultivated crops. Nutrient elements necessary for plant growth and production (but not absorbed from the air), i.e.: boron, calcium, chlorine, cobalt, copper, iron, magnesium, manganese, molybdenum, nitrogen, phosphorus, potassium, sodium, sulphur and zinc, are all needed at different rates by the date palm culture.

2.1 Soil pH

Nitrogen

Nitrogen plays a major role in plant life processes such as photosynthesis, vegetative growth and the maintenance of genetic identity. This ensures high yield at the end of the season.

Nitrogen is freely available to plants within the pH range of 5.5 to 8.5. When the soil pH is below 5.5 or above 8.5, the availability decreases to the extent that plants are not able to take up any nitrogen from the soil profile.

Phosphorus

Phosphorus also plays a role in processes such as photosynthesis, respiration, vegetative growth, reproduction and maintenance of the genetic identity. It is also associated with cell division, root development and flowering.

Phosphorus is freely available to plants within the pH range of 6.0 to 8.0 and above 8.5. When the soil pH is below 5.0, phosphorus is, for all purposes, not available to plants. At a pH of around 8.0 to 8.5, phosphorus is relatively unavailable to plants, but from approximately 8.5 and above it becomes freely available again.

Potassium

Potassium is found in cell sap and plays a role in the transport of nitrogen in the plant and the promotion of photosynthesis. This nutrient helps to strengthen fi bre and has an infl uence on the opening and closing of the stomata. Potassium is also associated with resistance to drought, cold and the improvement of fruit quality.

Potassium is freely available to plants within the pH range of 5.5 to 7.5 and above 8.5. When the soil pH is below 5.0, potassium, is for all purposes, not available to plants. At a pH of around 7.5 to 8.5, potassium is relatively unavailable to plants but from approximately 8.5 and above it becomes freely available again.

Hence, measures are needed to adjust the soil pH to ensure the availability of nitrogen, phosphorus and potassium for plant utilisation.

Boron

Boron is an essential nutrient in pollination and the subsequent reproduction processes, i.e. the formation and growth of flowers and fruits. It also plays a role in the uptake of calcium, magnesium and potassium.

2.2 Soil texture

Nitrogen and potassium are easily leached from the soil profile when excess water is applied. Therefore, it is important to control the irrigation schedule on sandy soils to avoid any unnecessary leaching. When working with sandy soils, it is also recommended to divide the amount of fertilisers over two or more applications to decrease nutrient losses.

3. Nutrients lost through date palm plants

The amount of nutrients lost through fruits and pruned leaves as well as the world-wide application of fertilisers were considered as a basis for the calculation of the amount of fertilisers required by an adult date palm. Our study was based on related literature, experiments and fi ndings in various countries (Algeria, Iraq, Morocco and USA). Hass and Bliss (1935) showed that one hectare (120 palms), exports 29 kg of nitrogen, 5 kg of phosphate and 70 kg of potassium. Embleton and Cook (1947) estimated that leaf pruning of one hectare caused the loss of 25 kg of nitrogen, 2 kg of phosphate and 74 kg of potassium.

Nixon and Carpenter (1978) recommended for most Coachella Valley soils, the use of 1.81 to 2.72 kg of actual nitrogen per palm, divided into two to three applications on sandy soils to reduce leaching. While other authors (Furr and Barber, 1950) estimated the nitrogen export per hectare of Deglet Nour variety at about 78 kg.

For the above, it is estimated that in order to produce 50 kg of date fruits per palm, the fertilisation needs are about 45 kg of nitrogen, 13.5 kg of phosphate and 81 kg of potassium, of which most of it could be covered by irrigation water (Djerbi, 1995).

Unfortunately, there are variations amongst the results of different scientists and, it was therefore decided to calculate the average between the different sources in order to recommend a fertilisation programme at three levels: nursery, young plants (less than 4 years old) and adult palms. It must also be indicated that, in most cases, the relationship between the nutrients lost through fruits and leaves is roughly constant. Tables 41 and 42 illustrate the average nutrient loss and the average world-wide fertilisers application, respectively.

TABLE 41
Average nutrient loss

Nutrient	Loss/Palm/Year (g)*	Loss/Ha/Year (kg)
Nitrogen	350	42
Phosphorus	90	11
Potassium	540	65

TABLE 42
Average world-wide application

Nutrient	Appl/Palm/Year (g)*	Appl/Ha/Year (kg)
Nitrogen	650	78
Phosphorus	650	78
Potassium	870	104

* For both Tables 41 and 42, it is assumed that 121 palms are planted per hectare.

4. Micronutrients

Rare are the cases where defi ciency of micro-elements were studied as most of them are found in the irrigation water. However, boron defi ciency was probably responsible for the death of some date palms; both the terminal bud and the root system were affected (Djerbi, 1995). Boron has an effect on the activity of some enzymes, increases cell membrane permeability and enhances the transport of carbon hydrates; it also participates in the lignin's synthesis. Boron controls the ratio between potassium and calcium contents and plays an important role in the synthesis of proteins and cell division.

According to Djerbi (1995), lack of manganese was also found in several Tunisian date plantations, causing the death of palms within a period of five to seven years (called disease of broken leaves). Manganese is a catalyst of several enzymatic and physiological reactions. It is involved in respiration and activates enzymes that are active in the metabolism of nitrogen and the synthesis of chlorophyl. Iron could also be defi cient in some soils and symptoms are usually characterised by a sound yellowing of the older (outer) leaves (Figures 58 and 59).

In conclusion, measures to correct defi ciencies of micro nutrients are to be taken, early enough, through a simulation study based on leaf/soil analysis and date palm requirements.

5. Fertilisation programme recommended for the nursery

In order to ensure strong, healthy plants for transplanting and to shorten the period in the nursery, (approximately six to eight months instead of eight to ten months), a fertilisation programme is recommended (Table 43).

TABLE 43
Fertilisation recommendation for date palm nursery plants

Time of soil application	Nutrient value	Product	Application
2 × per month	N: 5.5 % P: 0.75 % K: 1.6%	SeaGro: Organic plant food	Mix 5 ml of SeaGro product per litre of water and apply around the plant.

6. Fertilisation at fi eld planting

Part of the fertilisation programme starts at the time prior to transplanting, during the land preparation phase. At that stage, attention is to be given to the improvement of the soil which may have a direct infl uence on the utilisation of certain nutrients which are necessary for plant growth.

Actions that precede this phase include the initial hole preparation, application of lime/gypsum/organic material, and a leaching programme in the case of saline soils.

Instead of opening the original hole again to apply the required fertilisers, only a smaller planting hole (± 60x60x60 cm) is prepared and the fertilisers are mixed with the soil from this hole before it is put back at transplanting.

The application rates for nitrogen and phosphorus are calculated by adding 50 % to the average loss of nutrients through fruits and pruned leaves. The amount of potassium is not increased due to the fact that most soils normally yield a relatively high natural potassium content. If soil analysis shows a decrease in potassium content over a period of time, this fi gure should be increased.

TABLE 44
Application rate for date palms younger than 4 years

Nutrient	Appl/Palm/Year (g)*	Appl/Ha/Year (kg)
Nitrogen	262	31.7
Phosphorus	138	16.5
Potassium	540	65

* It is assumed that 121 palms are planted per hectare.

Table 45 shows the necessary nitrogen quantities for a date palm of four (4) years and older. For newly transplanted palms up to and including the age of three years, only 50 % of the amount of nitrogen is recommended as shown in Table 44.

TABLE 45
Application rate for date palms 4 years and older

Nutrient	Appl/Palm/Year (g)*	Appl/Ha/Year (kg)

Nitrogen	525	63
Phosphorus	138	16.5
Potassium	540	65

* It is assumed that 121 palms are planted per hectare.

7. Annual fertilisation programme

7.1 Time of application

In an effort to obtain the best results from any fertiliser application, it is important to link the stages of application to critical times over the growing period, i.e. vegetative phase, reproduction phase. The same principle applies to date palm fertilisation and therefore the time of application is co-ordinated with certain growth phases during the year.

The date season is divided into two growth phases: vegetative and reproductive. The latter is also divided into two stages namely the fl ower formation stage (February - April in the northern hemisphere and June - August in the southern hemisphere), and the fruit development stage (July - October in the northern hemisphere and November - February in the southern hemisphere). Scheduling the application of fertilisers according to these phases ensures an increase in the amount of properly developed flowers and a potential increase in yield. The best results will be realised when the fertiliser applications are done as soon as possible after the initiation of the two stages (fl ower and fruit formation). Therefore, it is recommended that these applications take place during February and July for northern hemisphere, and June and November for southern hemisphere.

To prevent root burn, not all the required fertilisers should be applied at the planting stage, and therefore the following is recommended as a follow-up programme:

- Apply 300 g potassium sulphate four weeks after transplanting and repeat four weeks later,
- Apply 250 g sulphate of ammonia six weeks after transplanting and repeat six weeks later.

Although no major problems are noticed with the above technique (twice per year), some commercial plantations, mostly in Israel, apply the fertilisation throughout the year monitored with irrigation (fertigation). This programme is aimed at applying the required nitrogen during 8 months (November till August in northern hemisphere and April till November in southern hemisphere); while for phosphorus and potassium the application is at a three months interval (4 times per year).

The following table (Table 46) summarises this fertilisation programme:

TABLE 46
Date palm annual fertilisation programme

	Nitrogen Nutrient (*)	Ammonium Sulphate product (*)	Phosphate Nutrient	Maxi Fos Product (**)	Potassium Nutrient	Potassium chloride Product (**)
	(g)	(kg)	(g)	(kg)	(g)	(kg)
6 Years and above	125	0.6 (1)	69	0.345 (4)	816	1.625 (7)
3 to 5 years	95	0.456 (2)	52	0.257 (5)	502	1.000 (8)
Young palms till 3 years old	60	0.3 (3)	35	0.173 (6)	251	0.500 (9)

(*) Amount to be applied per palm and per month for a period of 8 months.
(**) Amount to be applied per palm every 3 months.

(1) A total of 4.8 kg per palm for the eight months.
(2) A total of 3.65 kg per palm for eight months.

(3) A total of 2.4 kg per palm for eight months.
(4) A total of 1.374 kg per palm to be distributed in 4 applications (every 3 months).
(5) A total of 1.030 kg per palm to be distributed in 4 applications (every 3 months).
(6) A total of 0.692 kg per palm to be distributed in 4 applications (every 3 months).
(7) A total of 6.5 kg per palm distributed in 4 applications (every 3 months).
(8) A total of 4 kg per palm distributed in 4 applications (every 3 months).
(9) A total of 2 kg per palm distributed in 4 applications (every 3 months).

The three months frequency for both potassium and phosphate could be: 1 November, 1 February, 1 May and 1 August for northern hemisphere and 1 April, 1 July, 1 October and 1 January for southern hemisphere.

Once the young palms have been planted and the follow-up fertilisation programme completed, an annual fertilisation programme should be introduced to ensure sufficient supply of nutrients to the young palms.

7.2 Transplanting

Before transplanting can take place, and as stated above, a planting hole must be prepared to ensure that the nutrient needs of the small plant are satisfi ed once it has been planted into the fi eld. In addition to this, a fertiliser application at this stage also serves as a measure of soil improvement by adding nutrients to a possibly poor soil.

The exact amounts and types of fertilisers to be applied will be determined by soil analysis. The aim of this section is to make a general recommendation with regard to the fertilisers included in the process of plant hole preparation.

The recommendation presented in this chapter is to be used as an example as well as a general recommendation, for sandy/sandyloam soil types. When digging the hole, ensure that the top and bottom soil are separated, because the fertilisers are mixed with the top soil.

General recommendation:

- 10 to 15 kg	Manure (good quality, properly matured and dry);
- 0.7 kg	Maxi-fos or Double Superphosphate;
- 15 kg	Gypsum (in case the soil is heavily charged with sodium);
- 1.25 kg	Sulphate of ammonia; and
- 1.08 kg	Potassium chloride.

The sulphate of ammonia and potassium chloride can either be mixed into the top soil together with the rest of the products or it can be applied through the irrigation system after transplanting. It is important to note that nitrogen and potassium should be applied separately with two or three irrigation cycles in-between.

7.3 Method of application

7.3.1 Manual

This method is used when applying fertilisers to a plantation where the fertiliser can not be supplied through the irrigation system. Fertilisers are then measured in small quantities and applied by hand to individual palms. The most important precaution when applying through this method is to ensure an even distribution of the fertilisers within the palm drip area and not too close to the base of the palm (Figure 60). However, the disadvantages are:

- time consuming;
- labour intensive;
- root burn may occur if not evenly distributed; and
- the correct amount of fertiliser is not always applied.

A product like phosphorus, which does not move well in the soil profi le, should be applied though holes within the drip area to ensure contact with the roots.

7.3.2 Through irrigation system (Figure 61)

This method called fertigation, is used when the irrigation system is designed for fertiliser application. All top dressing of soluble fertilisers are applied through the irrigation system. Nonsoluble fertilisers, however, still have to be applied by hand. The main advantage of this system is that the correct amount of fertiliser is evenly distributed within the drip area.

8. Soil, water and leaf analysis

The importance of fertilisation can be summarised as follows:

- Overcome nutrient defi ciencies in the soil;
- Ensure proper establishment, growth, and development; and
- Increase the yield potential.

This chapter serves merely as a fertilisation guideline, since there are many potential variables among different locations. The aim is to supply a reference document to serve as a framework in fertilisation planning, and it is highly recommended that the date grower consults the local extension offi cer regarding the exact application of nutrients for his/her specifi c conditions, based on leaf, soil and water analyses.

Van Zyl (1983) summarised the optimum age of leaf and time of the year for leaf analyses of dates in the southern hemisphere plantations (Table 47).

Element	Years	Optimum age of leaf - Remarks	Optimum month (*)
N	1 - 2	level decreases with age	Oct
P	1 - 2	level decreases with age	Oct
K	½	level decreases rapidly with age	Nov-Dec
Ca	-	level increases with age	Oct-Nov
Mg	1 - 3	level increases at a young stage	Aug-Sept
Na	½ - 3	level increases at a young stage	Sept-Oct
Cl	½ - 1	level decreases with age	Oct-Nov
Fe	1 - 2	level increases with age	Nov-Dec
Zn	½ - 1	high at first, drops and increases again	Aug-Sept
Mn	-	varies	-
Cu	-	varies	June-July
B	1½ - 2	level increases with age	Aug-Sept
SiO_2	-	level increases with age	Oct-Nov

Source: Van Zyl, 1983.

(*) The optimum month indicates the period when the element concerned remains most constant. However, and for a commercial plantation, only two periods are recommended:

(i) Just after harvesting and before the emergence of new leaves (April for southern hemisphere and November for northern hemisphere), and

(ii) After flowering and before final fruit set (August for southern hemisphere and April for northern hemisphere).

In the literature, data on leaf analysis of dates vary from one place to another and results depend strongly on edaphoclimatic conditions. The authors advise to set own-standards, based on the performance of the date palms in the local plantations, rather than taking over data from other areas. For setting standards for soil and leaf sampling, the authors are proposing the following:

- 12 palms/ha will be randomly and representatively selected over each ha of date plantation (10 %).

- 1 kg of soil/profile sample will be used.

- For leaf: At least one kg of fresh leaf material is needed/palm.

- Leaflets and rachis of approximately 10 photosynthetic leaves are the parts to take.

- The 12 palms and their soil profiles will be followed up for at least 4 years (with two samplings per year).

- Metal markers must be used to identify the site of soil profile and will also be reported on the site map).

- Soil information to request for the laboratory: pH, EC (ms/m); SAR; Exchangeable Sodium percentage, with textural class. All micro and macro elements (N, P, Ca, Mg, Boron, Molybdenum, Sulphate, Iron, Mn, Zinc, etc.).

- For leaf analysis: Request in percentage the content of the following: N, P, K, Ca, Mg, S, Na, and Cl. While we need the content in mg/kg of Fe, Cu, Mn, B, Zn and Mo.

- For water analysis: pH, EC (ms/m), TDS (mg/L), SAR (meg.) with content of all micro and macro elements.

Figure 55. Irrigation design and lay-out of a date plantation with 10 m × 8 m spacing (Eersbegin, Namibia).

Figure 56. A m³ planting hole; note that the top 1/3 and the bottom 2/3 soils are separated.

Figure 57. A device to make sure that workers do respect the required 1 m³ volume.

Figure 58. Iron defi ciency symptoms on a Barhee variety at Naute (Namibia).

Figure 59. Potassium defi ciency symptoms on a Barhee variety at Naute (Namibia).

Figure 60. Fertilisation damage on one year old Medjool tissue culture palm at Eersbegin, (Namibia).

Figure 61. Fertigation system at Eden Research Station (Israel).

CHAPTER VII: DATE PALM IRRIGATION

By P.J. Liebenberg and A. Zaid
Date Production Support Programme

This chapter describes date palm irrigation and aims to calculate water requirements of this species as well as schedule irrigation to ensure that the date palm gets the necessary quantity of water when needed.

1. Introduction

Like any other fruit tree, date palm needs suffi cient water of acceptable quality to reach its potential yield. In Table 48 quantities of water made available to date palm around the world can be seen. It is worth mentioning that all these countries use fl ood irrigation, except for Israel, which uses drip irrigation.

Table 48
Date palm irrigation around the world

Place	Quantity (m^3/ha)
Algeria	15,000 - 35,000
California, USA	27,000 - 36,000
Egypt	22,300
India	22,000 - 25,000
Iraq	15,000 - 20,000
Jordan Valley, Israel	25,000 - 32,000
Morocco	13,000 - 20,000
South Africa	25,000
Tunisia	23,600

Table 49 shows differences in summer and winter requirements in Tunisia. Summer water requirements (July, August and September) are about 7,154 m^3/ha, while only 4,372 m^3/ha are needed for the winter period (December, January and February). Summer requirements are almost double the winter ones and constitute $^1/_3$ of the total annual consumption. Note these values are made available to the trees through fl ood irrigation.

Differences in water requirements between different regions of the same country are common as illustrated in the case of Algeria (Table 50). The date growing area of the Sahara needs approximately 34,190 m^3/ha/year,while Ziran region needs only 15,000.

Table 49
Water quantity consumed per ha of Deglet Nour date palm at Tozeur (Tunisia)

Month	Consumed Quantity (m^3/ha)
January	1339.2
February	1693.4
March	1874.8
April	2073.6
May	2142.7

June	2073.6
July	2410.5
August	2410.5
September	2332.8
October	2142.7
November	1814.4
December	1339.2
Annual consumption	**23,647.4**

Table 50
Approximate water requirements of date palm at different regions of Algeria

Scientist (Year)	Region	Number of trees per ha	Approximate needs (m^3/ha/year)
Rolland (1894)	Sahara (Algeria)	130	34190
Rose (1898)	Ziban (Algeria)	144	10368
Jus (1900)	Oved Rhir (Algeria)	130	22750
Wertheimer (1957)	Ziran (Algeria)	120	15000

2. Factors infl uencing water requirements

It is necessary to take certain aspects into consideration in order to calculate the volume of water required by a palm. The following aspects play a major role in this calculation:

a. *Soil salinity*: If the soil is saline, more water must be given to enable a leaching process for clearing the salt from the soil.

b. *Temperature*: The higher the temperature, the higher the rate of evaporation and the more water the plant needs.

c. *Humidity*: The lower the humidity level, the more water needed.

d. *Wind* (speed and occurrence): Higher constant wind speeds cause higher evaporation and thus higher water demands.

e. *Cloud cover*: More water is required during periods of less cloud cover.

It is worth mentioning that all above factors infl uence evapotranspiration, which strongly determines the water requirements.

Irrigation

Irrigation is the timely application of water to a crop in need of water. Any water applied when not necessary, is a waste of a precious commodity. For example: if water is applied too late in the season, then it is useless because the crop is already dead or the production suffered so much that there will be no fruit, even though defi cient water is then applied over the growing period. The opposite is also true; if too much water is applied, the plant may also suffer. The crop may die due to waterlogging. Usually date palms do not suffer from too much water although, as illustrated, i t is possible in uncontrolled fl ow from artesian wells at Qatif, Saudi Arabia (Dowson, 1982). It, will however, still be waste of water, as the farmer could use this water to irrigate other palms or crops.

Irrigation must take place where the roots of the plant can easily reach it. It is of no use to the plant if water is applied where the roots cannot reach it. Let us look at the root development of a date palm tree. If the soil is divided into four layers of equal depth from top to bottom, 40 % of all roots can be found in the top layer, 30 % in the second layer, 20 % in the third layer and the remaining 10 % in the last layer. The same percentages apply in concentric rings around the plant (Figure 62). The same percentage of water will also be extracted from the soil in the different layers due to the presence of the roots in these respective layers.

For mature date palms, the depth is about 5 m,and 3 m radius around the trunk. Thus, it is seen that for dates 40 % of all water is extracted from the first 50 cm, 70 % is from the first 100 cm, 90 % is from the top 150 cm and only 10 % is from the last layer or 150 to 200 cm and deeper. For young date plantlets this depth can vary from 25 to 50 cm and the radius from 10 to 30 cm, depending on the size of the plant. This means that the irrigation water must be applied within these boundaries to enable the plant to reach it. However, it is important to apply water be applied in such a way that it does not reach the deeper soil levels in order to ensure proper root development of the date palms.

Localised irrigation (e.g. drip and micro) will therefore be more effi cient than non- localised one (e.g. fl ood irrigation).

After planting small tissue culture-derived date palms, the volume of soil from which it can extract water is very small. If a person is not careful, suffi cient water may be applied, but not enough will be available to the plant for optimum growth. It is thus necessary to ensure that enough water reaches the area where the roots are. Irrigation must preferably be done by basin, micro or drip methods. Due to the shallow root depth at this stage, frequent irrigation is also necessary to ensure that the palm does not suffer from water deficiency. Even more care should be given if the palm is planted in a very sandy soil.

3. Different irrigation techniques

Different irrigation techniques are available to irrigate crops, but not all of them are suitable for date palm irrigation. The following methods are of importance and each has its own advantages and disadvantages:

a. Flood irrigation

This irrigation method is the oldest method known, and is also the method most widely used in date palm culture. It has, however, advantages as well as disadvantages which are outlined below:

i. Advantages:

(1) running costs are low;
(2) easy to apply; and
(3) initial costs are low if the area is fairly flat.

ii. Disadvantages:

(1) diffi cult to achieve a high effi ciency rate;
(2) labour intensive;
(3) irrigates areas in between where no palms are planted; and
(4) not well suited for sandy soils.

b. Furrow and basin irrigation

It is basically a redesign of fl ood irrigation to eliminate some of the disadvantages listed above and thus make it more effi cient.

i. Advantages:

(1) running costs are low;
(2) easy to apply; and
(3) initial costs are low if the area is fairly flat,

ii. Disadvantages:

(1) labour intensive; and
(2) interferes with mechanical operations.

c. Sprinkler irrigation

This is the oldest modern irrigation method and was introduced to enhance effi ciency and to enable automation.

i. Advantages:

(1) more effi cient use of water is possible;
(2) easy to schedule - manage;
(3) less labour is needed; and
(4) tpography is not a limitation.

ii. Disadvantages:

(1) expensive (installation);

(2) running costs are high;

(3) heavily influenced by wind and temperature (spray pattern and evaporation);

(4) not well suited for small palms because water can enter from above into the growth point of the palm.

d. Micro irrigation

This method was more recently introduced and was developed in South Africa to irrigate mine dumps to prevent the wind from blowing the sand away. It was then adapted for irrigation of trees and other crops.

i. Advantages:

(1) more effi cient use of water is possible;

(2) running costs are lower than sprinkler irrigation (lower pressure needed);

(3) easy to schedule - manage;

(4) only areas that need water are irrigated;

(5) topography is not a limitation;

(6) It is easy to automate;

(7) It is not labour intensive; and

(8) several spray patterns are available to suit date palms (e.g. gaps in the spray pattern so as not to wet the growth point or the trunk of the palm.)

ii. Disadvantages:

(1) Installation costs are high;
(2) needs clean water; and
(3) infl uenced by wind and temperature (spray pattern and evaporation).

e. Drip irrigation

This is the latest irrigation method introduced and was developed in Israel where there is scarcity of water (Figure 62).

i. Advantages:

(1) more effi cient use of water;
(2) running costs are low;
(3) easy to schedule/manage;
(4) topography is not a limitation;
(5) only the water needed by the palm is applied;
(6) not infl uenced by wind;
(7) easy to automate; and
(8) not labour intensive.

ii. Disadvantages:

(1) expensive (Installation);

(2) requires very clean water; and

(3) sometimes difficult to determine if the correct amount of water has been applied by the system, and when it becomes clear that it is too little, it may be too late.

4. Methods for calculating date palm water requirements

From the earliest times, different methods were used to calculate the water requirements of different crops. As a result, numerous methods have been developed and adopted for date palms. Some of these methods are more accurate than others and some more convenient to use than others, because of the availability of information for the site where the date trees will be planted. The following are a few of the methods available:

- Evapotranspiration/Class A Pan Method;
- Penman's Equation;
- Blaney-Criddle Equation; and
- Solomon and Kodama's Equation.

a. ETP Class A Pan

In Israel, USA and Southern Africa, the evapotranspiration/Class A Pan Method is frequently used because the needed information, is readily available.

Where:

AWR = Amount of water required during period under observation.
ET_{pan} = Evaporation for period in mm as measured with Class A Pan.
CF_{pan} = Crop Factor for that period.
h = Efficiency of irrigation system (in decimal).

Table 51 shows in more detail the calculations done to forecast water requirements of the palms for the 12 months of the year and using different irrigation methods for Naute - Namibia. (Note that this is for the Southern Hemisphere harvesting period is March to April)

b. Revised Penman-Monteith Method

The Penman method is widely accepted as the most accurate method of calculating water requirements for crops. This method makes use of daily climatic information (e.g. maximum and minimum temperatures, wind velocity, humidity and radiation per day) to calculate the reference evaporation ETo. Due to the relative complexity of the formula, it is best used with the help of a computer program. The reference crop evaporation (Eto) is first determined and then the water requirement is calculated using the following formula:

Where:

kc = Crop Factor
Et_o = Reference Evaporation mm/day
Et_{crop} = Crop Evapotranspiration mm/day

$$ET_{crop} = kc * ET_0 \ [mm/day]$$

In Tables 52, 53 and 54, calculations done with Cropwat 7 can be seen. Cropwat 7 is a computer programme based on the revised Penman-Monteith method, to calculate crop water requrements (Smith, 1992)

TABLE 51
Water requirements for date palm at Naute, Namibia

MONTH	N. of days	kc[i ii]	ET_{pan}	ET_a NETT	AWR_{nett} TOTAL for	GROSS APPLICATION FOR DIFFERENT SYSTEMS					
					MONTH	Micro irrigation		Drip irrigation		Flood irrigation	
			mm/day	mm/day	mm	mm/day	mm/month	mm/day	mm/month	mm/day	mm/month
JAN	31	0.67	15.30	10.3	317.8	12.1	373.9	11.4	353.1	17.1	529.6
FEB	28	0.61	13.20	8.1	225.5	9.5	265.2	8.9	250.5	13.4	375.8
MAR	31	0.55	10.80	5.9	184.1	7.0	216.6	6.6	204.6	9.9	306.9
APR	30	0.49	9.00	4.4	132.3	5.2	155.6	4.9	147.0	7.4	220.5
MAY	31	0.43	8.10	3.5	108.0	4.1	127.0	3.9	120.0	5.8	180.0
JUN	30	0.37	6.30	2.3	69.9	2.7	82.3	2.6	77.7	3.9	116.6
JUL	31	0.37	6.70	2.5	76.8	2.9	90.4	2.8	85.4	4.1	128.1
AUG	31	0.43	7.90	3.4	105.3	4.0	123.9	3.8	117.0	5.7	175.5
SEP	30	0.49	9.90	4.9	145.5	5.7	171.2	5.4	161.7	8.1	242.6
OCT	31	0.55	12.30	6.8	209.7	8.0	246.7	7.5	233.0	11.3	349.5
NOV	30	0.61	14.40	8.8	263.5	10.3	310.0	9.8	292.8	14.6	439.2
DEC	31	0.69	14.90	10.3	318.7	12.1	375.0	11.4	354.1	17.1	531.2
TOTAL APPLICATION PER YEAR (mm)					2,157.2		2537.9		2,396.9		3,595.4

Flood Irrigation ® h = 60%
Micro Irrigation ® h = 85%
Drip Irrigation ® h = 90%
i - This is an estimate according to some desk study by the authors of this chapter - 1989.
ii - Use this crop factor only with class A evaporation pan fi gures.

TABLE 52
Monthly reference evapotranspiration (revised Penman Montheith)

Meteostation: NAUTE		Country: NAMIBIA				Altitude: 700 m		
		Coordinates: -26.57 South 17.55 East						
Month	MinTemp °C	MaxTemp °C	Humid. %	Wind km/day	Sunshine Hours	Radiation $MJ/m^2/day$	ETo-PenMon mm/mon	Eto mm/day
January	18.6	35.1	28	345	11.3	28.6	303.6	9.8
February	18.5	33.7	36	302	10.6	26.4	233.0	8.3
March	17.5	31.8	40	294	9.7	22.6	218.9	7.1
April	13.7	28.1	40	302	10.2	19.8	175.2	5.8

May	9.8	24.1	38	328	9.8	16.3	151.6	4.9
June	7.2	21.2	39	372	9.6	14.6	133.5	4.5
July	6.2	21.2	36	380	9.9	15.6	146.6	4.7
August	7.2	23.4	31	389	10.3	18.8	180.1	5.8
September	10.5	27.4	27	363	10.5	22.5	215.1	7.2
October	13.1	29.9	24	380	10.6	25.6	265.7	8.6
November	15.6	32.6	24	371	11.6	28.7	288.0	9.6
December	17.3	34.4	25	354	12.0	29.9	310.3	10.0
Year	12.9	28.6	32	348	10.5	22.5	218.5	

TABLE 53
Crop data

Growth stage	Crop name: DATEPALM					
		Init	**Devel**	**Mid**	**Late**	**Total**
Length	days	150	35	150	30	365
Crop coefficient	coeff.	0.80	0.80-1.00	1.00	0.80	
Rooting depth	meter	2.00	2.00	2.00	2.00	
Depletion level	fraction	0.50	0.50	0.50	0.50	
Yield response factor	coeff.	0.80	0.80	0.80	0.80	0.80

TABLE 54
Crop evapotranspiration and irrigation requirements

	Rain climate station: NAUTE ETo climate station: NAUTE				**Crop: DATEPALM Planting date: 01/04**			
Month	Dec	Stage	Coeff	ETcrop	ETcrop	Eff.Rain	IrReq	IrReq.
Apr	1	Init	0.80	5.00	50.0	0.0	5.00	50.0
Apr	2	Init	0.80	4.67	46.7	0.0	4.67	46.7
Apr	3	Init	0.80	4.42	44.2	0.0	4.42	44.2
May	1	Init	0.80	4.17	41.7	0.0	4.17	41.7
May	2	Init	0.80	3.91	39.1	0.0	3.91	39.1
May	3	Init	0.80	3.79	41.7	0.0	3.79	41.7
Jun	1	Init	0.80	3.68	36.8	0.0	3.68	36.8
Jun	2	Init	0.80	3.56	35.6	0.0	3.56	35.6
Jun	3	Init	0.80	3.63	36.3	0.0	3.63	36.3
Jul	1	Init	0.80	3.71	37.1	0.0	3.71	37.1
Jul	2	Init	0.80	3.78	37.8	0.0	3.78	37.8
Jul	3	Init	0.80	4.07	44.8	0.0	4.07	44.8
Aug	1	Init	0.80	4.36	43.6	0.0	4.36	43.6
Aug	2	Init	0.80	4.65	46.5	0.0	4.65	46.5
Aug	3	Init/Dev	0.81	5.06	55.7	0.0	5.06	55.7
Sep	1	Dev	0.85	5.68	56.8	0.0	5.68	56.8
Sep	2	Dev	0.90	6.47	64.7	0.0	6.47	64.7
Sep	3	Dev	0.96	7.33	73.3	0.0	7.33	73.3

Oct	1	Dev/Mid	0.99	8.06	80.6	0.0	8.06	80.6
Oct	2	Mid	1.00	8.57	85.7	0.0	8.57	85.7
Oct	3	Mid	1.00	8.91	98.0	0.0	8.91	98.0
Nov	1	Mid	1.00	9.26	92.6	0.0	9.26	92.6
Nov	2	Mid	1.00	9.60	96.0	0.0	9.60	96.0
Nov	3	Mid	1.00	9.74	97.4	0.0	9.74	97.4
Dec	1	Mid	1.00	9.87	98.7	0.0	9.87	98.7
Dec	2	Mid	1.00	10.01	100.1	0.0	10.01	100.1
Dec	3	Mid	1.00	9.94	109.3	0.0	9.94	109.3
Jan	1	Mid	1.00	9.93	99.3	0.0	9.93	99.3
Jan	2	Mid	1.00	9.89	98.9	0.0	9.89	98.9
Jan	3	Mid	1.00	9.37	103.0	0.0	9.37	103.0
Feb	1	Mid	1.00	8.81	88.1	0.0	8.81	88.1
Feb	2	Mid	1.00	8.32	83.2	0.0	8.32	83.2
Feb	3	Mid	1.00	7.90	63.2	0.0	7.90	63.2
Mar	1	Mid/Late	0.97	7.26	72.6	0.0	7.26	72.6
Mar	2	Late	0.91	6.40	64.0	0.0	6.40	64.0
Mar	3	Late	0.84	5.57	55.7	0.0	5.57	55.7
		Total			**2,418**	**0.0**		**2,418**

From tables 51 & 54 it is clear that the date palms at Naute (Namibia) need between 2,157 and 2,419 mm Nett irrigation per annum to fulfi l their needs.

5. Leaching

As mentioned earlier, the date palm needs suffi cient water of *acceptable quality* to enable it to reach its full yield potential. To reach this aim, if all agricultural practices are catered for, (except water), then the average electric conductivity of the soil (ECe) must not exceed 4 dS/m (Ayers and Westcot, 1985), and that of the water (Ecw) not 2.7 dS/m. If situations occur where these values are exceeded then leaching must be practised to overcome this problem. However, due to the scarcity of water or the high cost of water, it will not always be viable to meet the leaching requirements. In such a case it may be viable to opt for a lower yield which may be more economical. In Table 55, ECe and ECw values corresponding to % of yield for date palm are shown.

TABLE 55
ECe and ECw values corresponding to yield percentage

YIELD %	ECe (dS/m)	ECw (dS/m)
100	4.0	2.7
90	6.8	4.5
75	11.0	7.3
50	18.0	12.0
0	32.0	21.0

However, to calculate the quantity of water needed for leaching, the following formula is used:

$$LR = \frac{EC_w}{[5(EC_e - EC_w)]}$$

Where:

LR = Leaching Requirement (fraction).
Ecw = Electric conductivity of the water (dS/m).
Ece = Electric conductivity of the soil at % yield to be obtained (dS/m).

This quantity of water is over and above the nett irrigation required by the crop during the season. The total annual requirement is then calculated from the following formula:

$$AW = \frac{ET}{[1 - LR]}$$

Where:

AW = Depth of water supply (mm/yr).
ET = Total annual water demand (mm/yr).
LR = Leaching requirement.

6. Scheduling

Once it is known how much water to apply, it is also important to know when to apply it. To determine this, knowledge of the type of soil and how deep it is, is required. This gives an indication of how much water is in the soil and how much is available for the palm. This information, combined with the daily usage of water by the palm, enables the determination of when the next irrigation cycle is due.

The following fi gures are mean values of available water for the three major soil types:

Light soils	- 100 mm/m
Medium soils	- 140 mm/m
Heavy soils	- 180 mm/m

The best approach is to determine, through laboratory tests, the water holding capacity of the specifi c soil under consideration and then to establish an effective scheduling program.

To ensure that the palm will not be put under water stress, it is the normal practice to allow for only a fraction of the available water to be extracted. For date palm, as illustrated below, this fraction equals 0.4 or 40 % of the available soil water.

EXAMPLE

The water usage of date palm for a certain period is 8.7 mm/day. Table 56 shows that the available water for the soil is 140 mm/m depth. The rooting depth of a full grown date palm is 2 m. Thus:

Available water	= 2 × 140	= 280mm
Extraction allowed	= 0.4 × 280	= 112mm
Cycle period	= 112 ÷ 8.7	= 12.87 days. 13 days (Practically)

In Tables 57 and 58, an example of a fi xed scheduling programme can be seen for date palm at Naute (Namibia) as done by Cropwat 7. For this example, note that no rainfall is taken into consideration.

TABLE 56
Soil data

Soil type: Medium	
Total Available Soil Moisture (TAM)	140.0 mm/m

Maximum Rain Infiltration Rate	60 mm/day
Maximum Rooting Depth	200 cm
Initial Soil Moisture Depletion (% TAM)	0 %
® Initial Available Soil Moisture	140.0 mm/m

TABLE 57
Irrigation scheduling

Rain station: NAUTE			**Crop: DATEPALM**			**Plant date: 01/04**					
ETo station: NAUTE			**Soil: Medium**			**Timing: Fixed intervals (7, 7, 7, 7 days)**					
Application: Refill up to Field Capacity						**Field Efficiency: 85 %**					
No. Irr	Int days	Date	Stage	Deplet %	TX %	ETa %	Net Gift mm	Deficit mm	Loss mm	Gr.Gift mm	Flow l/s/ha
1	7	8 Apr	A	12	100	100	35.0	0.0	0.0	41.2	0.68
2	7	15 Apr	A	12	100	100	33.7	0.0	0.0	39.6	0.66
3	7	22 Apr	A	12	100	100	32.5	0.0	0.0	38.2	0.63
4	7	29 Apr	A	11	100	100	30.9	0.0	0.0	36.4	0.60
5	7	6 May	A	11	100	100	29.7	0.0	0.0	34.9	0.58
6	7	13 May	A	10	100	100	28.7	0.0	0.0	33.7	0.56
7	7	20 May	A	10	100	100	27.4	0.0	0.0	32.2	0.53
8	7	27 May	A	10	100	100	26.7	0.0	0.0	31.4	0.52
9	7	3 Jun	A	9	100	100	26.3	0.0	0.0	31.0	0.51
10	7	10 Jun	A	9	100	100	25.7	0.0	0.0	30.3	0.50
11	7	17 Jun	A	9	100	100	25.0	0.0	0.0	29.5	0.49
12	7	24 Jun	A	9	100	100	25.1	0.0	0.0	29.6	0.49
13	7	1 Jul	A	9	100	100	25.4	0.0	0.0	29.9	0.49
14	7	8 Jul	A	9	100	100	26.0	0.0	0.0	30.5	0.51
15	7	15 Jul	A	9	100	100	26.3	0.0	0.0	30.9	0.51
16	7	22 Jul	A	10	100	100	26.8	0.0	0.0	31.5	0.52
17	7	29 Jul	A	10	100	100	28.7	0.0	0.0	33.8	0.56
18	7	5 Aug	B	11	100	100	30.6	0.0	0.0	36.0	0.60
19	7	12 Aug	B	12	100	100	32.7	0.0	0.0	38.4	0.64
20	7	19 Aug	B	13	100	100	36.5	0.0	0.0	42.9	0.71
21	7	26 Aug	B	14	100	100	40.4	0.0	0.0	47.5	0.79
22	7	2 Sep	B	15	100	100	42.6	0.0	0.0	50.2	0.83
23	7	9 Sep	C	17	100	100	46.7	0.0	0.0	55.0	0.91
24	7	16 Sep	C	18	100	100	49.2	0.0	0.0	57.9	0.96
25	7	23 Sep	C	18	100	100	51.1	0.0	0.0	60.1	0.99
26	7	30 Sep	C	19	100	100	53.5	0.0	0.0	62.9	1.04

27	7	7 Oct	C	20	100	100	56.3	0.0	0.0	66.2	1.09
28	7	14 Oct	C	21	100	100	58.1	0.0	0.0	68.4	1.13
29	7	21 Oct	C	21	100	100	60.0	0.0	0.0	70.6	1.17
30	7	28 Oct	C	22	100	100	62.4	0.0	0.0	73.4	1.21
31	7	4 Nov	C	23	100	100	63.4	0.0	0.0	74.6	1.23
32	7	11 Nov	C	23	100	100	64.8	0.0	0.0	76.2	1.26
33	7	18 Nov	C	24	100	100	67.2	0.0	0.0	79.1	1.31
34	7	25 Nov	C	24	100	100	67.7	0.0	0.0	79.7	1.32
35	7	2 Dec	C	24	100	100	68.3	0.0	0.0	80.3	1.33
36	7	9 Dec	C	25	100	100	69.1	0.0	0.0	81.3	1.34
37	7	16 Dec	C	25	100	100	69.8	0.0	0.0	82.1	1.36
38	7	23 Dec	C	25	100	100	69.9	0.0	0.0	82.3	1.36
39	7	30 Dec	C	25	100	100	69.6	0.0	0.0	81.8	1.35
40	7	6 Jan	C	25	100	100	69.5	0.0	0.0	81.8	1.35
41	7	13 Jan	C	25	100	100	69.5	0.0	0.0	81.7	1.35
42	7	20 Jan	C	25	100	100	69.3	0.0	0.0	81.5	1.35
43	7	27 Jan	C	24	100	100	66.1	0.0	0.0	77.8	1.29
44	7	3 Feb	C	23	100	100	64.5	0.0	0.0	75.8	1.25
45	7	10 Feb	C	22	100	100	61.7	0.0	0.0	72.6	1.20
46	7	17 Feb	C	21	100	100	58.7	0.0	0.0	69.1	1.14
47	7	24 Feb	C	20	100	100	57.0	0.0	0.0	67.0	1.11
48	7	3 Mar	D	19	100	100	54.0	0.0	0.0	63.5	1.05
49	7	10 Mar	D	18	100	100	50.8	0.0	0.0	59.8	0.99
50	7	17 Mar	D	16	100	100	45.7	0.0	0.0	53.7	0.89
51	7	24 Mar	D	15	100	100	42.3	0.0	0.0	49.8	0.82
52	7	31 Mar	D	14	100	100	39.0	0.0	0.0	45.8	0.76
END	2	1 Apr	D	2	100	100					

CROPWAT 7.0 (The information in the last column is only valid for fl ood irrigation.)

TABLE 58
Water requirement using cropWat 7

Total Net Irrigation	2457.8 mm	No yield reductions	
Total Irrigation Losses	0.0 mm	Effective Rain	0.0 mm
Moist Deficit at harvest	5.6 mm	Total Rain Loss	0.0 mm
Actual Water Use by Crop	2463.4 mm	Actual Irrigation Requirement	2463.4 mm
Efficiency Irrigation. Schedule	100.0 %	Potential Water Use by Crop	2463.4 mm
Deficiency Irr. Schedule	0.0%	Efficiency Rain	- %

7. Layout of date palm orchard and irrigation

The spacing between date palms differs worldwide. This can be ascribed to differences in variety as well as climatic conditions. In Namibia, the trend is to a 10 × 8 m spacing, 10 m between rows and 8 m in the rows. Some private farmers also use a 8 × 8 m spacing but, it is not advisable to use a narrower spacing.

The usage of micro irrigation is recommended due to the sandy soils where date palm is commonly grown, and the efficiency of this type of irrigation. Care should however be taken that no water is sprayed into the crown of the small palm. To this effect, micro's with a 300° - 320° spray pattern should be used. Furthermore, to optimise the efficient usage of water it was decided to change the type of micro's during the initial growing period of the date palm to ensure 100 % coverage of the drip area (rooting area). As stated before, due to shallower rooting in the first years of development, a more frequent irrigation schedule is recommended during these years than in the later ones. From planting to year (4) the area covered is about 12 m^2 and the flow rate 96 *l*/h/palm, from year (5) to year (10) the area covered = 18 m^2 and the flow rate 104 *l*/h/palm and from year ten the area covered = 28 m^2 and the flow rate 156 *l*/h/palm (Figure 63). This bigger area covered in the initial years (0 -3 and 5 - 8) will lead to waste of water, but on the other hand it will serve as a leaching operation that will benefit the date palm as a whole. Due to shallower rooting in the first years of development a more frequent irrigation schedule is required in those years

Figure 62. Drip area of adult date palm tree and root distribution

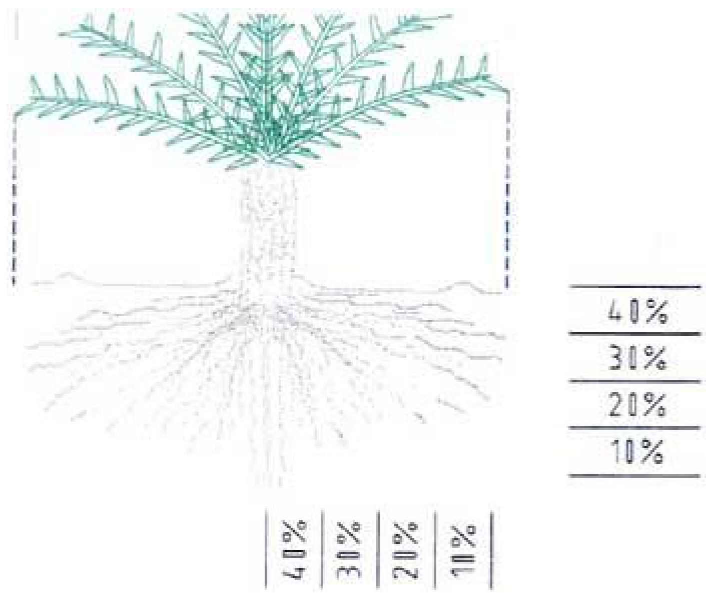
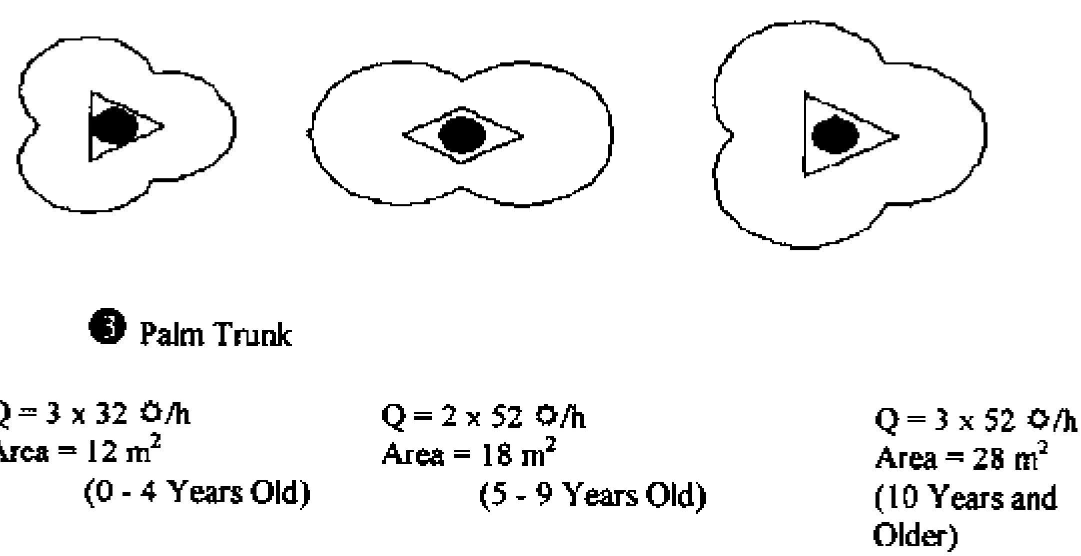


Figure 63. Wetting pattern of Micro's



CHAPTER VIII: POLLINATION AND BUNCH MANAGEMENT

by A. Zaid and P.F. de Wet
Date Production Support Programme

I. Pollination

Being a dioecious species in character, date palm sexes are borne by separate individuals. The unisexual flowers are pistillate (female) and staminate (male) in character. The male palm produces the pollen and the female palm produces the fruit. The fl ower stalks are produced from the axils of the leaves in similar positions to those in which offshoots are produced. The inflorescence consists of a long stout spathe which, on bursting, exposes many thickly crowded floral branchlets which are stout and short in male, and long and slender in female. One adult female palm, on average, produces 15 - 25 spathes that contains 150 to 200 spikelets each. The male flowers are borne single and are waxy white, while the female flowers are borne in clusters of three and are yellowish green in colour.

Natural pollination by wind, bees and insects is found to yield a fair fruit set in various areas of the date growing countries (Marrakech/Morocco; Elche/Spain; San Ignacio, Baja/Mexico; Ica/Peru, for example). All these regions are characterised by their 100 % seedling composition with about 50 % males. In the absence of such natural pollination, female flowers are not fertilised. This leads to the development of carpels and consequently parthenocarpic fruits without any commercial value are obtained. Date growers in these areas are aware of artifi cial pollination techniques, but because of insufficient economic pressure incentives, such techniques are not applied.

The very old and primitive pollination technique consisted of placing an entire male spathe in the crown of the female palm and leaving the rest to wind pollination. According to Chevalier (1930) and Dowson (1961), this technique was used in Mauritania and Libya, respectively. It has been abandoned because it could not yield uniformly good fruit sets and requires the availability of large number of male spathes (Dowson, 1982).

Commercial date production necessitates artificial pollination which ensures good fertilisation and overcomes disadvantages of dichogamy and also reduces the number of male palms. The male/female ratio in a modern plantation is 1/50 (2 %). Artificial pollination could be realised according to a traditional method or by using a mechanised device (Enaimi and Jafar, 1980).

1. Pollination techniques

Depending on the type of pollen available, one of the following three techniques is used:

1.1 Fresh male strands

The most common technique of pollination is to cut the strands of male flowers from a freshly opened male spathe and place two to three of these strands, lengthwise and in an inverted position, between the strands of the female infl orescence. This should be done after some pollen has been shaken over the female inflorescence (Dowson, 1982) (Figure 64). In order to keep the male strands in place and also to avoid the entanglement of the female cluster's strands during their rapid growth, it is recommended to use a twine (a strip torn from a palm leafl et or a string) to tie the pollinated female cluster 5 to 7 cm from the outer end.

1.2 Pollen suspension

Laboratory and fi eld experiments on three varieties from Saudi Arabia (Khalas, Ruzaiz and Shishi) have shown that a pollen grain suspension, containing 10 % sucrose and 20 ppm GA3 could be used for pollination (Ahmed and Jahjah, 1985). Pollination sprays were found to be as good as hand pollination in relation to fruit setting. Similar results were also obtained by Ahmed and Al-shawaan (1983) who tried pollen grains suspended in 10 %

sucrose solution. Fruit set was 80 % using this suspension technique while only 60 % was obtained when using the classical hand pollination technique. On the other hand, a suspension solution containing pollen grains, sucrose, boron, glycerine and GA3 did not match the results of hand pollination (Hussain et al., 1984).

1.3 Dried pollen

This pollination technique is more economical and allows proper use of the pollen as well as adequate control of the timing of pollination. Dried pollen could originate from the last season, from early maturing males of the same season, or from few days old male flowers. There are several techniques to apply dry pollen:

(a) Cotton pieces: The most common technique of using dry pollen is to dust it on cotton pieces about the size of a walnut and place one or two pieces between the strands of female inflorescences.

(b) Use of a puffer: A small manual insecticide duster, known as a 'puffer' is also used to apply dry pollen. This technique is used either alone or in addition to the cotton pieces technique (Nixon, 1966).

(c) Mechanical pollination: Mechanical pollination was developed mostly in the New World of date palm (USA and Israel) where labour is expensive and not always available. It consists of pollinating freshly opened female spathes from the ground with the use of a special apparatus. Mechanical pollination has been one of the most important alternatives when the labour has been reduced by 50 - 70 % (Nixon and Carpenter, 1978; Ghaleb et al., 1987). It is estimated that a man must climb a date palm eight to ten times from the time of pollination through to crop harvesting. According to Perkins and Burkner (1973) all other cultural operations for a 25 ha plantation could be completed with a labour force of approximately 200 men, whereas pollination requires nearly 700 men-days during the peak period. Mechanical pollination from ground level for three times and with 1:4 (pollen/fi ller ratio) was recommended by Nixon and Carpenter (1978) to achieve high yielding of most date varieties. It seems that the frequency of mechanical pollination as well as the suitable concentration of pollen/fi ller ratio are the most important factors in date palm pollination.

According to Perkins and Burkner (1973), a ground-level duster is capable of pollinating 24 to 32 ha per season. In order to accommodate the palm height and also to direct the pollen delivery tube near the bloom area of each palm, the machine is equipped with a variable height platform capable of 4.5 m vertical movement. The duster is driven along one side of the date row and then returns on the opposite side to fi nish the pollination cycle. Such mechanical pollination will require two labourers and could be realised according to two approaches:

(i) Pollination of each freshly opened female spathe or;
(ii) Spraying of the whole female leaf canopy just above the opened spathes.

The first approach is the more accurate one, but requires the farmer to have good knowledge of his plantation as well as good record- keeping to ensure the pollination of all spathes. The second technique is economically feasible and saves time. However, a high rate of aborted fruits could occur when this technique is used.

During early season pollination, or when the pollination season is characterised by low normal temperatures, it is recommended to alternate pollination of sides of the palm at 4 to 7- day intervals. This overlapping of pollination was shown to yield more reliable results than full palm pollination at one time (Nixon and Carpenter, 1978).

There is a trend to use a simple mechanical device called hand pollinator. It is made of a rubber "bulb", a plastic bottle containing pollen, 5 to 8 m plastic tube attached to a solid aluminium tube (Figures 65 and 66). By repeatedly pressing the "bulb", pollen located in the bottle is expulsed with the produced air and moves through a plastic tube towards the female spathes. Fruit set resulting from the use of mechanical pollination is usually poorer than that following hand pollination, but fruit quality and yields are found to be equal as a result of decreased thinning of the mechanically pollinated inflorescences. Furthermore, it is worth mentioning that mechanical pollination requires approximately 2 or 3 times more pollen than manual pollination. To overcome this problem, date growers are mixing the pollen with adjuvants, also called fillers, such as talc, bleached wheat flour, walnut-hull dust with a ratio of pollen/filler 1:9 or 1:10. One gram of pollen could then pollinate ten female spathes. Adjuvants must present the following characteristics: their particle size must be similar to the pollen grain with no harmful effect on the pollen's viability, or its germination on female stigmates. Hamood and Mawlood (1986) found that repeating mechanical pollination, 4 times during the season by using 1:10 (pollen/fi ller ratio), increased the total yield of Zahdi cultivar.

The advantages of mechanical pollination could be summarised as follows:

* reduction of labour and duration of pollination, both contributing to the reduction of the cost of pollination. Furthermore, it does not require a highly trained labour as with the traditional technique;

* ensuring the possibility of pollinating a palm at several times in a short period of time;

* Allowing the use of a mixture of pollen originating from different sources, thus ensuring good fertilisation;

* eliminating the risk of accidents occurring as with the old method of climbing a palm several meters high.

(d) Aircraft pollination: Experiments with pollinating of dates with an aircraft were conducted in the Coachella Valley of California on Deglet Nour variety by Brown and Perkins (1972). Results showed that even though temperatures and weather conditions were favourable, both the helicopter and fi xed-wing methods of application yielded less fruit sets than the hand pollination method. This technique was abandoned as it required at least 4 to 5 times the amount of pollen traditionally used, and was also found to be not economically feasible.

2. Pollen harvest and handling

A male spathe that is ready to split assumes a brown colour and a soft texture. Immediately after the spathe breaks, the male inflorescence reaches its maturity and male flower clusters must be cut at this stage. To prevent wind or bees from causing loss of pollen it is recommended that the freshly-opened spathe be cut early in the morning.

Date growers traditionally harvest the male spathes one or two days after their opening and place them in a shaded and moisture-free area for drying (Figure 67). Strands are then detached and stored till needed for the pollination of female inflorescences. Transport of strands for a long distance (between two date plantations) must be handled with maximum care. The use of paperbags is recommended to preserve the pollen and avoid losses.

The common practice of cutting the male spathe a day or two before its natural opening as practised in the Old World (Middle East and North Africa) is not recommended because it requires a high level of experience and familiarity with the male palms (Nixon and Carpenter, 1978). The technique is to press the middle or lower part of the male spathe between the thumb and forefinger. If a crackling noise is heard, it is a sign of maturity of flowers. In such a case the spathe could be cut and flowers taken to the storage room for drying.

A pollen-handling protocol necessitates the rapid and effi cient dehydration of moist pollen before its storage.

High temperatures have a negative effect on pollen drying and storing processes. Pollen exposed to direct sunlight or placed near a source of heat, will rapidly deteriorate and lose viability (also called vitality) Viability is defi ned as the ability of a pollen grain to germinate and develop (Gerard, 1932).

3. Extracting, drying and storing pollen

The emergence of many early inflorescences on female date palms before the opening of an adequate number of male spathes on available male palms always results in scarcity of pollen. Furthermore, it is well known that, depending on climatic conditions, a date grower could face a season where a heavy early female bloom develops.

Consequently, the storage of pollen within the pollination season (2 to 3 months) or from one season to another is a necessity, mainly for pollen known to have a high metaxenia effect. Date growers should plant enough males, select the best ones and propagate them in order to meet their own needs without relying upon other sources for pollen.

Freshly opened male flowers contain a high level of moisture; consequently if they are not to be used immediately, their prompt drying is important in order to avoid the destruction of pollen by moulds. As mentioned above, air movement and sunlight are to be avoided in order to protect pollen viability. There are various ways and techniques to store the pollen depending on the quantity to be stored, storage conditions and the duration of storage.

- ***Storage of strands***

It is a simple way to store a small quantity of pollen; strands are separated and spread in a thin layer on paper in a shallow tray in a shaded/protected area.

- ***Male fl ower clusters***

Clusters are put on top of screen-wire trays or shelves with a container beneath to catch the dry pollen that falls from the fl owers; Note that the pollen quality remains unchanged even though the flowers turn dark within 3 to 7 days. This storage technique is mostly used for handling larger quantities of pollen.

Date growers in Iraq (Dowson, 1921) and in Egypt (Brown and Bahgat, 1938) conserve the pollen by placing the flowers, usually dried and crushed, in a muslin bag and left in a well dried-ventilated area.

- ***Mechanical pollen extractor and collector***

The machine is made of a vertical shaker, a collection barrel, a cylindrical screen tumbler, a rotating screen disk, a cyclone separator and a suction fan (Figure 68). The machine can daily handle up to 450 male fl ower clusters and collects approximately 40 % more pollen than any other extraction method. The pollen viability and longevity were found to be unaffected by such mechanical extraction.

Moderate temperatures in a dry room will be satisfactory enough to store pollen for 2 to 3 months consequently covering the needs during the pollination season. Pollen storage from one year to the next requires more controlled conditions and an adequate drying system. Once the pollen is well dried and cold stored in an airtight container, it could be safely re-used during the next season with very little loss of viability. Nebel (1939) found that a relative humidity of 50 per cent and a temperature of 2 to 8°C were the optimum conditions in deciduous trees for storage of pollen for more than four years.

Aldrich and Crawford (1941) emphasised the importance of keeping the pollen as dry as possible during the storage period. To maintain zero per cent humidity, dry pollen is placed in an open jar within a larger airtight container (a dessicator) in the bottom of which are well dried lumps of calcium chloride (Ca Cl2) as a dehydrating agent (Figure 69). Other absorbents that can also be used are saturated solutions of zinc chloride (ZnCl2), calcium nitrate ($N(CaO)_3)_2$-$4H_2O$) and potassium chloride (KC1).

Dessicators must then be maintained at low temperatures in a refrigerator (between 4°C to 7°C) (Aldrich and Crawford, 1941; Oppenheimer and Reuveni, 1967). According to the same authors, approximately 500 g of calcium chloride is enough for 2 - 3 kg of pollen.

According to Hamood and Bhalash (1987), in order to obtain good fruit set it is recommended that the stored pollen first be tested for its viability; once proven the pollen should be mixed with a filler (e.g. wheat flower; industrialised-non perfumed talc; etc.) at a rate of 1/9 respectively; the mixture must be prepared immediately before pollination. It is also a good practice to mix the fresh pollen with that stored for one year.

Cold storage using a common refrigerator (4° to 5°C) or a freezer (-4 to - 18°C) was proven to be satisfactory (Figures 70 and 71). According to Nixon and Carpenter (1978), lower temperatures under conditions subject to less fluctuation are safer. As mentioned earlier, the evaluation of the viability of the pollen, either fresh or stored, is important before the pollination operation. The use of selected pollen with a high degree of viability will ensure a better fruit set and consequently an acceptable yield. Pollen could be dried by lyophilisation using freezing temperatures between -60 and -80°C. Water is eliminated by sublimation between 50 and 250 mm Hg (Djerbi, 1994).

It was also found that pollen from the date palm could be cryogenically stored successfully using liquid Nitrogen (-196°C) (Tisserat et al., 1985). The longest period that palm pollen was treated with liquid nitrogen, was 435 days (Tisserat et al., 1983). These results suggest that long-term storage of pollen from the date palm, using ultra-low temperatures, can be used with no deteriorating effect on pollen viability and on fruit set. Recently, Kristina and Towill (1993) placed date pollen over a saturated salt solution with a lower relative humidity (CuSO4 - 5H2O) for approximately 2 hours; the moisture content was reduced to less that 15 %, and the amount of freezable water in the date pollen dropped to 5 % making storage in liquid nitrogen feasible (Table 59).

TABLE 59
Germination values for fresh, dry and liquid nitrogen stored pollens

Pollen	Fresh	% Germination Dry	LN[1]	% Moisture Dry
Date	54	59	29	5
Cattail	2	45-	43	10
Pear	50	47	41	5
Pecan	-	78	61	6
Apple	58	17	27	7
Pine	82	88	84	4
Spruce	87	86	84	9
Maize	45	49	39	12

Source: Kristina and Towill, 1993.

¹ Time in liquid nitrogen storage for these samples ranges from 24 h (maize) to six months.

² Cattail and pecan pollens were dry when collected: fresh and dry percent germination values are synonymous.

4. Pollination effi ciency

Pollination of 60 - 80 % of the female flowers is considered satisfactory and will usually lead to a good fruit set. The pollination efficiency is affected by several factors and consequently fruit set is highly dependent on these factors. The pollination time, fl owering period of male palm, the type of pollen, its viability and amount, and the female flowers receptivity are the main factors to take into account.

Pollination time

Satisfying pollination results are obtained within 2 or 4 days after the female spathe has opened. March and April is the normal pollination period in the Northern Hemisphere; July and August for the Southern Hemisphere. Variety and season could delay or advance the opening of the flowers.

Flowering period of male palm

Flowering periods of male and female palms should be synchronised in order to have enough pollen when the female spathes open. It is preferable if the male spathe opens 2 to 4 days earlier than the female spathe. Hence, male palms should receive the same cultural techniques as the female palms and must preferably be planted in areas that receive more sunlight; (i.e. in the northern hemisphere, their exposure to the south favours, in general, early fl owering). Lack of irrigation during fall and winter at the northern Negev (Israel) was found to be the only reason of delaying the fl owering date, and consequently resulting in low fruit set (Oppenheimer and Reuveni, 1965).

Pollen source and quantity

Studies conducted by Nasr et al. (1986) revealed that seedling males are highly variable in their growth vigour, spathe characteristics and pollen quality. Also, the amount of pollen grains produced by spathe varied greatly from one male to another (0.02 - 82.29 g/spathe). The size of the pollen grain was also found to vary among males (Asif et al., 1987); Mean diameter of pollen varied from 16 to 30 microns.

It is well known that different varieties of date palm require different amounts of pollen (Dowson, 1982). Using fresh male strands, the number required for pollinating a female spathe may vary from 1 to 10 depending on variety. Furthermore, some varieties have larger female inflorescences than others, which require more male strands.

The results of a research experiment conducted at the USDA Citrus and Date Station (Indio, California-USA) have however shown that all except 3 or 4 of more than 100 varieties of dates have been pollinated uniformly with satisfactory results by using only 2 to 3 male strands per female inflorescence (Nixon and Carpenter, 1978). Applying more strands (when pollen is not scarce) is considered as good insurance and will have no disadvantages.

Most of the male date palms used throughout the world's date growing areas are of seedling-origin with a great variation regarding pollen quality. However, and thanks to the selection programme conducted in various countries, several male palms were selected and are actually beginning to be recognised as varieties (Mosque, Mejhool BC3, Deglet Nour BC4, Fard No. 4, Jarvis No. 1, Boyer No. 11 (USA); Deglet Nour, Hayani and Bentamouda (Egypt and Sudan). There is however, still room for improvement and a date grower should take into consideration the following desired characters before selecting and using any male palm:

**** Clusters of the male flowers***

The size and number of produced inflorescences per male palm are the first criteria to look for. Indeed, the more and larger the male inflorescences available, the fewer palms per ha will be required. As mentioned earlier, the average pollen bearing capacity of a good male palm should be suffi cient for 50 female palms. The abundance of pollen is determined by both the number of flowers and the pollen quantity per fl ower.

According to Monciera (1950) and to Wertheimer (1954), good male palms from Algeria annually produced an average of 740 g of pollen with a maximum of 2,133 g. However, both the number of inflorescences and the weight of pollen of these palms showed an alternancy phenomenon between high and low yielding years. According to Djerbi (1994), a good male palm should produce an average of 500 g of pollen with a regular production over time. Large quantities of pollen do not however, guarantee the quality of pollen produced and consequently its effect on the fruit (Metaxenia).

In regions where inflorescence rot occurs (caused principally by the fungus *Mauginiella scaettae* cav.), pollen should be taken only from healthy male palms. Evidence suggests that contaminated pollen may spread the fungal spores and establish the disease in female palms.

**** Metaxenia***

It is well known that the pollen not only affects the size of the fruit and seed (affected more by fruit thinning) but also the time of ripening (Swingle, 1928). Metaxenia is not to be confused with Xenia, which is the effect of the pollen on the endosperm (embryo and albumen). Metaxenia effect was verifi ed by several investigations in the USA (Nixon and Carpenter, 1978), in Israel (Comelly, 1960), in Pakistan (Ahmad and Ali, 1960) and in Morocco (Pereau-leRoy, 1958). The effect of pollen on the time of fruit ripening was proven to be beneficial and is actually considered as the most important practical application of metaxenia. Producing and selling date fruits at high prices early in the season, along with the aim of having more uniform and short ripening period (avoiding a prolonged harvest) are the two main objectives of using a selected pollen of high metaxenia effect. A third useful application of metaxenia is where the development period of the plant is characterised by an insuffi cient sum total of heat for the fruit ripening of late varieties.

It is worth mentioning that metaxenia effect could also be successfully used to speed up the fruit maturity and consequently escape the rain damage that is usually expected at the end of the fruit development period (Algeria, Tunisia, USA, etc.); The use of the Fard 4 male has advanced the maturation stages of various varieties all around the world by two weeks. However, under a summer-rain season, (India, Pakistan, Namibia, Republic of South Africa, for example) late ripening could be more desirable and the selection of males with late ripening effect is recommended.

***** ***Male-female compatibility***

Usually, a male seedling of a specifi c variety will set better fruits with specifi c female varieties. Djerbi (1994) observed that some date varieties will have a better yield if they are pollinated with some males rather than with others. However, several authors (Monciero, 1954; Pereau-leRoy, 1958) did not observe any interclonal incompatibility, and fruit sets obtained were always satisfactory. Pollen of 75 different Tunisian date males with more than 10 female varieties were examined so as to select those that have advanced maturity and improved date quality (Bouabidi and Rouissi, 1995). Six types of pollen were proven to be earliness-inducing (DG9, DG4, DF4-1, HF4-1, HF4-3 and HF4-5). Such a character depends on the female variety with no relationship between time of maturity and date fruit quality. These results confi rm the fi ndings of Bouguediri and Bounaga (1987).

As a first conclusion, a test to verify if the pollen of the potential male is satisfactory for the varieties on which it will be used, is important before looking into other characteristics.

Pollen viability

The capacity of pollen to germinate and grow normally is known as viability. The assessment of viability of freshly collected as well as stored pollen is often desirable before using them for pollination. The pollen from genetically different male palms have varying viability. Therefore, a viability test can help in selecting the pollen types which are highly viable. The use of highly viable pollen is likely to result in more fruit set and higher yield.

Applying enough pollen does not guarantee a good fruit set unless the pollen used is viable with a high germination percentage. As mentioned earlier, the evaluation of pollen's viability, whether fresh or stored, is essential before the pollination operation. The use of selected pollen with a high degree of viability will ensure a better fruit set and consequently an acceptable yield. Because of their seedling-origin, different male palms will produce different pollen from the quality point of view (cf. Metaxenia) and also different percentages of viable pollen.

Pollen from both the earliest and the latest male inflorescences was found inferior to that of others on the same palm (Monciero, 1954). The low fruit set resulting from the use of either the earliest or the latest male inflorescences could be explained by the non-maturity of their pollen, usually caused by low summation of heat.

Environmental conditions such as high temperature, low humidity, salinity build up and UV radiation may infl uence pollen viability.

5. Germination test of pollen grains

In vitro germination allows the measurement of the pollen intrinsic aptitudes to germinate outside any interaction between pollen and stigma. Furthermore, pollen capacity to fertilise the ovule and set the fruit is considered as an estimation of natural intrinsic aptitudes. Hence, in vitro germination is considered as the most valuable test of pollen viability (Boughediri and Bounaga, 1987). There are several rapid and reliable techniques that ensure excellent and fast germination, normal pollen tube growth and almost no bursting of pollen grains.

Albert's germination technique (1930)

A small amount of pollen grains is dusted on a drop of 20 % sucrose placed on a cover glass, which is then inverted over a glass cell. A thin fi lm of vaseline is placed on the top of the cell to seal the cover glass to it. It is then placed in an incubator at 27°C for 12 to 14 hours and inspection is done under a microscope. An initiation of a pollen tube growth is considered as evidence of germination. Germination counts must be taken from 4 fields for each slide.

Monciero's germination technique (1954)

The medium is a solid and consists of 1 % of agar and 2 to 10 % of glucose; It is executed at an average temperature of 27°C during 24 hours.

Brewbaker and Kwack's medium (1963)

It is a liquid medium developed in 1963 but modifi ed later by Furr and Enriquez (1966):. 15 % sucrose, 0.5 g of boric acid (H3BO3), 0.3g of calcium chloride (Ca(NO3)2. 4H20), 0.2 g of magnesium sulphate (MgSO4) and 0.1 g of potassium nitrate (KNO3), are added to 1 litre of distilled water. Ten mg of pollen grains is then added to 50 ml of medium and put in 125 ml Erlen fl ask and dark incubated at 24 to 32°C. This latter temperature was found to be the optimum.

The best percentages of in vitro germination of date pollen of various Algerian cultivars were obtained with 15 % of sucrose and 0.1 % of boron at 27°C in the dark (Boughediri and Bounaga, 1987). Maximum pollen germination was also observed at 0.05 ppm succinic acid and 0.5 ppm fumaric acid in a basic sucrose (20 %) and agar (1 %) medium (Asif et al., 1983).

Tisserat et al. procedure (1983)

Pollen grains are germinated in a liquid medium consisting of 500 mg.l $^{-1}$ H3BO3, 300 mg.l $^{-1}$ Ca(NO3)2.4H2O, 200 mg.l $^{-1}$ MgSO4. H2O, 100 mg.l $^{-1}$ ethylenediamine tertra acetic acid and 200 g.l $^{-1}$ sucrose. Ten milligrams of pollen grains is to be added to 250 ml Erlenmyer fl ask containing 5 ml of the germination medium. The fl asks are capped with sterilised cotton plugs and incubated at 27 - 28°C for 24 hours under dark conditions. Two drops of germination liquid medium from each treatment are separately spread on a slide and examined under a light microscope to obtain the germination percentage. Four random replicates are to be used and only 100 pollen grains could be examined in each replicate. The emergence of pollen tube growth is considered as an indicator of pollen germination.

The best medium from all the above for date pollen germination is the modifi ed Brewbaker and Kwak's medium.

Staining technique of Moreira and Gurgel (1941)

Take a small amount of the pollen grains and place them on a slide with 1 - 2 drops of 1 % acetocarmine solution. The slides are then heated for a few minutes on a hot plate. Examination is conducted under a microscope at 200 × magnifi cation power to assess the viability of the pollen grains (use 4 fi elds for each slide). Pollen grains stained red are considered viable, whereas, the colourless pollen grains are considered non-viable.

Al-Tahir and Asif (1982) determined the effectiveness and reliability of fi ve staining agents as indicators of viability of date pollen. A correlation coeffi cient between pollen staining percentage and germination percentage for 3 (4-5-dimethyl-thiazolyl-2) 2,5 - diphenyl tetrazolium bromide was positive and signifi cant. A similar technique was developed by Alexander (1969) who was able to differentiate between viable pollen grains which turn dark red and non -viable ones which become green.

The above staining techniques are based on the colouring of pollen resulting from the fixation of some chemical products on a specific cell's components; Cytoplasmic and enzymatic colouring agents are the two existing staining products. Within the enzymatic ones we can fi nd 2,3,5 triphenyl-tetrazolium chlorid (TTC) and 3 (4-(dimethyl-thiazolyl 1,2) 2,5 diphenyl tetiazolium bromide (MMT), both at a concentration between 0.1 and 0.7 %. These staining techniques, even though they are easy and rapid, are not recommended because they are not precise enough when compared to the germination test.

6. Female fl owers' receptivity

Before discussing the receptivity of female fl owers, it is worth mentioning that the female fl owering period is variety and temperature related and does not exceed 30 days (El Bekr, 1972). According to Munier (1973), this period is between 30 to 50 days and could even be longer when the daily average temperature is low. In the northern hemisphere, it is located during February, March and April, while in the southern hemisphere it is from July till early October.

The length of the receptivity period of the pistillate flowers could, in general, vary up to 8 or 10 days depending on the variety (Albert, 1930; Pereau- le Roy, 1958). According to Djerbi (1994), the receptivity period for North African cultivars varies from one variety to another (30 days for Bousthami Noire, 7 for Deglet Nour, 8 days for Jihel and Ghars and only 3 days for Mejhool, Boufeggous and Iklane). Beyond these limits, the percentage of parthenocarpic fruits is higher than 40 %. In Iraq, receptivity of "Ashrasi" variety was found to be optimum before the natural opening of the female spathe, while another variety (Barban) until approximately 20 days after the spathe's opening (Dowson, 1982).

Al-Heaty (1975) found that the stigmas of Zahidi variety have a receptivity period for 10 days. Oppenheimer and Reuveni (1965), in work conducted on the varieties Khadrawy, Zahidi and Deglet Nour, found that fruit set declined signifi cantly when pollination was delayed 10 days or more after the spathe cracked.

According to Ream and Furr (1969), female flowers of the Deglet Nour variety do not become receptive for possibly 7 days or more after the spathe cracks. Further delay to 13 days caused moderate reduction in fruit set and delays exceeding 13 days greatly reduced fruit set.

Within the pollination period, during which the percent fruit set obtained does not differ statistically, there was a day on which maximal fruit set was obtained: in Khadrawi, on the day of spathe crack; in Zahidi, on the day after and in Deglet Nour, on the seventh day after spathe crack (Reuveni, 1970). Another interesting fact, especially noted with Deglet Nour, is that the day of optimum receptivity varies in different inflorescences of the same date palm.

As mentioned earlier, satisfying pollination results are usually obtained within 2 to 4 days after the female spathe has opened followed by a second pollination passage 3 to 4 days later (Table 60). Furthermore, and as a conclusion, it is well confi rmed that the longer pollination is delayed after the opening of the spathe the poorer the fruit, set and if more than a week lapses the yield is usually greatly reduced.

TABLE 60
Length of the receptivity period of various date varieties

Variety	Receptivity period after spathe opening (days)	Reference(s)
Most varieties	8 to 10	Albert, 1930; Pereau-le Roy, 1958
Khadrawy, Zahidi and Deglet Nour	10	Oppenheimer and Reuveni, 1965
Deglet Nour	7 to 12	Ream and Furr, 1969; Djerbi, 1994
Zahidi	10	Al-Heaty, 1975
Ashrasi	before opening	Dowson, 1982
Barban	20	Dowson, 1982
Bousthami Noire	30	Djerbi, 1994
Jihel and Ghars	8	Djerbi, 1994
Medjool	3	Djerbi, 1994

7. Effect of environmental factors

7.1 Effect of temperature

High temperatures inhibit the development of spathes resulting in a delay of the pollination season. Low temperatures, usually early in the season, also have a negative effect on the fruit set. However, if female flowers open early in the season and their pollination is essential, then the sets could be improved by placing paper bags over the female inflorescence at the time of pollination. Bagging of fl ower clusters early in the season could be practised as an insurance against poor fruit sets caused by cold weather. Bags must be fastened in order to prevent the wind from blowing them off. Such bags must be removed two to three weeks later.

Bagging female spadices using paper bags (40-70 cm) immediately after pollination and during the first four weeks was found to result in a signifi cant increase in fruit set, yield and fruit dimensions of Hallawy cv. (Galib et al., 1988). Furthermore, growth of the pollinated carpels in the bagging treatment was faster that with the unbagged one.

According to Reuveni et al. (1986), improved fruit set obtained on bagged inflorescences might not always be attributable to improved temperature conditions; it probably delays drying of the styles and permits the normal progress of the pollen tube into the ovule even at relatively low temperatures.

Efficient pollination is localised within the period when pollen could fertilise the ovules. It depends on the ovule longevity as well as on the growth speed of the pollen tube, which is highly susceptible to low temperatures. During the pollination season, it is recommended not to pollinate in the early morning or late afternoon, because of the negative effect of low temperatures on the fruit sets. Ten to 15 % higher fruit set was experimentally obtained when pollination was conducted between 10:00 a.m. and 03:00 p.m. (Surcouf, 1922; Pereau-Le Roy, 1958). Laboratory results have concluded that an average temperature of about 35°C is optimum for pollen germination; lower temperatures decreased the germination percentage (Reuther and Crawford, 1946).

At locations where daily maximum temperatures during pollination are frequently less than 24°C, mechanical pollination method is not recommended. (Brown et al., 1969).

7.2 Effect of rain

There is controversy concerning the effect of rain on fruit set. Some consider rain that occurs just after pollination as a washing agent that takes away most of the applied pollen before it plays its role. In such a case, it is necessary to repeat pollination after the rain has ended. Other people consider the negative effect of rain on fruit set as an indirect effect via low temperatures that accompany or follow rain. If temperatures are between 25 and 28°C, most of the pollen tubes reach the base of the style of Hayani variety flowers within 6 hours (Reuveni, 1986); while at 15°C, pollen tubes do not reach the base of the style even after 8 hours. A third explanation of the effect of rain is the reduction of the pistillate fl owers' receptivity by contact with water. Rain is also responsible for increasing the relative air humidity which favours attacks by cryptogamic diseases that result in the rotting of infl orescences. This high relative humidity is also associated with reducing the pollen's blow out.

In conclusion, date growers must assume that rain can cause all the above effects, and any pollination operation immediately followed by rain must be repeated in time. Following pollination experiments conducted at the USDA research station at Indio, California (Dowson, 1982) and also according to Pereau-leRoy (1958) there is a limited period (4 to 6 hours either before or after pollination) during which, if rain occurs, pollination and fruit sets are affected and the pollination operation must then be repeated.

7.3 Effect of wind

In most date growing areas the latter part of the pollination season is usually characterised by severe hot and dry wind which dries out the stigmas of the female fl owers. Cold winds disturb the pollen germination. It seems, therefore, that dry wind storms lead to a faster drying of the styles before the pollen tube reaches the ovule. (Reuveni et al.,1986). Wind velocity could also have an effect on the pollination effi ciency; light wind is beneficial and favour pollination while high speed winds will take away a great deal of the pollen, especially for palms found at the edges of the plantation. In some cases severe wind could also break the infl orescence's fruit stalk (rachis), blocking the movement of sieve nutrients and fi nally causing the death of the bunch.

Dust storms which leave dust deposits on the flowers during the pollinating season in the southern parts of Israel, and in California are sometimes considered to be the cause of poor fruit set.

II. Fruit thinning

Fruit thinning is commonly practised in most date growing regions of the world in order to benefi t from the following improvements:

a. Avoiding the alternancy phenomenon and ensuring adequate fl owering for the next season. Thinning will allow the palm to produce regularly each year rather than to be weakened during one or two years by a heavy production and causing it to produce small and skinny fruits in the next year;

b. Improving the fruit size and consequently satisfying market preference;

c. Improving the fruit quality and texture which will refl ect on the price;

d. Ensuring an early ripening and be first on the market;

e. Early thinning will allow room for the development of the fruit; and there will be less loss of nutrients (N,P,K.) that have to be replaced by fertilisation.. Most sources are hence recommending earlier thinning rather than late thinning.

f. Reducing the weight and compactness of the fruit bunches which will benefi t the harvesting and packing operations.

Date fruit thinning may be realised at three levels:

(i) reducing the number of bunches per palm (removal of whole bunches);

(ii) reducing the number of strands per bunch (mostly from the central part of the bunch); and

(iii) reducing the number of fruits per strand (bunch thinning; removal of a proportion from each bunch).

1. Bunch thinning

Bunch thinning that is based mainly on the cutting back of strands will have a maximum effect on the size of fruits if applied at the time of pollination (Nixon and Carpenter, 1978). Cutting out centre strands must wait until the cluster has emerged further. However, and generally speaking for most varieties, it is recommended to wait 6 or 8 weeks after pollination in order to apply the adequate thinning method.

The operation of bunch thinning of the Deglet Nour variety is highly related to the climate and helps reduce damage due to humidity by a greater air circulation around the fruits. This ventilation will reduce the risk of later fruit fermentation, rot and souring. However, with some varieties, the reduction of fruits per bunch may increase the susceptibility of fruit to checking (cracking of the fruit skin; minute cracks in the cuticle and epidermal cells) or blacknose (darkening and shrivelling of the tip). In other climates and with other varieties, Al Bakir and Al Azzauni (1965) found no pronounced effect of thinning on the fruit size.

The objective of bunch thinning is to obtain more uniform bunch sizes depending on the fruit set (removal of fl ower strands if the set is poor and vice versa). Date growers are advised to take into consideration the variety, the relative importance of size and local weather conditions before selecting the thinning method and its degree. Furthermore, the growers should also keep in mind that:

(i) an overthinning will increase puffi ness and blistering (separation of skin and fl esh);

(ii) the earlier thinning is practised, the more effective it is in increasing size;

(iii) large bunches combined with damp weather, will result in fruit rot and souring;

(iv) whatever technique is adapted, all bunches should be thinned uniformly in order to obtain uniform size and quality.

By keeping accurate records, a date grower can soon ascertain the optimum production potential of his palms. Individual palm records would be most useful in working out an effective policy for thinning. Records of the number of fl ower clusters formed annually, will assist to ascertain whether the grower is thinning out too lightly or too severely.

When cutting back the tips and in thinning out the strands, the removal of a total of about 50 to 60 percent of the flowers or fruits on the bunch has been found highly desirable. To justify the expense and work involved in thinning bunches, culture and insect control must be adequate to ensure a harvest of sound fruit.

According to Nixon (1966), fruit thinning in the bunches of Deglet Nour and other long- strand varieties is practised differently, depending on the nature of the bunches of the variety.

Long- strand varieties (e.g.. Deglet Nour)

- Removal of the lower one third or slightly more of the bunch by cutting back tips of all strands (Figure 72). The total number of flowers on a strand of average length must be counted in order to determine the desired number to remove and consequently its equivalent by strand's length.

- Removal of entire central strands in order to reduce the number of strands in the bunch by one third to about one half on very large bunches (Figure 72). The total number of strands should be counted to determine how many are to be cut from the centre. Whole outside strands should never be removed because the fruit stalk may die.

With other varieties, the technique is commonly modifi ed with respect to the fi nal amount of dates per strand (20 to 35) and the number of strands per bunch (30 to 50). An average of 7 to 11 kg of ripe fruit per bunch will be obtained depending on the original size of the bunch before thinning, the percentage of fruit set and the amount of thinning.

From experiments conducted by El-Fawal (1972) on an Egyptian variety "Samany", it would be suggested that the best results may be obtained from a thinning treatment in which about 40 % of the fruit is removed in two step: the first is to cut back, at the time of pollination, the tips of strands suffi ciently to remove about 20 % of the total number of flowers. The second step is to remove about 20 % of the total number of strands from the centre approximately 8 weeks after pollination.

Results from Khairi and Ibrahim's work (1983) on fruit thinning of Khastawi variety (Iraq) concluded that cutting back tips of strands to reduce the initial fruit load by about 30 % at the time of pollination, and removing weak bunches with low fruit load at the time of bunch bending six weeks later, is useful bunch management to produce high fruit quality.

According to Glasner (personal communication), the thinning of Barhee variety is handled in Israel as follows: At the opening of the spathe, the top 1/3 is cut and 3 to 4 weeks later the grower will come back to thin another 1/3 from the inside. This technique leaves 45 to 50 spikelets per bunch, and 20 to 25 fruits per spikelet.

In general, bunch thinning concerns not less than one-half and not more than three-quarters of the total number of fruits. For most varieties it is generally desirable to reduce both the number of strands per bunch and the number of fruits per strand. However, any method of reducing the number of fruits per bunch will increase the size and weight, and to a certain extent (5 to 10 %) improve the quality; Furthermore, there is no positive correlation between fruit and seed weights amongst all thinning experiments indicating that increase in weight is due to increase in the weight of pulp, but heavy thinning will increase the susceptibility to checking which will reduce grade.

Short strands varieties (e.g. Hallaway and Khadrawy)

These varieties have shorter but more numerous strands than Deglet Nour. Consequently, their thinning must focus on the removal of entire central strands and less should be cut from the tips of the strands. The removal of one-tenth to one sixth of the strands' tips along with cutting out entirely about one-half of the total number of strands from the centre of the bunch, has given very satisfactory results. According to Russel (1931), the number of strands in Hallaway and Khadrawy varieties should be restricted to 40 to 60 out of 80 to 100 strands by removing the inner ones, and the length of strands should be 35 to 45 cm long by cutting out the ends 7-10 cm. Each strand will then carry 20 fruits (800 - 1200 fruits on each bunch).

Extra large and fancy date varieties (eg.. Medjool)

The Medjool variety, because of its high fruit quality, is the only variety commonly thinned by removal of individual fruits by hand. Instead of cutting back strands, only a certain proportion of fruit is removed from the strands. The fruits of Medjool are so large at maturity that, with a normal set of fruit many fruits are too crowded to be picked without damage and fruits are often misformed by pressure from adjacent fruit born on the same strand. According to Glasner (personal communication), satisfactory results are obtained in Israel by thinning

Medjool to approximately 30 spikelets per bunch. 3 to 4 weeks after pollination, the spikelets are thinned by hand, leaving only 10 fruits per spikelet. At the time of harvest, 300 fruits are obtained per bunch with an average weight of 20 g per fruit. An adult palm bearing 10 to 12 bunches, will hence yield 60 to 72 kg of high quality Medjool dates.

2. Bunch removal

A regular practice is the removal of entire bunches when their number per palm is too high. An adult date palm could produce 20 or more fruit bunches. In fact, if the number of fruit bunches per palm is not reduced to an appropriate level, the next year's production will be low, and consequently an alternancy phenomenon is established.

Another advantage of bunch removal is to keep a proper balance between the number of leaves and fruit bunches. According to Nixon (1966), a Deglet Nour adult palm, along with other long-strand varieties, pruned to 100 - 120 leaves (a ratio of eight to nine leaves per bunch) is able to give satisfactory yield without an alternancy phenomenon.

The number of fruit bunches for a palm to carry safely is dependent on its age, size, vigour, variety and the number of good green leaves it carries: None for the first three years (at this age, growth is more important than fruit production until the palm is well established); one or two in the fourth year, three or four in the fi fth year and so on.

Depending on variety and growing conditions, full production accompanied with the maximum number and size of leaves is usually reached at 10 to 15 years and then about 10 bunches per palm can be allowed.

Bunch removal is practised immediately after fruit set. Priority, of bunches to remove, should be given to the following:

- bunches with a poor fruit set;

- early and late bunches: generally are small, poorly pollinated and located at the lower and higher position of the inflorescences production level;

- bunches that are high in number on one side of the palm (their removal will ensure equilibrium for the palm); and

- bunches with snapped fruitstalks or broken strands.

Fruitstalks of bunches to remove must be sharply cut at their base (departure point from the stipe); the operation is usually performed with a single cut, since the fruitstalk is relatively tender at this stage.

3. Leaf-fruit bunch ratio

An adult Deglet Nour palm, pruned to 100 - 120 leaves, is able to annually carry 12 to 15 moderately thinned fruit bunches without any alternancy phenomenon; the leaf-bunch ratio is 8 to 9 leaves for each fruit bunch (Nixon and Carpenter, 1978). Similar results were obtained with Zahdi cultivar in Iraq (Hussain et al., 1984). A grower is advised to take into account the variety, the state of his palms and existing cultural conditions before determining which leaf- bunch ratio to adopt.

It is worth mentioning that it is a complicated operation since the value of the leaf to the palm declines with age and no two leaves are of the same age. Furthermore, leaves 4 years old are only about 65 percent as effi cient in photosynthesis per unit of area, as leaves 1 year old (Nixon and Wedding, 1956). Under good cultural conditions, a leaf can support the production of 1 to 1.5 kg of dates. Regardless of the leaf-bunch ratio, several factors may affect fruit production: i.e. lack of fertilisation and insuffi cient irrigation which may reduce the number of fl ower clusters and limit the bearing capacity of the palm.

How to determine the number of leaves per palm

Leaves are grouped in 13 nearly vertical columns, spiralling slightly to the left on some palms and to the right on others. The grower must only count the number of leaves in one of these columns and multiply by 13. According to Nixon and Carpenter (1978) and in order to allow for uneven pruning at the base, counts could be made on opposite sides and divided by two (Chapter 1; Figure 4).

4. Bunch lowering and support

With most commercial date varieties, after the pollination season, the bunches are pulled downwards through the leaves, gently enough not to break any of the strands, and the bunch fruitstalk is tied for support to the midrib (leaf rachis) of one of the lower leaves to avoid breaking. This operation is executed when the fruitstalk is fully extended (long enough) but still fl exible to permit some of the curvature to be distributed, so that the base will not take all the stresses. This also makes the bunch easily accessible for thinning, bagging and/or pesticide application.

Tying could be done with twisted frond leafl ets, with rope or with twine (Figure 73). It also prevents damage caused by scarring and shattering of the fruits during high wind, and lessens the later danger of fruitstalk breakage by supporting the bunch as the weight increases (Nixon and Carpenter, 1978).

After the pollination season, some of the smaller and later bunches are not always old enough to tie when the earlier and larger bunches are ready for such an operation, and could thus be tied 3 to 4 weeks later. In general, the fruitstalk grows rapidly during the first few weeks after pollination and shows pliability and high bending capacity. When elongation ceases, breakage and obvious loss of the fruitstalk is to be expected (Figure 74). Usually, the bunch does not require support until the fruit has attained about 3/4 of its full size. When the fruit bunch ripens, it could quite easily reach a weight of 35 kg or more. It is worth mentioning that bunch management of soft date varieties should receive more attention than that of the dry date varieties.

With young palms, bunches are held off the ground by attaching the fruitstalk to one end of a wooden stake (with a fork shape, called pole) (Figure 78).

5. Bunch covers

Date palm bunch covers offer several advantages and are commonly used in the New World of date culture areas in order to protect fruits from high humidity and rain, from bird attacks and also from damage caused by insects.

Protection from high humidity and rain

In various date growing areas (USA, Algeria, Tunisia, etc. in the northern hemisphere; and in Namibia, RSA in the southern hemisphere), rain could coincide with the ripening season and consequently causes severe loss of fruit. A sturdy light-brown craft-paper is used in the USA to cover and provide good protection of the bunch during the ripening season (Figure 32).

Protection is applied to the bunches in late kimri stage. Paper covers, wrapped around the bunch and tied to the fruitstalk, could be used in combination with a pesticide programme because the lower part of the bunch is not covered. Covering bunches too early may lead to the sunburning of the outer young fruits, once the cover is removed.

With varieties such as Khadrawy and Hallawy having a relatively open crown, white paper covers have been found to cause less sunburn than brown paper covers. Medjool bunches are usually protected with a lightweight white cotton bag of which the upper portion is water-proof. Plastic bags are to be avoided because of sunburn and heat damage to the fruit as well as build up for humidity.

Wet weather resulting from very high humidity and/or from rain will produce various levels of damage depending on the fruit ripening stage:

Immediately before the Khalal stage, minute superficial breaks, or checks in the fruit skin occur. The abundance of these checks and their types (transverse, longitudinal or irregular) vary in different varieties. When the checking is severe it is usually followed by a darkening and shrivelling of the tip (blacknose).

At the Khalal colour (yellow to red), checking no longer occurs and water will produce deeper and longer breaks or cracks (splitting phenomenon) in the skin and fl esh beneath. Furthermore, humid weather during the Khalal stage also favours the attack by various fungi causing serious spoilage from rot.

At the Rutab stage, moisture no longer causes skin breakage, but the fruit absorbs moisture and becomes sticky, less attractive and more diffi cult to handle. High moisture content of the fruit will result in fermentation and souring that often results in heavy losses.

At the Tamar stage, high humidity and rain cause little damage to the fruit except when it is neglected. The timing of bunch protection from rain is usually when the fruit starts to acquire its Khalal colour. An early covering will increase checking and blacknose because it reduces ventilation within the bunch. Although, the fruits escape damage by actual wetting, damage by excessive humidity increases.

Protection from birds

Birds of various species cause severe damage by eating on the fruit during the Rutab and Tamar stage (Figures 75 and 76). Parrots, besides eating the fruits while on the bunches (mostly at the Khalal stage), kick the fruit off the bunches with their legs, resulting in the loss of date fruits that fall to the ground.

Bird attacks are common in Sudan, Sahel countries and also in the southern hemisphere (Namibia, Republic of South Africa, for example). The most common birds causing damage to date fruit in Namibia and RSA are the Redbilled Quelea *(Quelea quelea),* Redheaded Finch *(Amadina erythrocephala),* Lesser Blue-Eared Starling *(Lamprotornis chloropterus),* and the Redeyed Bulbul *(Pycnonotus nigricans). The* Grey Lourie *(Corythaizoides concolor),* Rupell's Parrot *(Poicephalus rueppellii),* and the Rosyfaced Lovebird *(Agapornis roseicollis).*

When there is danger of severe bird or/and parrot damage, it is advised to initiate a bird control system. With the paper bags, the bunch should also be protected beneath with a good grade of porous cloth or netting that will exclude birds and insects, but at the same time not interfere seriously with ventilation of the fruit.

The importance of ventilation increases during the later stages of fruit growth and ripening as well as with the frequency of showers and periods of high humidity. If such conditions occur, it is advised to use a cover flared out and not extending down around the sides of the bunch. The thinning of central-strands of a bunch will promote better aeration of fruits. Rings or spreaders 15 to 30 cm in diameter, made usually of heavy wire, could be inserted in the centres to keep the bunches open as the fruit becomes full sized. Such accessory is mainly recommended with short-strands varieties, bearing fairly soft fruits. Those of a many-pointed star shape (or corrugated wire) remain in place better than circular ones and they must be inserted before the fruit reaches the Khalal stage.

Protection from insects

The bags retain the fruit and provide some protection from birds, but they do not hinder fruit-infesting insects (Carpenter, 1981). Unless only Khalal fruit is harvested, insects may damage more than 50 % of the Rutab fruit. Stored dates from such palms will show large infestation by living and dead insects.

Physical exclusion of most insects by use of screen bags is a practical measure used in various localities in the Middle East (Carpenter, 1975). Moths and other insects larger than fruit beetles *(Nitidulidae)* are excluded. The bags are of flexible 18 × 20 mesh wire or shade net (80 % is recommended) and are 1.0 to 1.5 m^2, depending on the bunch size to be covered (Figure 77). It is closely tied to the fruitstalk to ensure that rain water will not enter and also to prevent it from being blown away by wind. The best timing of its placement is mid-to-late chimri stage.

The date grower is advised to conduct proper insect control in the field, followed by prompt fumigation of fruits immediately after harvest. Packing house sanitation is closely related to field insect control. The packing facility should be insect-free to prevent re-infestation of fumigated fruit by "Dried fruit-infesting insects", flies, roaches and other pests.

Furthermore, the bags eliminate the need for pesticides on fruit and thus maintain biological control of *Parlatoria* scale and other insects.

6. Leaf pruning

To avoid confusion, one should differentiate between pruning in general terms and pruning in date palm. Pruning in fruit trees and bushes of temperate fruit consists of the removal of living wood, while pruning in date palm is in general the removal of only dead, or nearly dead fronds and their bases (Figure 79). Depending on variety and cultural conditions, date palm leaves can remain alive for at least seven years with a maximum activity during the first year and an ultimate decrease in their photosynthetic capacity. As the leaves do not drop of their own accord, they must then be cut off.

Pruning is desirable in order to improve date fruit quality and also enhance the bearing capacity. In fact, when too many leaves (as many as 180 leaves/palm unpruned for 5 to 6 years) are retained and reaching below level of the fruit bunches, a high percentage of fruit affected with checking and blacknose and of fruit in the dry grades is obtained. Checking, occurring during mid-summer,is increased by high relative humidity caused by lower leaves. Furthermore, such lower leaves probably compete with the fruit, and create favourable sites for diseases and pests. Removing the leaves up to about the point where the lower ends of most fruit bunches are exposed is highly recommended for adult full bearing palms.

Pruning is mainly practised after fruit harvest; Pruning could also be realised at any convenient time between the harvesting and the flowering season (thinning period is recommended) and because of the greater ease in cutting, it is desirable to remove them before the bases became hard and dry. The dry, old hanging and withering or diseased leaves are cut along with superfluous offshoots. Leaf pruning could also be synchronised with tying down of bunches or with bagging. It is recommended that leaves which are still green are not pruned so as to take full advantage of photosynthesis. Considerable evidence shows that, other conditions being equal, the fruit bearing capacity of a date palm is in proportion to the number of green leaves it carries.

During the pruning operation, unwanted offshoots should also be removed to foster growth of those that are retained on the palm for propagation, to make access to the palm easier and to promote growth and bearing of the parent palm. In very dense offshoots growth, some of the small plants may be seedlings rather than true offshoots, and must be discarded.

However, where there is any fear of frost in the coming winter, no pruning is recommended and the leaves are left for the protection from the cold of the young tender leaves.

7. Dethorning:

Another important pruning process is the removal of spines, also called thorns. It is advantageous to annually remove spines from the base of new leaves in order to facilitate pollination and handling of fruit bunches. Cut thorns themselves are a source of some danger, because they lodge in leaf bases on the soil where they persist as a hazard.

Date spines are usually removed from the new growth of fronds in the crown of the palm just before the pollination season to allow easy access to the date spathes as they emerge. If the palms have been dethorned the previous year, the new growth will be 2 or 3 rounds of fronds, each round developing 13 new leaves, a total of about 26 to 36 fronds to be dethorned. Such an operation will ensure a safe approach to the spathes for their pollination and also avoid any risk of injury to labourers during other technical practices (tying down, protection of bunches, harvesting, etc.)

It is common to use dethorning knives of various designs to remove these spines: a long sharp curved blade or pruning knife mounted on a wooden handle 30 to 45 cm long, or a sickle type blade with a sharp cutting edge.

Figure 64. Pollination technique using two to three male strands.

Figure 65. Hand pollinator in use in Zagora, Morocco.

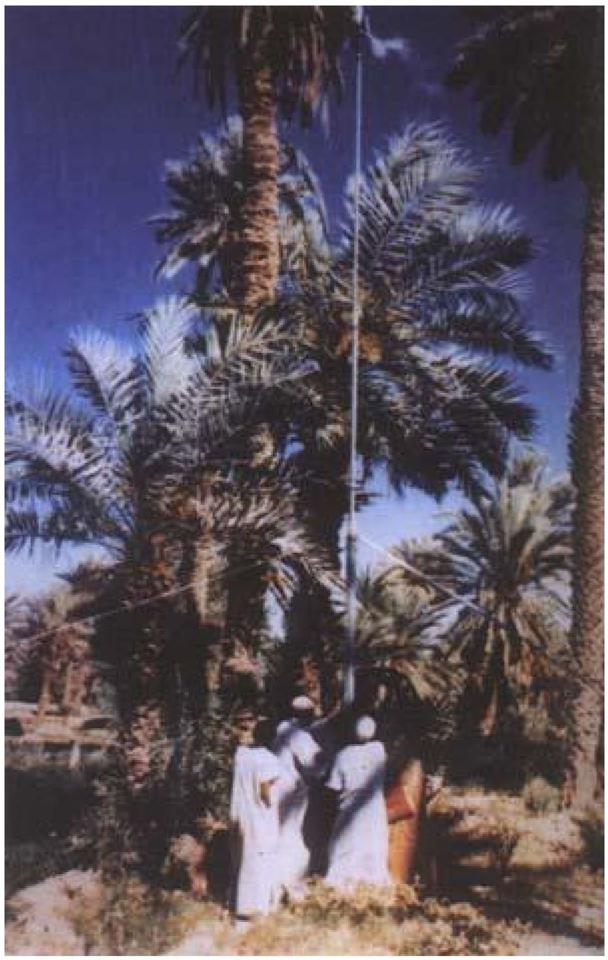


Figure 66. Scheme to show various components of the hand pollinator

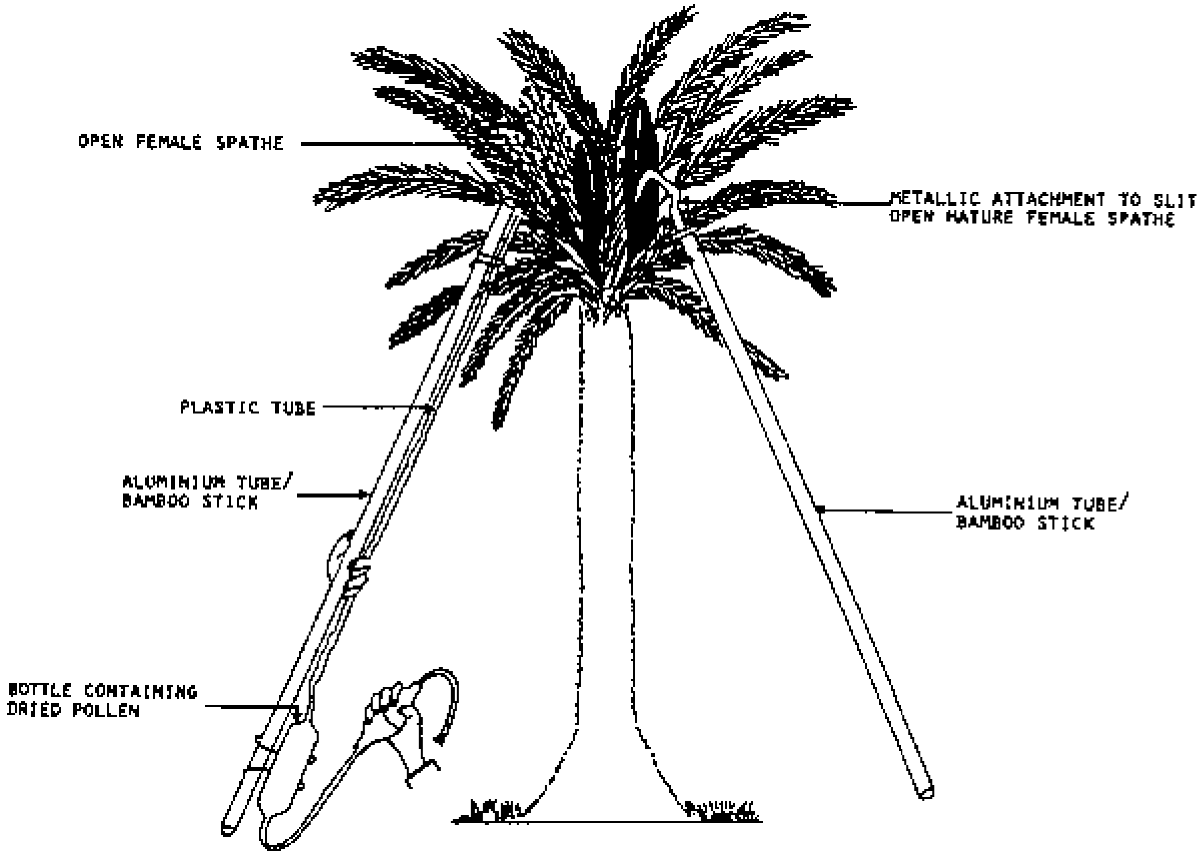


Figure 67. Drying of male spathes in a shaded and moisture-free area

Figure 68. Mechanical pollen extractor and collector

Figure 69. Dessicator used for long term pollen storage

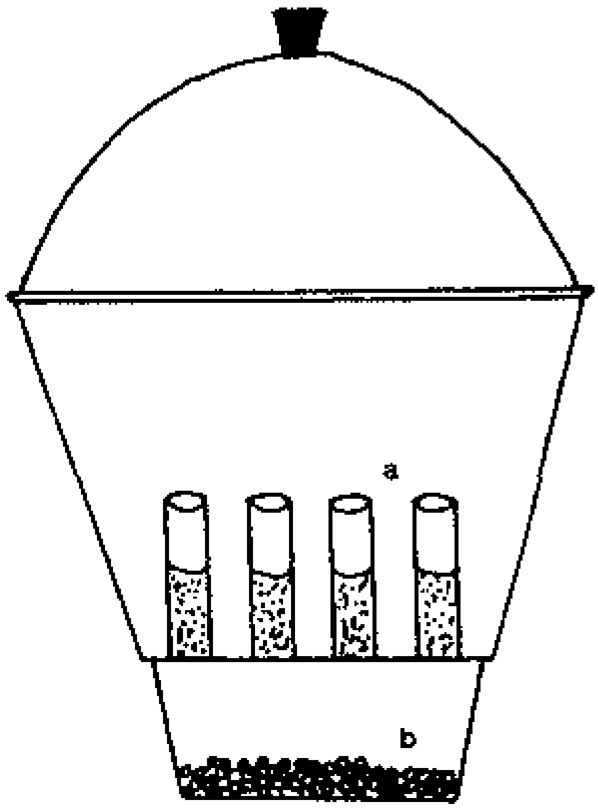
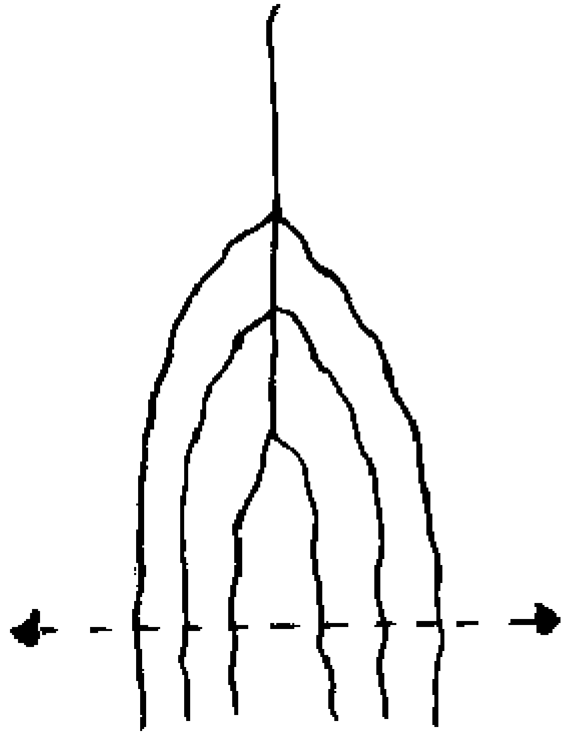


Figure 70. Storage of date pollen at low temperatures: (-4°C down to -18°C).

Figure 71. Even at low temperature storage, a dehydrating agent (calcium chloride) is needed.

Figure 72. Thinning methods:

A - Removal of the lower one third of the bunch



B - Removal of entire central strands.

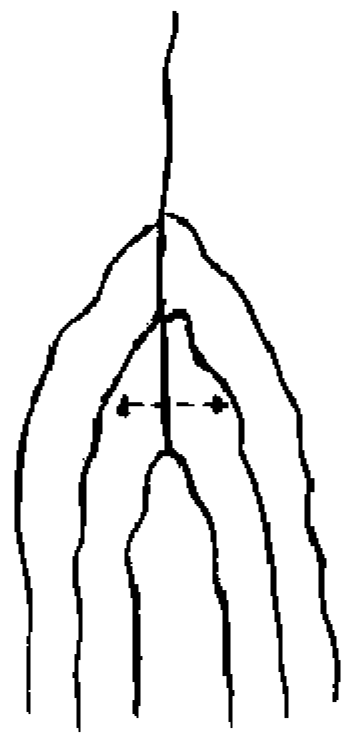


Figure 73. Bunch support using a twine.

Figure 74. Breakage of non- supported bunch

Figure 75. A non-protected fruit bunch showing the damage caused by birds.

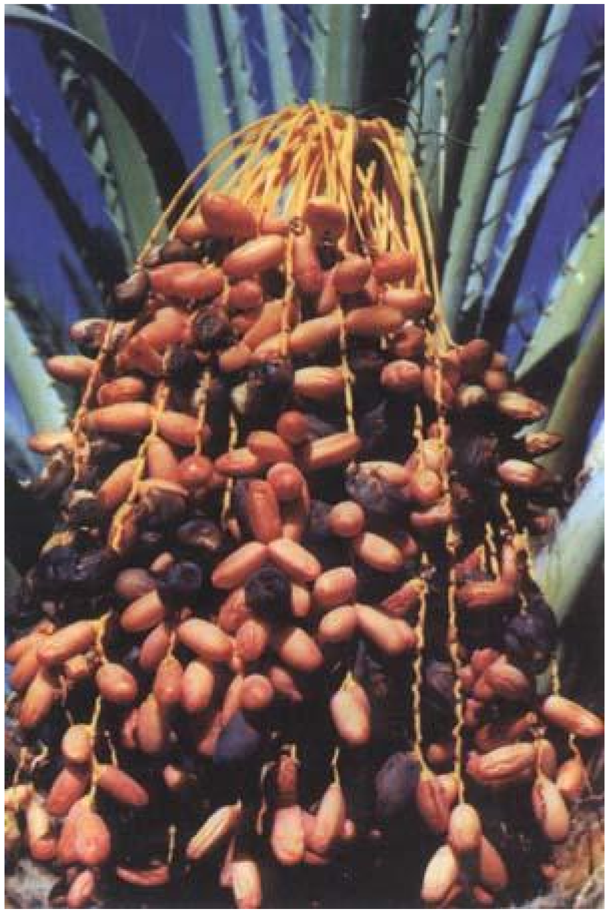


Figure 76. Fruits damaged by birds that eventually dry out and fall on the ground.

Figure 77. Shade net bags used to protect date fruit from birds and insects attack, (Right: 60 % and left 80 %).

Figure 78. Support of bunches on a young date palm using a fork shaped wooden stake.

Figure 79. Pneumatic tool used for leaf pruning and fruit bunches harvest.

CHAPTER IX: DATE HARVESTING, PACKINGHOUSE MANAGEMENT AND MARKETING ASPECTS

By Baruch **"Buki"** *Glasner, A. Botes,*
A. Zaid and J. Emmens

1. Introduction

Date Production is a world agricultural industry producing about 4,7 million tonnes of fruit in 1997 (FAO, 1998).The date fruit, which is produced largely in the hot arid regions of Southern Asia and North Africa, is marketed all over the world as a high value confectionery or fruit, and remains an extremely important subsistence crop in most of the desert regions.

In this chapter the main focus is on date harvesting, packinghouse management and marketing aspects for the purpose of selling the produce as whole dates. Other date palm products, mostly prepared from dates of lower quality than those sold as whole dates, are also described.

In their analysis of the essence of quality, all modern approaches focus on the client (the consumer), his perception of the product, and the behaviour of the product according to defi nite specifi cations. There is progressive improvement in the quality of the product in line with the rising expectations of clients. This process must be stable, repeatable and capable of producing identical qualities for any length of time.

People very often think of marketing as the activities which take place after the product leaves the production point. Marketing, however, involves more than just that and might be defi ned as the set of economic and behavioural activities that are involved in co-ordinating the various stages of economic activity from production to consumption (Purcell, 1979). It is important to note that the benefi ts of a year- long and outstanding job of production can be wiped out with a single bad marketing decision.

A farmer's job does not begin and end with producing something. The first agricultural marketing job is thus to determine accurately and in quantitative and qualitative terms just what consumer demands are in time, place and form, and what changes are taking place in those demands over time. The more time, effort and money a fi rm spends in carefully and completely planning the product which it wants to produce, the less time it is likely to need to spend in selling.

Large amounts of money are being spent to produce the fruit. One should thus put in as much effort as possible to capitalise on the investment through marketing. Marketing is expensive, but to be successful one needs to invest and to be creative. Fresh dates are not something new on the European market. Therefore, to be able to sell the date fruit, the packaging should be more attractive, and the contents should be of a higher quality than the competitors'. Low input gives low output.

Profitability is also an important measure, making additional investments possible for improvement and growth. The approach is one of delegation of authority to the people who are at the heart of the production process; who may work according to well defi ned procedures and at the same time use their common sense and act judiciously. Emphasis is placed on cooperation between suppliers and clients in order to make it possible to work with precision, to receive feedback detecting mishaps, and to develop new products.

Emphasis has traditionally been placed on the commodity involved, or the economic functions performed, or the institutions that are involved in performing the various functions. Focusing on these issues separately is important, but the marketing strategy should be to adopt a marketing approach where emphasis is placed on the total system. With this, the entire continuum, from producer to consumer, becomes the focal point.

While describing the process which the fruit undergoes in the packinghouse, from the moment of entry until the product is ready for marketing, emphasis is given to the various aspects of quality control, mandatory in high quality products.

2. Harvesting considerations

There are specifi c harvesting and packing considerations for each date variety and the form in which they will be consumed.

Harvesting means physically detaching the fruit from the palm. Differences in the state of the fruit, from the point of view of harvesting, are great at the level of spikelets, bunches and palms. These differences are both visible, such as the fruit colour and the degree of ripeness; and invisible, such as the percentage of water and of sugar and the activity of various enzymes.

Whole dates are harvested and marketed at three stages of their development. The choice for harvesting at one or another stage depends on varietal characteristics, climatological conditions and market demand.

The three stages are as follows:

> Khalal: Physiological mature, hard and crisp, moisture content: 50 - 85 %, bright yellow or red in colour, perishable;
>
> Rutab: Partially browned, reduced moisture content (30 - 45 %), fibres softened, perishable;
>
> Tamar: Colour from amber to dark brown, moisture content further reduced (below 25 % down to 10% and less), texture from soft pliable to fi rm to hard, protected from insects it can be kept without special precautions over longer periods.

In general, when dates reach the Khalal stage, they are regarded to be ready for trading as "fresh" fruit. Dates in Khalal stage are the first in the harvesting season and therefore have aready market. Only date varieties with a low amount of tannin at Khalal stage are suitable for consumption. The low amount of tannin results in low astringency. Furthermore, it is important that the fruit is sweet and not bitter. Date varieties suitable for marketing at Khalal stage are Barhee, Zaghlool, Hayany and Khalas. Of these varieties, only Barhee is sold in England, France and Australia, while the other two are mostly consumed locally.

Experience in most date producing countries showed that a well matured Rutab, handled with care, is one, if not the most, appreciated form in which the dates is consumed and which gives the grower the highest rate of return. However, Rutab has three serious setbacks: it is produced in comparatively short periods with the tendency of production peaks; it is highly perishable; and it is delicate, which makes handling and transport diffi cult and expensive.

Major commercial date varieties harvested at Rutab stage are Deglet Nour and Medjool. Deglet Nour is harvested yearly in tens of thousands of tons in Algeria, Israel, Tunisia and the USA. The production of Medjool is more limited (less than 5,000 tons per year) and mostly produced in Coachella Valley and Bard in California, USA, Morocco and Israel. Small amounts are produced in Mexico, Namibia and South Africa.

Fruit harvested at Tamar stage is non-perishable, i.e. micro-organisms cannot grow on it, moisture uptake and its consequences, and changes in colour and taste occur during storage. Most of the dates of Dayri, Halawy, Khadrawy, Thoori, Zahidi, Sayer and Aliig varieties are harvested after the fruit has undergone the process of ripening and drying on the palms.

Fruit at the Tamar stage is ideal for marketing as "dried" dates. This fruit is used for preservation and year-round consumption and also for the production of various types of products, e.g. cakes, sauces and components of granules or date honey.

The main outlets for dates at the Tamar stage are the following:

- home consumption, local markets
- wider regional distribution
- collecting/bulk packing centres
- small, medium, and large-scale packing plants for bulk shipments and retail packs.

The softening of the fruit is mainly infl uenced by polygalacturonase and cellulase enzymes. The activity of these enzymes depends on the slow drying of the fruit.

The invertase enzyme determines the speed and level of transition from disaccharid to two monosaccharids, fructose and glucose. These changes determine the speed of evaporation of water from the fruit. The level of fructose and glucose infl uences both the speed of drying and the activity of the polygalacturonase and cellulase, and also the relationship between the water activity Aw and the water content, and so the extent of shelf life. Water activity can be expressed by Equilibrium Moisture Content (EMC) expressed in percentages; the EMC expresses the sensitivity of the fruit to microbiological infestation. EMC below 65 % ensures resistance to microbiological factors such as moulds, yeast and bacteria that attack the fruit (Figure 87).

2.1 Harvesting

Although attempts are being made to harvest the fruit by shaking the trunk of the palm in order to avoid having to climb it, it is still necessary to reach the top of the palm to harvest the fruit. The palm grows up to one meter every year (depending on variety and the intensity of treatment). Harvesting the fruit entails the use of experienced workers, or investment in aluminium ladders, in attaching ladders to the palms permanently or in purchasing mechanical appliance to lift workers to the top of the palm (Figure 80).

Harvesting in the northern hemisphere takes place at the end of summer and in the fall, starting at the end of July (depending on the geographical area), with the harvesting of the Khalal varieties (especially Barhee), and ending in the middle of November. The harvesting of certain of the varieties continues after the rain starts (The end of summer rain in California,and the fall rain in North Africa and Israel). Rain can cause damage to the fruit and impair its quality due to rotting, fermentation and insect infestation. The fruit must therefore be protected against rain with the help of wax-covered paper or nylon sleeves. In the southern hemisphere harvesting takes place in February, March and April.

Harvesting must be faultless and clean, since it signifi cantly affects the rest of the process (packing and marketing). Harvesting the fruit straight into containers suitable for transport to the packinghouse prevents the infection of the fruit by the soil and sand under the palm and ensures that the fruit arrives in good condition, and that it is not crushed.

2.2 Field sorting of fruit

In 1997 the world production of dates was 4.7 million tons (FAO, 1998). Much of this fruit is still grown and processed by traditional methods described in great detail by Dowson (1962). These methods involve mainly the drying and curing or ripening of the fruits (which have been laid out on cloths or mats) in the sun, pitting (destoning) by hand and storing in jars.

The harvested fruit is transferred into containers (large plastic bins) for transport to the packing station. Each container contains 200 - 450 kg fruit and is suitable for dry fruit. Large wooden, plastic or cardboard cases of various sizes are also used, focusing on the need to prevent damage to the fruit (especially to soft and sensitive fruit). Baskets and sacks (for very dry fruit), as well as trays are also used. It is desirable to separate damaged fruit which is not destined for the market, while still at the site. Dates that are rotten, sour, with remains of insects, crushed, shrivelled up, unfertilized, or unripe fruit which are not intended for artifi cial ripening should be removed from the plantation. These fruits should be destroyed or fed to animals, in order to maintain sanitation of the plantation.

2.3 Transporting to the packinghouse

When transporting the fruit we must also take into account its sensitivity, and the importance of every link in the chain in the treatment of the fruit. Dates harvested at the Khalal stage must be transported as soon as possible to receive appropriate treatment, whether it is Barhee, Khalas, Hayany or Zaghlool for local consumption or for export. The fruit must be transported in the early hours of the morning to avoid the heat; if the distance is great, refrigeration during transport is advisable. Deglet Nour, which is to be marketed on the branches must not beshaken during transportation in order to prevent the fruit from falling off the branches. Speedy transport will also prevent infection by pests which attack the fruit during the post- harvesting period.

2.4 Quality control on the use of chemicals

Many clients, especially from European markets, demand that the quality control processes used be documented by the growers; especially a report concerning treatment (spraying) against insects. Such a report includes a list of the materials permitted for use and approved by an offi cial agent, in addition to the timetable of the spraying with details of materials used, the date, concentration, number of days before harvesting and the level of residue of pesticides; the level permitted appears in the Codex Alimentarius published by FAO. This book gives the permitted level MRL (minimum residue limit) according to types of material and species of fruit, vegetables and other foodstuffs. Today, it is possible to reach a level of detection of such remains at PPB (part per billion), but the cost of the test is considerable.

3. Facilities and process

Packing is a vital stage in both the traditional and modern methods of marketing. At this stage many varieties of varying quality, water level and rate of pest infestation can be preserved up to a year. The aims of packing are:

a) To make it possible to transport the fruit by various means: from baskets made of palm leafl ets, to the use of modern packing containers, and transport by air or by sea in containers. The sturdiness of the packing must be adapted to the methods of transport.

b) To protect the fruit when packed so that it will remain in good condition under various circumstances and for various periods of time. The packing materials should be chosen according to the quality of the fruit as required by international standards or consumer needs (e.g. it is forbidden to use PVC). Packing must preserve the moisture of the fruit, prevent further drying out of the fruit and any loss of moisture in moist fruit. It must withstand conditions during storage (there are materials which do not withstand a temperature of - 18° C). The packing must preserve the fruit for as long as necessary.

c) To use packing in order to promote marketing. Some of the data on the packages are relevant to the laws in the importing countries; some provide information for the client and some serve the promotion of sales, or as labelling (such as EAT ME for Deglet Nour or CALIFORNIA DATES, or KING SOLOMON for American and Israeli Medjool, respectively). In most importing countries, the law demands that data such as weight, country of origin, quality and date of expiry, appear on the package.

The Packinghouse

In various countries there are several kinds of contracts between growers and the packinghouse. Family packinghouses may be small or large, built in or near the plantation, and they are owned by the grower. In such a packinghouse there is continuity and coordination between the activities at the plantation and in the packinghouse. Workers at the plantation supply thefruit in accordance with the potential of the packinghouse and the relevant installations to receive it, for instance for fumigation, refrigeration and storage. The packinghouse also adapts itself to the constraints of harvesting, such as the speed of ripening of varieties harvested at the Khalal stage, adding another shift when necessary, increasing its workforce (temporarily), renting storage space and operating fumigation rooms continuously.

Cooperative packinghouses are set up to exploit the advantage of size; growers get organised according to a specific region or fruit variety (especially for the packing of Deglet Nour on branches). These packinghouses usually accept fruit according to one of the following methods:

a) By keeping the fruit from each grower separate during all stages. To do this, labels (with the grower's number) are put on the crates (or any other packaging) at entry, during fumigation and storage, and during sorting and packing. One can also separate the fruit from different growers by storing it in different labelled areas or packing it on different days.

b) By sampling the fruit at entry. After sampling the fruit is separated according to the management, production and marketing needs (not according to suppliers).

Private packinghouses usually buy the fruit as raw material directly from growers. This has the following advantages:

* The grower is paid immediately for the crop.
* The packinghouse can sometimes acquire the fruit at a competitive price.
* The packinghouse functions independently of the grower after the purchase.

Disadvantages are:

* The grower usually receives a lower price, since all the risks are transferred to the packing-house.

* The packinghouse may not receive good quality fruit.

Sub-contracted packinghouses usually receive the fruit after it has already undergone several processes, especially fumigation and preliminary sorting. These packinghouses are not always in the area or country where the fruit is grown. Some of them specialise in small scale packaging, directly connected to the marketing networks; they defi ne the desirable quality to the supplier and check the fruit at entry according to the required criteria.

3.2 Processes used to improve or maintain fruit quality

In the packinghouse there are a number of processes, designed to improve or maintain fruit quality. These processes are: fumigation, washing, storage, refrigeration, hydration, dehydration and curing.

3.2.1 Fumigation

In order to store the fruit for a long period (several months to one year), it must be completely cleaned of any pests (eggs, pupas, larva or adults). This is done by fumigation, either in the fi eld under various kinds of plastic sheets, or at the packinghouse in special sealed rooms.

Fumigation must not be carried out when the fruit is fresh, harvested at the Khalal stage, (Barhee, Khalas, Zaghlool and Hayany) or when stored under deep refrigeration. The substance most frequently used for fumigation is methyl bromide (CH_3 Br), which makes most of the insects come out before they are killed by the gas. The concentration of the gas is 30 ppm, i.e. 30 g methyl bromide in 1 m^3 of air. The time recommended for fumigation is 12 - 24 hours. The temperature must be above 16° C. It is important for the air to swirl within the fumigation installation, in order for it to spread uniformly within the chamber.

Methyl bromide is a dangerous poison. This fumigation process must, therefore, be done according to the law and all the regulations concerning the equipment and the protection of the people involved.

After fumigation the chambers must be aired according to the producers' instructions. The level of fumigation described above kills insects, while keeping within the level of remains at the MRL, permitted according to the Codex Alimentarius (FAO). After fumigation the fruit must be stored under conditions that prevent re-infestation. It is therefore undesirable to store fumigated fruit together with unfumigated one.

Additional substances and methods are also being used, for instance irradiation by gamma rays or exposure to ozone. For dates grown and marketed by the bio-organic method, can be used. fumigation by CO_2

It should be noted that in 1992 methyl bromide was placed under the Montreal Protocol on substances that deplete the ozone layer, because of international concern about the continued increase in its production and its damaging effect on the ozone layer. Actions taken by countries party to the Montreal Protocol are:

* Limitations on an increase in the production of methyl bromide from 1995, and
* Consideration of longer-term options to completely phase out its use.

At the moment there are no restrictions on the import/export of methyl bromide treated products. Restrictions on the import/export of these products were postponed till the year 2003. The latest information can be obtained from the UNEP Secretariat to the Montreal Protocol.

Alternatives for methyl bromide:

* Phosphine is the principal alternative to methyl bromide for fumigation of durable commodities and is widely used in developing countries.

* Controlled atmospheres high in carbon dioxide are in regular use in South East Asia for disinfecting bag-stacked durable commodities.

* The applications of physical control methods such as fi ltering, heating or cooling regimes, active oxygen (ozone, hydrogen peroxide) and irradiation. However, some of these methods are very costly (CBI, 1997/1).

3.2.2 Storage and refrigeration

After packing, the fruit will be sent according to market orders, or stored as the fi nished product. During storage, the material in which the fruit is packed must also be taken into account, for example: cardboard is sensitive to humidity; various plastics are sensitive to low temperatures; wooden surfaces may be attacked by various pests.

In the storehouses the produce must be protected from recontamination by pests (insects and rodents). The surfaces and packages must be well made in order to withstand being loaded, shaken on the way and unloaded.

The aim of storage is to attain the state of DQ = 0 for a long period (Q = quality; D = variation), which means creating a situation in which the quality of the fruit does not change during storage.

Much of the fruit is marketed throughout the year (especially fruit at the Tamar stage), and sometimes even after a year has passed, because of the need to prepare the fruit for Christian festivals, or at times when the Muslim Feast of Holy Ramadan is close to harvest time.

According to traditional methods, the fruit is protected from external hazards and preserved by being dried to a level of moisture that will ensure that it is not sensitive to microbiological contamination even in ambient temperatures, or by being pressed into sealed baskets or jars.

The current market demands fruit with higher moisture content. Preservation is ensured by storage under low temperatures.The temperature at which the fruit is stored is adapted to the time lag until the next treatment or until marketing. The temperature must ensure the continued extermination of insects that have survived fumigation, and prevent loss of moisture, or in the case of dry fruit, increase the moisture. Refrigeration must not infl uence properties, such as texture, moisture and colour.

The temperature and the speed of refrigeration also affect physiological phenomena, such as sugar crystallisation. Sugar crystallisation is caused by the breaking of cell walls or the tearing of the skin, facilitating the movement of water inside the fruit or out of it. This is connected to the amount of moisture in the fruit.The risk increases when the amount of moisture rises above 20 % (also in low temperatures). This phenomenon does not exist in Deglet Nour. Today, the temperature commonly used for long-term preservation of dates of several varieties including Medjool is - 18° C (0° F). This temperature decreases possible water loss and also decreases the sugar crystallisation and skin separation phenomena.

However, research done in Tunisia showed that:

* storage under conditions of 26 % humidity or higher requires a temperature of 0ºC enabling a storage period of 6 - 8 months;

* the storage period can be more than 1 -year if humidity is less than 26 %;

* if humidity is less than 20 %, dates can be stored at 25ºC for up to 1- year; and

* high sugar content coupled to high humidity tends to aggravate the situation of fruit going bad.

Varieties sold at Khalal stage, such as Barhee and Zaghlool, are stored at a temperature of 1°C, which increases their shelf life from a few weeks up to 6 - 8 weeks.

3.2.3 Washing

Just like all agricultural products, dates are grown in the fi eld and exposed to various types of contamination of physical, chemical or/and microbiological nature.

Physical factors: Sand and soil - both as a result of sand storms in many regions where dates are grown, and soil sticking to fruit lying on the ground.

Chemical factors: These are especially remnants of pesticides, some of which can be removed by washing.

Microbiological factors: External cleaning of the fruit by washing removes some of the microbiological pollution, also excretions of birds, which may spoil the fruit (Figure 81).

Clean water must be used and care taken that all the fruit is washed. Other methods exist, such as damp towelling attached to sloping mechanical shakers (California - USA). The fruit from Barhee and Deglet Nour are also cleaned by air pressure specially adapted for the removal of dust and sand, before they are packed on branches. While the fruit is still hanging, it can be cleaned by water spray, accompanied by the use of fine swivelling brushes, but they must be dried before being packed.

When the fruit is packed immediately after washing, it is important to dry it in drying cubicles or by means of large fans.

3.2.4 Hydration, curing and dehydration

The aim of dehydration and hydration is to improve the quality of the fruit, to produce uniform fruit with regard to moisture, and to extend its durability during storage and marketing.These processes are carried out by artifi cial means in the packinghouse when hydration or dehydration are not carried out earlier, during the treatment of the fruit in the field. When treated in the packinghouse, the fruit is dehydrated or hydrated after it has been stored or washed, when the moisture can range from 10 % in very dry fruit to 30-45 % in fruit at the stage of curing (Rutab). Of course, the moisture of the fruit also depends on variety, the region and the weather at the time of harvesting.

Hydration

Some varieties (for example Amri and Zahidi) have a dry and hard texture in regions where, during the ripening of the fruit (the transition from Khalal to Rutab and from Rutab to Tamar), the temperature is high and moisture is low. In this situation moisture must be increased by hydration. This is a process of fruit saturation with water or steam, while ensuring the appropriate temperature in order to create optimal conditions for enzymatic activity, which will cause the fruit to soften. This softening is often accompanied by a rise in moisture to a level that can endanger the fruit by exposing it to microbiological elements (when moisture reaches over 20 % and EMC over 65 %). The appropriate hydration process depends on how long the dates have been exposed to these conditions.

Curing

An activity similar to hydration, by integrating temperature and moisture, is carried out when some of the dates are unripe, Khalal, or when a stage has been "skipped". Unripe fruit enters the packinghouse for two reasons:

* In cold regions (for example Elche in Spain) where the fruit does not ripen under natural conditions, or rain may threaten the fruit.

* When harvested in the usual way (Khalal).

"Skipping a stage": This situation arises when the transition from Khalal to Tamar is very fast (in hot regions) and some of the fruit is not ripe while the fruit is already shrivelling and at the Tamar stage. Such dates (usually of the Medjool variety) have white shoulders or are naturally white - these are the parts of the fruit in a light unripe state against a light brown background of Tamar. Most of the Deglet Nour in California is harvested when it is very dry and hard, and only hydration treatments bring it to a moisture of 23 to 25 %, and make it suitable for marketing (to meet consumer demands).

Dehydration

Dehydration is undertaken when the moisture of the fruit is higher than planned (with respect to market needs). In order to preserve the fruit for any length of time (without refrigeration), it is important to decrease the moisture to below 20 % (depending on variety). At a moisture percentage of 15 % to 20 %, varieties such as Khadrawy, Halawy and Medjool can be preserved for a long time, unharmed by microbiological processes (such as fermentation, souring or the emergence of mould). If the moisture percentage is too low, the fruit will be hard to eat and inappropriate for some of the consumers (mainly on the European market). Decreasing the moisture also reduces the risk of sugar crystallisation.

It is important to ensure moisture uniformity. Fruit at an undesirable level of moisture will be spoilt by microbiological processes. This phenomenon is found in "Juicy Medjool" and in Deglet Nour on branches, when packed with a high level of moisture. First, alcoholic fermentation takes place as a result of yeast activity, and later a process of souring, caused by the activity of various kinds of lactobacilli. The following factors infl uence appropriate dehydration: temperature, moisture, speed of airfl ow, uniformity of the above variables and length of dehydration time.

Dehydration is carried out in special chambers. These chambers control the entry and fl ow of hot air, to ensure the appropriate moisture level. All these conditions must preserve the quality of the fruit, especially with regard to skin separation. The temperature must not rise above 70°C in order to prevent "the burning of sugars" (caramelisation). High temperatures will also cause the fruit to darken. Different temperatures suit different date varieties: Halawy 55°C (and 20 % moisture during the process); Deglet Nour and Medjool 50°C.

Quality control during hydration and dehydration

The amount of water in the fruit exerts a great infl uence on its quality and shelf life. It is mandatory to have a constant follow-up on the product by various means of testing. This is to ensure that the client receives fruit of the quality he or she requires, both with regard to softness and to moisture, which must not be too high. The latter prevents harmful microbiological processes and the rise of sugars.

An important aspect of quality control is the documentation of the findings, making it possible to check the amount of moisture during the various processes and facilitate the traceability of the product, which is important for the detection of mishaps during the various stages of production.

3.3 Sorting

In order to ensure that the results of sorting are appropriate to client requirements, it is important to provide sorters with precise, unambiguous defi nitions of the defects of the fruit they are to transfer to another category. The following defects can be identifi ed in date fruits:

1. Defects stemming from **microbiological** processes: fermentation (alcoholic) resulting from the activity of yeast; souring resulting from lactobacilli, acetobacteri or aspergilus niger, a fungus which creates a black promycelium which fi lls up the stone cavity. These types of defects cannot be tolerated, such fruit must not reach the customer, nor can it serve as raw material for products. These defects may be due to inappropriate conditions during storage (for example wet fruit without refrigeration) or may arise while the fruit is still in the fi eld.

2. Defects caused by pests, resulting from the activity of insects and various mites. The most common are the remains of various moths, sour bugs and mites. Some of these pests leave signs of nibbling inside the fruit; some spoil the look of the skin. Tolerance for these defects differs according to various standards, going up to 4 %; in all cases there must be no live insects inside the package. Defects caused by birds, mice, bats or other rodents (mainly signs of nibbling on the outside) are often found on fruit grown without being covered by a net or paper, or stored under inappropriate conditions. Such fruit must be removed. These pests may leave remains of feathers, excrement of mice or birds, which stick to the fruit and may cause microbiological contamination.

3. Mechanical defects, as a result of the fruit being crushed while wet after harvesting, or grazed or scraped during the period of growth, leaving scars on the fruit. Sometimes the fruit is so badly soiled by earth and by mud that washing does not clean it.

4. Physiological defects:

* Unpollinated fruit that reaches sorting in an unripe state (its colour depending on the variety);

* Shriveled and dry dates, usually dates which have been detached from the spikelet while still unripe;

* Defects caused by water stress (excess or shortage), which may lead to checking (in Barhee) or blacknose.

Some defects will appear more frequently in certain species. Workers must become familiar with them. This information can be provided by drawings of the defects, and there must be guidance during the sorting and control of its results (Figure 82).

Quality control during sorting

Control and sampling is done by laboratory workers. Control must ensure that the demands of the sorting instructions and defi nitions have been respected. Testing for internal defects is done by cutting the fruit with a knife and checking the internal cavity. Sampling is carried out according to procedures defi ning the frequency of sampling and the size of the sample. The results are written on a specifi c form, and the forms are kept for the follow-up according to the demands of clients.

The clients are the buyers whose quality system demands that the suppliers have authorization, either via an acknowledged certifying body, or according to client specifi cation, which includes documented traceability.

3.4 Grading/Selecting

This is usually done together with sorting, on the same installation, thus avoiding the need to transfer to a different storage (at the intermediate stages) and additional pouring of fruit onto the conveyer belt. Many attempts have been made to make this process more effi cient by automatic grading, but, owing to the complexity of the processes and the diffi culty of imitating human senses, especially that of sight, no solution has yet been found for sorting and grading "without human hands".

The aim of grading is to produce packed fruit which is uniform in size, shape, colour, texture, moisture and skin separation. For each variety the standards are different. Client's requirements can also determine the criteria during grading:

Size sorting can be done in one or two stages.

Stage 1:

- Grade A: Perfect fruit
- Grade B: Fruit with skin separation
- Grade C: Fruit for pitting and for industrial use
- Grade D: Rotten and damaged fruit

Stage 2:

The second stage of sorting is to sort the grade A product to size (jumbo, large and medium). This is particularly important for varieties with large fruit such as Medjool or Amri. For Medjool in Israel, sizes have been defi ned according to the weight of the fruit (moisture content fi xed at 16 % - 19 %):

Jumbo:	more than 23 g;
Large:	18 g to 23 g; and
Medium:	15 - 18 g.

In other countries (for instance USA) other defi nitions of size are used. Varieties with a certain texture can be mechanically sorted for size using a sorting machine on the basis of rollers, the diverging roller sizer. This machine is suitable for sorting species such as Amri, Zahidi, Deglet Nour and Hayany.

A uniform shape, typical for each variety, is required. Abnormal or misshaped fruit is removed. Regarding colour, one variety may have different colours depending on the way it was grown, the time of harvesting and the region. Texture depends mainly on the moisture content, but also on normal ripening which activates enzymes softening the fruit. Moisture must be appropriate to client requirements, to the date of marketing and to the conditions of storage.

Reasons for skin separation, also called puffi ng phenomenon, are still not known. During certain years, especially when it is relatively hot, the rate of fruit puffi ng is higher. Such fruit has not gone bad, but it is unsightly, especially when skin separation is extensive. The fruit lacks uniformity and its appearance is impaired. This phenomenon also differs in extent according to the region where the fruit is grown. It is more serious in varieties such as Medjool, signifi cantly lowering the price for export fruit.

Quality considerations during selection

It is important to make use of the laboratory at this stage; some of the criteria are quantitative and can be assessed objectively (unlike tests by human senses), and the tests are carried out according to defi nite standards, set by the importing countries or the customers.

It is important to document the tests and include the dates when they took place, their results, their Lot number or ID and deviation from the standard, corrective action (if necessary) and the signature of the authorised person. This ensures that the results conform

to the standard required and that any deviations can be treated. The laboratory and the people responsible for quality must have the authority (granted by regulations) to stop the process when its products are inadequate.

3.5 Packing

Fresh dates are perishable and are highly susceptible to losses from damage and deterioration between harvest and the fi nal consumer. Within the range of measures which can be applied to prevent such mechanical and/or biologically induced losses, appropriate packaging plays a vital role in protecting produce from avoidable deterioration.

Packing the fruit in various ways is the last stage of its preparation for the consumer. Therefore, there is no contact with the fruit itself, and we depend on packaging to protect, contain and market the product. Various methods of packing, including the traditional ways, are already described in detail by Dowson (1962). In this section we shall only relate to modern methods used for fruit intended mainly for export. The methods of packing are of two kinds: in bulk and for retail sales.

Bulk Pack

The dates are usually packed in cardboard boxes (sometimes in plastic bags for additional protection and preservation of moisture, before being placed in boxes). The usual weight is 5 kg or 15 lbs. (depending on the country where the fruit was produced or where it is to be marketed). The quality of the fruit may differ according to customer requirements. The fruit is sold on the open market and intended for customers wanting to buy fruit in large quantities. The fruit may be handed over to be repacked in the countries where it is to be marketed and where retail packing will be carried out according to the customer requirements.

The fruit may also be used for products in which dates are the main or secondary component, such as sauces, syrups, spreads and products used in baking.

Retail pack

Retail packing has been greatly developed in recent years, especially since the large networks have increased their share of the food market throughout the world. These packages have to be adapted to consumer demands at all levels, starting with the codes used by a certain network, to repackaging and to the surface on which they are to be placed, ending with the writing on the packages such as the nutritional composition, and the last date for sale or for use.

Retail packages can be divided into two categories:

> a) Packing according to some arrangement, usually 'fi sh bone', the traditional way, which was developed in Marseilles in France and is called 'glove box' or 'boite à gants' in French. There are usually 26 - 30 dates in this box, placed in two layers, separated by cellophane, weighing 220 g - 250 g. A natural or plastic spikelet is placed in the top layer. Most of the dates in such boxes are sold at Christmas time under various names. The variety most commonly used is Deglet Nour, but other varieties can also be found. Packing is done manually and much time is invested in arranging the dates in the boxes. The fruit is usually covered with glucose (natural) to give it a shine appearance.

b) Packing by automatic weighing (without any inner arrangement): Much packing is done in this way, starting with the 'window' type, where a cellophane window showing the fruit is part of the package design, which is usually made of cardboard.

Dates are also packed into tubs made of transparent plastic, showing the fruit as part of the package design. The information for the client is usually on the lid. This type of packing can be of varying sizes, according to the client demands. Bags, usually made of PET polyethylene, are the cheapest and most economical way of packing.

Many attempts are being made to introduce mechanisation and automation in order to save on packing and weighing. In recent years computerised combinatorial scales have been developed, making it possible to pack exact quantities, combined with automatic packing machines for many types of packages.

Quality considerations during packing

Quality control of packed products is the last time the fruit is checked before reaching the customer. Documented checking of the packages entails:

* weight of the package;
* weight of the fruit;
* arrangement of the fruit (in glove boxes);
* uniformity of the fruit;
* damage to the fruit;
* defects; and
* moisture content.

The surrounding area is also checked:

* cleanliness of the conveyer belts;
* calibration of the scales (automatic or manual);
* writing on the packages;
* satisfactory working of the metal detector (installed on every retail packing line);
* repackaging installations and marking; and
* qualifi cation for international standards such as ISO and HACCP (details follow in para. 6.2).

3.6 Shipment

Although modern management takes marketing into consideration at all stages of production, in actual practice the shipment of the fruit takes it away from the region of the supplier and places it at the disposal of the market. All shipments are carried out according to the planning and direction of both the local and the export markets. Ttypes of shipment (relating mainly to export) are:

* overland transport;
* shipment by sea;
* overland and sea shipment combined; and
* shipment by air.

It is advisable to choose the cheapest transport which will bring the fruit to the client with DQ = 0 and at the right time. (DQ = 0: The fruit must not be damaged during shipment. It must be protected physically and kept at the appropriate temperature). **The cheapest alternative** makes it possible to compete against other suppliers and saves on expenses.

The appropriate time for shipment sometimes forces us to use more expensive transport in order to satisfy client requirements. For example, at the beginning of the season, in order to get in before other suppliers, or sensitive fruit such as Barhee when being shipped over great distances.

Overland transport to markets where this is possible. The fruit must be transported in a way that will protect it from the environment and, if necessary, in refrigerated trucks.

Shipment by sea in containers, an effi cient and (relatively) cheap means of transport; the fruit is protected from the environment from the moment it leaves the producer to the moment it reaches the customer's door. The containers are refrigerated (if refrigerated containers are used) by cold air fl owing horizontally over the layers of fruit. This air is distributed uniformly throughout the container.

Overland and sea shipment combined refrigerated trucks go from the supplier to a port where it is loaded to a ship that will transport the product further to its destination. This method is more expensive than shipment in containers (in the

Mediterranean area and in Europe), but it is usually faster.

Shipment by air is the most expensive, but it is sometimes inevitable when the fruit must be supplied at short intervals. Transport to and from the airport must also be taken into account.

Documentation All the shipments must be documented in detail to ensure speedy transfer to the client (especially during export); beside documents for the customs, payment and transport, it is important to add a phytosanitary certifi cate stating that the fruit is healthy. This document is issued in every country by the relevant authorities and certifi es that the fruit is not infected by pests or diseases and is appropriate to the standards of the importing country.

Quality considerations during shipment

Sometimes the fruit is stored for a long time before shipment (up to several months). Owing to marketing conditions and packing possibilities, it is necessary to sample each consignment, in order to make sure that the quality of the fruit has not changed. During loading it is important to ensure that the surfaces or packaging are not damaged. All the labels and markings must be checked according to the requirements of the law and of the customer in the importing country.

Temperature recorder: Since temperature is an important factor in the preservation of the quality of the fruit, especially for fresh dates at Khalal or Rutab stage, a temperature recorder must be placed in the container, the truck or on the surface. This is a small mechanically operated unit. After the details of the shipment have been entered and the unit has been turned on, it records (on a ribbon) the necessary information about temperature during the shipment. The customer will only sign the receipt for the shipment if the temperature corresponds to the demands which were defi ned for the carrier.

4. Harvesting and packaging consideration for some important commercial date varieties

4.1. Barhee

Harvesting

This variety is harvested and consumed at an unripe yellow stage (Khalal). The fruit is locally marketed on branches or exported on branches in cardboard boxes. This way of marketing and consumption requires harvesting of the bunches in a state of Khalal before it turns into Rutab, and without any green fruit. Barhee can be consumed in this state owing to the low amount of tannin, which becomes non-soluble, and as a result the fruit is yellow Khalal with low astringency. It is also important that the fruit be sweet (not bitter) with a brix above 29. The timing of the harvesting of Barhee is very important to ensure that the fruit reaches customers in an unripe state. Whole bunches are harvested at the appropriate stage of ripeness. The harvesting of the bunch is carried out with a secateur or special knife, the heavy bunches (approx. 20 kg) are carefully lowered to the ground and placed on a clean platform or hung on a special hanger (Figure 84) and directly transported to the packinghouse. The harvesting is implemented in 3 to 5 rounds and only bunches in the appropriate state are cut off each time.

Packing

This variety (like Deglet Nour on branches) requires the combining of sorting with packing. The high moisture content of the date fruit at Khalal stage makes it necessary to shorten the time spent in packing and to keep the fruit at the appropriate temperature.

The fruit is packed on branches in cardboard boxes weighing 5 kg (in Jordan, Israel, USA and Saudi Arabia) (Figure 85). Green or ripe dates (Rutab) must be removed from the branches and only smooth, clean, yellow dates are packed. Since the fruit is fresh, the temperature must be lowered immediately after packing. It is also important to keep the fruit aired in order to remove substances, such as achetaldhide ethylene and CO_2.

Characteristics of the fruit

Unripe, yellow, clean, smooth, hard without scratches, the fruit attached to the branches; diameter 26 mm minimum.

Branches at least 10 cm long and at least 5 dates for every 10 cm.
No tolerance of live insects: the fruit is not fumigated.
Tolerance of green fruit: 1 % (of the number of dates).
Tolerance of cured fruit: 1 % (of the number of dates).
Detached fruit in the box: 3 % (of the number of dates).
Storage temperature: 1 °C.
Transport temperature: 1 - 5 °C.

4.2. Deglet Nour

Harvesting

Deglet Nour is marketed and consumed in two main ways, infl uencing considerations at the time of harvesting:

> a) Harvesting the fruit on branches: tens of thousands of tons are harvested in this way in Algeria, Tunisia and Israel, where it is consumed but also exported, mainly to France, Spain and Italy. When marketed in this state, the fruit must be soft and juicy, but with a potential shelf life of several weeks. The bunches are harvested when most of the fruit is in a state of Rutab, before they become Tamar, with a few Khalal. Fruit turning from yellow Khalal to Rutab will ripen between harvesting and consumption, during transport.
>
> The bunches are lowered carefully and placed in containers or on some other device, and transported to the packinghouse. In most cases the bunches are wrapped up in a net to protect them from pests or birds, or in waxed paper or nylon sleeves for protection against rain. It is important not to shake the bunch in order to keep the fruit from falling.
>
> Harvesting is carried out in 3 to 5 rounds and at intervals of 5 to 7 days, until all the bunches have been cut off the palms. Bunches which have a low percentage of fruit but which are suitable for marketing are shaken from the bunch and marketed in a different way.
>
> b) Harvesting loose fruits to be sold unattached: harvesting is done palm by palm and the fruit must be at the Tamar stage. This method is used for all Deglet Nour in the USA and for Deg-let Nour in other countries when it is to be marketed over a period of time. Since this fruit is subjected to hydration treatment, it can remain on the palm until all the fruit is at the same stage of ripeness and dryness. When harvesting is carried out, it is important to protect the fruit from rain, which causes rotting and fermentation, and from various pests.

Treatment of Deglet Nour in the packinghouse

A large part of the Deglet Nour crop grown throughout the world (in Tunisia, Algeria and parts of Israel) is marketed and consumed as Deglet Nour on branches. This product calls for special treatment, different from that described so far. Frequently, and mainly for fear of rain, bunches of Deglet Nour are harvested before they are completely ripe (at the stage of transition from Khalal to Rutab and the beginning of Tamar). Much of the fruit which has not ripened, ripens after it is harvested (fruit which is at the unripe stage, from red to yellow). These bunches are placed in aired containers or hung in large sheds (in Tunisia) and are kept for a certain period. This makes it possible to pack a larger percentage of the fruit.

The fl ow chart presented in Figure 86 describes the stages in the treatment of Deglet Nour for export (North Africa).

Various sorting systems are built in a way that makes it possible to perform several operations along the way and sometimes even to reach the fi nal stage of packing.

Packing Deglet Nour on branches

At first, all the packing for Europe was done in a packinghouse in the region near Marseilles, but in recent years it is carried out in the countries where the dates are grown. A telescopic cardboard box is used (it has a bottom and a lid), and the weight is 5 kg. The packages are decorated with pictures showing bunches of Deglet Nour or date palms.

The fruit is packed from hanging frames in sheds or from containers brought in from the fi eld. The branches suitable for marketing are cut and packed in rows along the length of the cardboard box. The size of the box is usually 50 × 30 cm and it is adapted so it can be stacked on a standard pallet of 120 × 100 cm. Transparent cellophane is placed on top of the fruit and the lid is closed using pressure to avoid reinfestation or moisture loss.

Suitable fruit

The standards for this product were set mainly by the Tunisians and the Algerians and adopted by importers and other suppliers (as in Israel). The fruit must be soft and juicy, preferably of a light colour and with a transparent look. In good Deglet Nour the seed can be seen when the fruit is held against the light. The fruit is attached to the branch and must be clean; the moisture must not rise above 26 %. Each branch is more than 10 cm long and for every 10 cm there are at least 5 dates. There should be no more than 1 % of green fruit and no more than 1 % of unripe fruit (Khalal stage). Unsuitable dry, rotten and unripe fruit is removed from the branches. Live insects are not tolerated; the fruit is fumigated by methyl bromide on entering the packing installation. It must not be covered with dust or sand; it is best cleaned by air pressure. Detached fruit should not amount to more than 3 % in the box. There is no defi nite standard size, but the desirable weight per fruit is more than 8.50 g.

Deglet Nour on branches offers two alternative packages:

> * Bunches: the fruit is packed in long cardboard boxes containing 2 bunches, with a total weight of 10 kg. The quality required is identical to that of fruit packed in 5 kg boxes.
>
> * Bouquets: 3 to 5 branches are packed in a cellophane bag on a little cardboard tray; the branches are tied at their base. This pack weighs 200 to 400 g and packaging is labour intensive. The quality of the fruit is identical to that in the 5 kg boxes.

Quality considerations in packing Deglet Nour

Since the texture of this fruit is unique, the soft and juicy textures are to be taken into account. It is also very important to ensure that there is no sand or dust on the fruit, and that its weight when packed is correct. During packing, storage and shipment conditions must be appropriate because the fruit is sensitive and goes bad quickly (mainly by souring); it is best kept at a temperature of 0 - 4^{o}C. Freezing will cause the fruit to darken.

4.3 Medjool

Harvesting

Most of the Medjool (less than 5,000 tons per year) is produced in the Coachella Valley and Bard in California, and in Israel, and additional small amounts in Mexico and South Africa. When harvesting this variety, clients' wishes (large soft fruit with a moisture content of about 20 to 26 percent) are also taken into account. Medjool is a soft and delicate fruit with a thin skin, requiring careful treatment. Harming the skin may cause sugar crystallisation. In a hot climate (such as at Bard in California and in southern Israel) harvesting begins by picking the dates one by one at the beginning of the ripening process, at the transition stage from Khalal to Rutab. The fruit which has remained on the palm will become too hard to satisfy the needs of customers. In less hot areas, besides the wish for fruit with a soft texture, the need to protect the fruits must also be taken into account. When the drying process is slow, the fruit is sensitive to fermentation bugs - *carpopilus*. The Medjool fruit dries slowly because of the relationship between volume and outside surface.

The harvesting method is planned in such a way as to ensure that the fruit has the appropriate texture when it reaches the market. It must be soft, elastic, so it can be packed and preserved without changing shape. Its moisture should be 20 % to 26 % (when fresh), with Equilibrium Moisture Content (also called Aw-water activity) of not more than 65 %. In this respect, EMC is very important, owing to the relatively high water content. Harvesting will therefore take place while the fruit has a relatively high water content in order to prevent the fruit from losing water and becoming hard in texture.

The demand is for large fruit (over 20 g) where no skin separation or blooming is taking place, with a soft texture, and colour ranging from light to dark brown. by timely and accurate thinning, appropriate irrigation and fertilisation (see Chapters VI, VII and VIII). The colour of the fruit is (probably) due to certain soil and climate related factors, not under the grower's control.

To make harvesting easy to handle, the worker is brought within reach of the bunch on a platform. Each bunch is then shaken gently to remove only ripe fruit i.e. those in the Rutab stage and at the beginning of transition to Tamar. The fruit is placed on shallow trays in a single layer.

Every bunch is harvested according to its state of ripeness, but it is important (especially in a hot climate) to begin when the ripe fruit is still soft; checking the fruit every fi ve to seven days makes it possible to harvest in an optimal condition, and prevents the fruit from being attacked by moths and *nitidulid* beetles. In regions where it is less hot the rounds can be made less frequently, keeping in mind that the fruit must be harvested before it dries. In some areas harvesting can also be carried out by selecting bunches with fruit that have passed from the Khalal to the Rutab stage; in this case some of the fruit will be at the Tamar stage.

The Medjool fruit falls off easily at the Rutab stage and the bunch is therefore wrapped up in a shade net (in Israel) or a cloth bag (in Bard, USA). The cover is open at the bottom and the ripe fruit is picked carefully from underneath through the openings, and placed on trays. This type of harvesting is very labour-intensive and costly; however at present the high price fetched by this fruit justifi es the process.

Field sorting Medjool

In order to preserve the softness of the fruit after harvesting, as described in the previous section, several rules must be respected: the fruit must be soft in texture but with a moisture content that will make it possible to pack and store it for a long time.

In order to preserve the softness of the fruit (together with the other criteria) it is necessary to obey certain rules while the fruit is being treated on site:

* Only fruit which has reached the Rutab stage but not yet the Tamar stage should be harvested.

* Fruit harvested at different levels of moisture content should be separated.

* Each section should be dried uniformly to 20 - 26 % of moisture content or according to EMC to the level of 65 - 70 %. (Figure 87)

* The dried fruit should be kept under conditions which will prevent further water loss (sealing and appropriate temperature).

Drying takes place on trays in one layer; spread out in the sun or on platforms or in drying ovens, depending on the climatic conditions at the time of harvesting and on technological solutions (Figure 88).

4.4. Harvesting other varieties

Beside Barhee, Deglet Nour and Medjool, the other varieties are harvested when all the dates in the bunch or even on the whole palm have less than 20 % water content (of the weight of the fruit). Dates containing more water must be dried (artifi cially or by the sun) to a level of 16 % to 19 %, to make it possible to preserve them without refrigeration. In this state the fruit has its customary appearance (according to each specifi c variety), with its characteristic wrinkles and colour, ranging from dark brown to light yellow.

There are many methods of harvesting, depending on different date growing countries, specifi c regions and local traditions. Some of the fruit is harvested when it is very hard and dr-y - stone dates. These varieties can be harvested at a great height and dropped right down to the ground.

Other varieties require gentler treatment, and the common method used is to cut the fruitstalk and to lower it on a rope with a hook or to use mechanised platforms which take the worker up to the bunch. For these varieties harvesting is also the first stage in the treatment process, so that the fruit reaches consumers in the state required.

5. Other date palm products and by-products

Here we shall only mention products and by-products made from the fruit itself. Other parts of the palm, such as the trunk, the leaves and the male pollen, are also used in various ways, but will not be discussed in this chapter.

The raw material used for the products usually consists of dates of a lower quality, with a low percentage of sugar, but on no account rotten, sour or fermented dates. Good quality dates may also be used when there is a surplus of fruit on the market.

Most of the dates are sold without seeds, 80 % of Deglet Nour are sold in the USA in this way for consumer convenience. The seeds are removed by hand or by machine, the methods range from seed removal while ensuring the dates remain whole and their texture is not harmed, to the complete grinding of the product. When seed removal is done by machine, some seeds may remain, and a warning must be included on the packed product.

Pitted pressed dates: This is a very useful basic product both in producing and in importing countries (European countries, the USA and South Africa). The dates are pitted by hand or by machine, pressed into a mould and vacuum packed. Packing in this way and with the right amount of moisture (less than 20 %) preserves the stability of the product over time without refrigeration. If these rules are not adhered to, the product may be harmed by microbiological processes or through sugar crystallisation. This product is used mainly as a fi lling for cakes and biscuits, especially during the Muslim Feast of Holy Ramadan (Figure 83).

Date paste: In order to preserve the stability of the products over time and prevent their going bad, specifi c rules must be followed during the date paste production stage. Brix must not be less than 65° and the acidity must not rise above pH 4.5. In this case the paste can remain in its natural state (without the need for preservatives). If the above conditions do not exist, the product must be pasteurised or sterilised. These pastes can be used as fi llings for cakes (with the addition of various fl avours, as required). The great advantage of these pastes is that their melting temperature is higher than that used in baking, so that the fi lling does not run out of the cake during baking.

Date syrup (sometimes called dibs or rub): Five production stages are involved: pretreatment, extraction of juice, clarifi cation, concentration and fi ltration. The rules with regard to brix and sourness must be strictly kept. The syrup is used to sweeten various foods.

Date products resulting from intensive processing: Sauces for steak or chutney: The dates serve as a source of sugar and to form the body of the sauce.

Other types of products are extruded date pieces or diced dates. The dates are pressed through holes of 5 - 12 mm; the product is covered with dextrose or oat fl our in order to prevent the little pieces from sticking to each other.

Alcohol: Alcoholic drinks can be produced by the fermentation of the dates.

6. Packinghouse management and quality standards

6.1 Packinghouse management

Modern management focuses on marketing and quality control. The manager is responsible for:

* Contact with marketing and production management according to the requirements of the market;

* The labour force (permanent and temporary), for its training and guidance in fulfi lling the necessary tasks, and for the well-being of the workers;

* The appointment of a team of assistants, and of the managers of the various departments;

* The purchase of raw materials and the administration of the stocks;

* For the whole issue of quality, working for constant improvement (standards, control, follow up);

* Development: long term perspectives of new ways of expanding the plant, its upgrading and the development of new products;

* Storage and shipment on the appropriate scale and according to demand;

* Ensuring funding of ongoing operations and of development, obtaining payments from clients and paying suppliers (especially suppliers of fruit, according to contract type);

* The execution of all safety instructions according to the law, in order to protect the workers;

* Care for the quality of the environment and the investment of the necessary funds (treatment of poisonous gases and of sewage etc.);

* Contact with the relevant Governmental institutions, the Ministry of Agriculture for phyto- sanitary permits and extension services, and other Ministries on the issues of quality and health;

* Ensuring the profi tability of the packinghouse by good management.

6.2 Quality standards

When dates are produced for export, certifi cation has to take place by an internationally recognized certifying body. Most importantly, it needs to be recognised by the buyer.

Quality standards for dates have been set by different bodies. Earlier in this chapter the Codex Alimentarius was mentioned. The Codex Alimentarius sets permitted levels of residues of pesticides (MRL = minimum residue limit) according to types of material and species of fruits, vegetables and other foodstuffs. The Codex Alimentarius is published by FAO and WHO and has been ratifi ed by most of the 146 member countries.

Furthermore, UN/ECE norms have been set for whole dates. Sorting criteria as well as criteria concerning moisture content are set in these norms, which are accepted in most EC countries, although the exact levels might differ per country.

Quality standards are set per country and per variety. Individual countries set their own standards with regard to quality. This can be seen as an agreement between the buyer and the producer with regard to what the product should look like.

Health regulations are designed to ensure that the produce is safe for human consumption.

Quality systems are complementary to the above technical requirements and those of the customer. They do not replace them.Two quality systems are ISO 9000 and HACCP- Hazardous Analytical Critical Control Point.

"ISO 9000". This is a quality system, a model for quality, assurance in design, development, production, installation and servicing, designed by the International Institute for Standardization (ISO). The ISO 9000 international standards were accepted as European standards in December 1987. On the one hand, these norms refl ect worldwide agreement in the fi eld of quality assurance, and on the other hand, they are binding for the European Union and the countries of European Free Trade Association.

Key concepts in the framework of the ISO 9000-9004 norms are: Quality management, Quality care, Quality system, Quality control, and Quality assurance.

Certification mostly takes place by checking and supervision, carried out by an independent, impartial and expert certification institution. In most countries, it is possible to obtain detailed information about ISO 9000 and certifying bodies fromN ational Standardization Institutes. Information can also be obtained from ISO, P.O. Box 56, CH-1211 Geneva, Switzerland. (CBI, 1997/2: European regulations manual).

In the usual type of production plants such as packinghouses for dates, the relevant standard is 9002. The standard defi nes the requirements of **the quality system.** They are mainly intended to prevent lack of coordination at all stages of quality control, from the reception of the fruit from the field (in some cases even before) until it reaches the client and consumer (and deals with complaints, if necessary). Keeping to this standard assures the customer that the quality system of the supplier ensures that the product fulfi lls the stated quality requirements (as defi ned by the client or by the standard).

ISO 9002: 1987 Quality system requirements

1. Management responsibility
2. Quality system
3. Contract review
4. Document control
5. Purchasing
6. Purchaser supplied product
7. Product identification and traceability
8. Process control
9. Inspection and testing
10. Inspection, measuring and test equipment
11. Inspection and test status
12. Control of non-conforming product
13. Corrective action
14. Handling, storage, packaging and delivery
15. Quality records
16. Internal quality audits
17. Training
18. Statistical techniques

Qualifying for "ISO 9000" has the advantage of providing a common language between supplier and client in matters of quality, ensuring that the product has been officially recognised as such.

Issues of quality will always be the responsibility of top management and will be passed down the hierarchy.

HACCP- Hazard Analysis Critical Control Point

The Hazard Analysis Critical Control Point (HACCP) is a European standard for the food industry. The EU Directive on Hygiene of Foodstuffs (93/43/EC) stipulates that "foodstuff companies shall identify each aspect of their activities which has a bearing on the safety of foodstuffs and ensure that suitable safety procedures are established, applied, maintained and revised on the basis of an HACCP system" (CBI, 1996). It is a method of analyzing risk factors related to food, the risks for the consumer using the fruit. The food is analyzed linearly throughout the process, and broadly for chemical, physical and microbiological risks. The method makes it possible to detect critical points of risk and fi nd ways of preventing it. The critical points in date processing are:

Chemical risk - in dates the source of risk is from the residue of substances used in pest control in the fi eld. This is a critical point when receiving the fruit at the plant. The solution lies in guidance and supervision in the fi eld, in the use of permitted substances only and in their correct concentration, and by sampling the fruit for testing for such residue.

Another, less signifi cant, chemical risk in the packinghouse is the use of detergents. This risk is prevented by the use of cleaning materials permitted in the food industry and separate locked storage.

Physical risk - various foreign bodies:

metals: the critical point is after final packing; using a metal detector; calibration and ongoing testing must be a regular procedure.

Glass: the following code must be followed:

a) no glass may enter the plant (no glasses, jars etc.)
b) light bulbs must be protected
c) the windows must be made of unbreakable material
d) specifi c procedures in case of broken glass

Microbiological risk - mainly infection, for example, by coliforms and salmonela. Prevention techniques are however available and can be summarised as follow:

1. Rules regarding personal hygiene; workers wash their hands with soap on entering the plant and on leaving the toilet.

2. Washing the fruit with water qualifying as drinking water.

3. Preventing fl ies, mice and birds from entering the area of the plant.

4. The sorting system must be cleaned according to regulations.

5. Ongoing checks of various parts of the plant in order to detect possible pollutants, ensuring that the fruit is clean.

6.3 Packinghouse requirements

In order to enter the supermarket level in Europe, it is necessary to maintain a minimum standard regarding cultural techniques, harvesting, post-harvest handling, packing, health and hygiene, and quality control systems.

Packinghouse

* Must be a separate, defined area which is used only for packing. Storage of cartons must not be carried out in the packinghouse.

* The fabric of the building must be in good condition. Windows when open, must be screened to prevent insect ingress.

* Light level must be adequate for selection and grading.

* There should be adequate facilities for the collection and disposal of waste material at frequent intervals to discourage fl y infestation and the development of latent fungal infection.

* Risk of contamination from local industries should be minimised.

* The packinghouse layout should be designed in such a way as to keep the raw material and the fi nished product separate, and to encourage the smooth fl ow of the product through the selection and packing system.

Packinghouse hygiene

* The packinghouse and equipment should be cleaned during the day on a "clean as you go" basis.

* Work surfaces should be non-porous and easy to clean. Materials such as stainless steel and formica are ideal.

* Containers used during production such as harvesting crates should be easy to clean polythene or other durable plastic. They should be cleaned regularly and stored in areas free from risk of contamination.

* Packing material must be stored in a clean dry area free from risk of contamination.

* All equipment used for quality control such as scales, temperature probes, refractometers, etc. must be regularly checked for accuracy.

The storage of packing material is very important and care should be taken that no insects can enter the material and be exported. Fly/insect catchers should be installed in the packinghouse and a no smoking policy should be implemented in the area where dates are packed.

Personal hygiene

* It is important that all staff are aware of their responsibilities for the health and

* Staff suffering from gastric disorders causing sickness must not be allowed to work until completely recovered and cleared of the disorder.

* All cuts, sores and other skin problems must be covered by a blue industrial dressing.

* Hand washing and toilet facilities should be adequate to meet staff requirements. Toilets must be maintained in a clean hygienic condition.

* Wearing of cosmetic jewellery should be discouraged and should be kept to an absolute minimum at all times.

Packhouse discipline

* Protective clothing that adequately covers day-to-day clothes must be worn in the packinghouse at all times.

* Smoking, chewing tobacco and spitting is strictly forbidden in the packinghouse.

* Rest areas, away from production should be provided for food and drink consumption.

* The storage of chemicals, fuel and oil should be in a secure area away from the packinghouse.

Packaging material

The following information should be printed on all packaging material for exports:

* net weight;
* country of origin;
* grown and packed by (address);
* product and variety; and
* category (class 1 or grade 1).

The aim of setting these packinghouse requirements is to maintain uniformity in products, quality, production standards and liabilities of all packing stations supplying to an umbrella marketing organisation.

The conditions and requirements actually implemented in Israel are:

1. Certification - approved by the authorities as a food packer, e.g. Ministry of Health, FDA or equivalent body.

2. Knowledge of the sorting, selection, grading and packing of dates.

3. Approved fumigation facilities for use of methyl bromide.

4. Approved and licensed operator of methyl bromide fumigation facilities.

5. On site quality control and data recording throughout the whole process.

6. Weighing and measuring standards and set-up of equipment maintained.

7. Long term cold storage rooms to accommodate a range of varieties before and after selection and packaging.

8. Administration and office facilities to meet internal and marketing organisation needs.

9. Equipment and ramp to load sea containers/trucks.

10. Documentation of produce in/out that meets marketing organisation needs.

11. Packing station product quality guarantee to the consumer.

Figure 80. Date harvesting by mechanical ladder (Israel)

Figure 81. Washing of dates

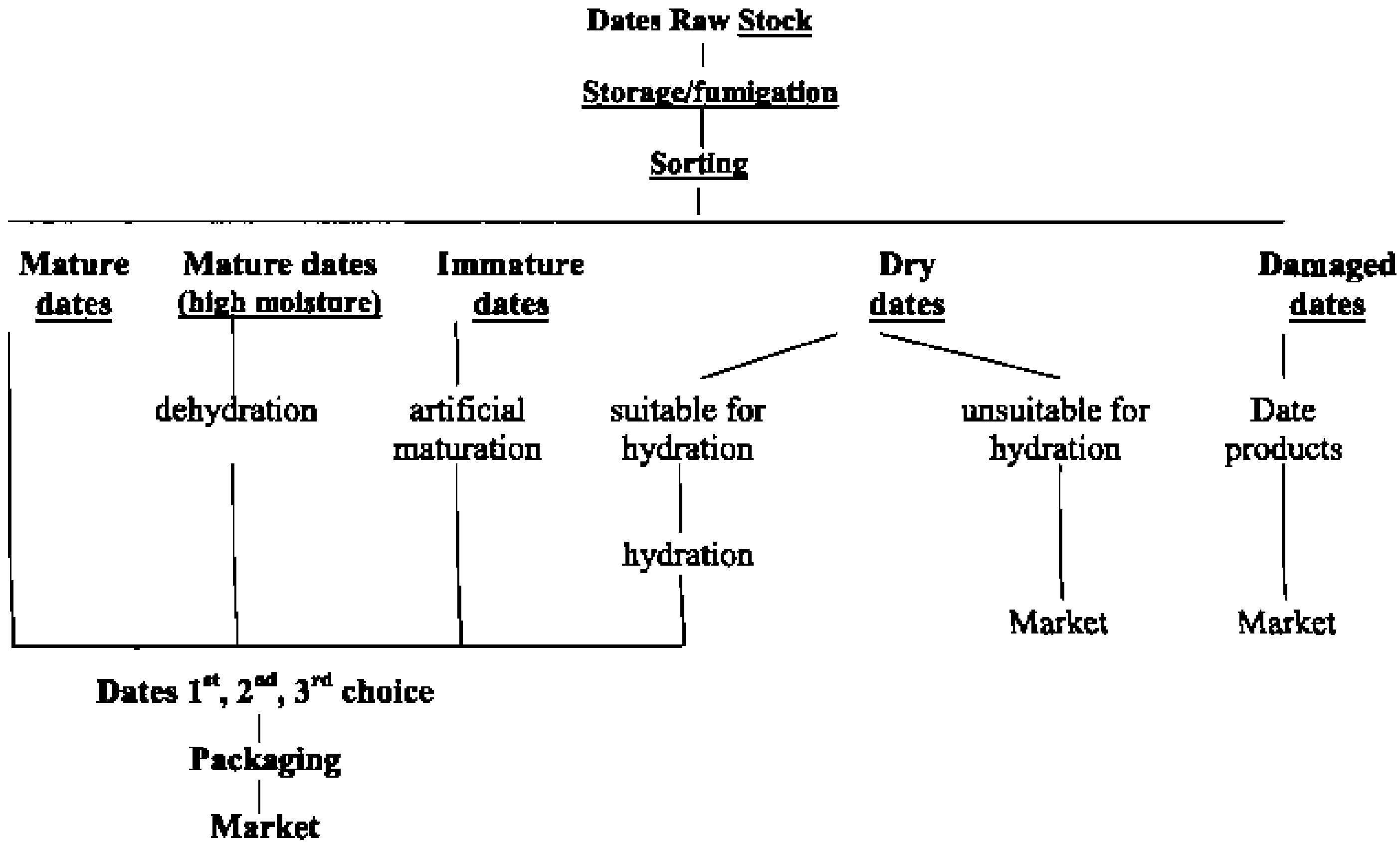
Figure 82. Sorting of Medjool

Figure 83. Pitted pressed dates

Figure 84. Transport of Barhee bunches from the fi eld to the packinghouse

Figure 85. Packing of Barhee bunches in the 5 kg boxes

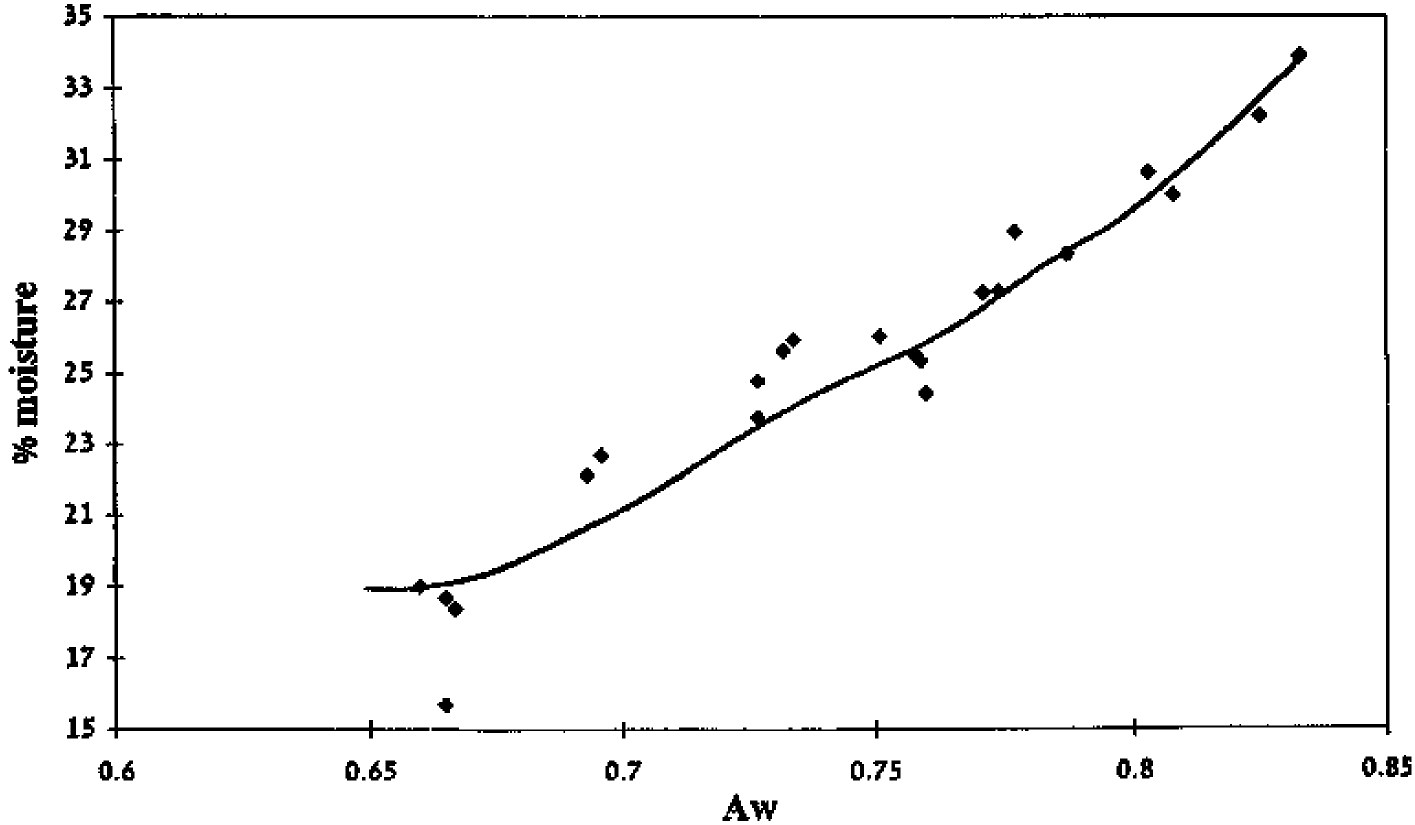
Figure 86. Classifi cation and treatment of Deglet Nour for export (North Africa).



(Source: Barreveld, 1993)

Figure 88. Sun drying of too soft Medjool fruits

Figure 87. The relationship between moisture % and water activity



% moisture
35
33
31
29
27
25
23
21
19
17
15
0.6
0.65
0.7
0.75
0.8
0.85
Aw

CHAPTER X: ESTABLISHMENT OF A MODERN DATE PLANTATION

by A. Zaid and A. Botes
Date Production Support Programme

1. Introduction

During the last ten years, reports have indicated the potential and viability for a date production industry. Most of these reports focused on economics and marketing of the date palm at national or regional level. This chapter will concentrate on useful information in both technical and fi nancial aspects for individual farmers. Technical establishment of a date plantation will cover the following components: f easibility study, suitability of the site, selection of varieties to be planted, site preparation, irrigation system and technical practices, while fi nancial establishment will highlight the establishment and operational costs and the cash fl ow statement.

2. Technical establishment of a date plantation

2.1 Feasibility study

After being convinced about the marketing potential of dates, and before purchasing land or developing his/her own farm, a potential date grower must seriously look at several factors and consequently conduct a feasibility study before any physical date establishment. The feasibility study should focus on the following:

- Survey of the area: with maximum information on its location (latitude, longitude and altitude), vegetation, communications and infrastructure;

- Meteorological data: The date grower must contact the nearest weather station to his plantation (within a circle of 30 to 50 km if possible) and request the following data for at least 10 - 15 years:

* Daily values of maximum temperatures (°C);
* Daily values of average temperature (°C);
* Daily values of minimum temperatures (°C);
* Daily values of rain (mm);
* Daily values of evapotranspiration (mm);
* Daily values of sunshine (Hr.);
* Daily values of wind (km);
* Daily values of maximum humidity (%); and
* Daily values of minimum humidity (%).

- Soil analysis: This is a primary factor since it will indicate the success potential of the culture, and will also be used as a guideline for future fertilisation programmes, and irrigation requirements.

- Water analysis: The most important factor to look at is the salinity level along with the depth of the underground water table, if any.

- Mode of irrigation: Depending on water availability, its quality and also taking into consideration all the above factors, a mode of irrigation system will be selected. Flood irrigation is discouraged for a commercial plantation. In order to ensure high water use-effi ciency the date grower should select either drip or microsprayer systems.

- Economical analysis: A local and national market survey is to be implemented to see how promising the market is.

- Climatic requirements: The two main climatic requirements for successful cultivation of dates is a long, hot growing season and an absence of heavy rain or high humidity during the ripening period. Frost incidence, is another environmental factor to take into consideration. Details on climatic requirements can be found in Chapter IV.

- Water availability: To maximise the probability of a successful date plantation, long term water availability must be ensured. Salinity level must not be too high (5 - 6 % at most) even though adult date palms can survive higher levels (9 - 10 %).

- Soil type: Date palms are grown in a wide variety of soils. The optimum soil should have a maximum water-holding capacity and good drainage. Sandy soils require excessive fertilisation and irrigation and permit rapid leaching of mineral nutrients. However, sandy soil that is underlined by more retentive soil of fi ner texture in the first two metres is appreciated. Growth development and fruit quality of dates are reduced under very saline soil conditions.

- Labour requirements: Date palm culture is labour intensive during pollination and harvesting/packing periods. Labour requirements for other operations during the year (bunch thinning, pulling down and tying, covering bunches, irrigation, pruning, fertilisa-tion, etc.) are lower.

2.2 Selection of varieties to plant

Local clones, which are exclusively of seed-origin, must be assessed for their suitability for commercial production. Even though some of these seedlings show signs of measuring up to the best internationally renown varieties, such as Medjool, Bou Fegouss, Barhee, etc, these seedlings must be thoroughly evaluated before large scale multiplication and planting can be initiated. The large scale multiplication and plantation of international renown varieties is essential for reaching the international market and getting high value from the plantation.

2.3 Site preparation

Once all the above factors and conditions have been assembled, the date grower must concentrate on the preparation of his/her site for the initiation and establishment of the date plantation. To avoid repetition, the reader is invited to refer to Chapter VI.

3. Financial establishment of a date palm plantation

3.1 Establishment cost

The introduction of a new enterprise to the farm business can be expensive. However, diversifi cation into date production is seen as part of the bigger existing farming business which will make use of existing infrastructure and mechanisation. Careful planning is thus needed to allocate scarce resources amongst the different farming activities, in a way that the best alternative satisfi es the respective requirements. Detailed calculations are necessary for the farmer to determine the capital needed to implement his/her plan and to forecast its fi nancial result.

It should be kept in mind that costs will vary from one farm to another, depending on the current setup in terms of existing infrastructure and machinery, source of water supply, irrigation system to be used, etc. Costs given are based on a Namibian Date Palm Project (80 ha at Naute/Keetmanshoop), quotations and some estimates of the authors.

In light of possible existing scenarios, the following costs are not included: acquisition of land; source of water supply; mechanisation; and marketing cost. Additional costs needed for date production will be highlighted.

The breakdown of cost items in this paper should be used as a guideline and need to be adapted for each specifi c situation. Table 61 gives an outline of the establishment costs involved per hectare, for a modern plantation of at least 20 ha. The spacing is 10 × 8 m and 125 palms are planted per hectare, of which 5 are males.

TABLE 61
Establishment costs per ha for a modern date plantation (US$)

COST ITEM		COST IN US$
Land Preparation:		
1. cleaning and levelling		20
2. ripping		60
Water Supply Line		1,600
On-land Irrigation System		1,200
Establishment of Plantation:		
3. plant material	(US$ 22 × 120)	2,640
4. fertilisers		24
5. labour	(4 × US$ 2 × 5 days)	40
6. hardening of plants		16
TOTAL COST		**5,600**

The irrigation system to be installed in a modern plantation should be such that effi ciency is at maximum (at least 85 %) and that volume of water per palm can be controlled. A well planned and effective irrigation system, based on the use of microsprayers or drippers, together with proper management and production practises will result in optimum yields.

The smaller producer establishing only 1 to 5 ha will not install such an expensive irrigation system and it is estimated that the establishment cost might be in the order of US$ 3,200 per ha. This amount includes US$ 2,640 for plant material, US$ 80 for labour, fertiliser and pesticides, and US$ 520 for water supply.

Table 62 gives an outline of additional capital expenses needed to build and equip a modern packing house, for a larger commercial plantation of at least 40 ha. The international food market is very competitive and quality control and hygiene criteria are strict. Thus, to enter the export market successfully and to sustain the supply of quality fruit, the facilities mentioned are essential.

Realising the magnitude of the total costs involved, the immediate question is whether the project will survive. This question will be answered in the sections to follow. It should be kept in mind that date production is a long term project and generates only income from year four or fi ve from establishment. Measures should thus be taken to maintain a cashfl ow during that period.

Various options exist, and the farmer, as a manager, should decide what option best fi ts his skills and business. The following can be successfully implemented as an intercrop: vegetable production; lucerne and citrus. An intercrop will however increase capital investment.

TABLE 62
Additional capital expenses (US$): buildings and equipment of a packing house

COST ITEM	COST IN US$
INFRASTRUCTURE	
Packing House/Shed structure	300,000
(office, ablution, packing room, cold rooms, etc.)	
Labour Houses	140,000
IMPLEMENTS	
Tractor and trailer	24,000
Pick-up	16,000
Equipment	

tools	200
plastic crates for harvesting	3,400
grading/sorting line/Table	3,000
washing Table	1,000
packing line/Table	2,000
electronic scale	1,000
press for pitted dates	1,000
vacuum packer	5,000
TOTAL	**496,200**

One of the advantages of a date plantation is that it creates a special micro climate favourable for other crops. Some plantations in the northern hemisphere, for instance, successfully produce citrus as an intercrop. Because of the high costs of needed facilities, i.e. packing house, cold rooms, labour houses, etc., it seems almost essential to have other crops also utilising these facilities. Other crops sharing these capital expenses have not been considered in the sections to follow.

3.2 Operational cost

Operational expenses represent those expenditures that occur only if production is undertaken. Capitalisation of the investment cost is dependent upon the production process. Each activity to improve yield and quality costs money and the manager should decide how much, of which activity and at what cost to apply.

A carefully worked out balance of inputs in relation to outputs is needed since maximum production does not necessarily result in maximum profi t.

Tables 63 and 64 represent the activities involved in date production, packaging and marketing with their respective costs over a 10- year period, for large and small commercial date plantations, respectively. Cost indications in Table 63 is per hectare and refl ects the Naute Date project (Namibia), while Table 64 represents activities and respective cost estimates to be encountered by the small date producer (5 ha plantation).

Analysing Table 63, it is clear that the expensive activities are packaging and export marketing. In year 10, full production, pre-harvest costs are about 6 cent (US) per kg and harvest costs are US$ 0.524 of which packaging material is US$ 0.496. At this point of the production cycle, one should decide whether to export in bulk, thus achieving lower prices, or whether to target the retail stores and pre-pack the date fruit in attractive "glove boxes", achieving higher prices.

TABLE 63
Operational cost per ha for a large commercial date plantation (US$)

		YEAR									
ACTIVITY		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Pre-harvest Cost:											
· water		28	28	28	28	28	28	28	28	28	28
· fertilisers		24	24	24	24	24	24	24	24	24	24
· labour (*)		6	12	12	12	14	17	20	24	29	32
· mechanisation		10	10	10	10	10	10	10	10	10	10
· protection:											
bags:	plastic					100		100		100	
	shade net					400	400	400	400	400	400
	pesticides	10	10	15	15	20	20	20	30	30	30
SUB-TOTAL (1)		*78*	*84*	*89*	*89*	*596*	*499*	*602*	*516*	*621*	*524*

Harvest Costs:										
· labour				5	10	30	60	80	100	120
· mechanisation				5	10	20	30	40	40	40
Packing Costs										
· packaging material:										
packages				480	960	960	2,400	2,400	2,40	3,36
cartons				62	124	217	310	310	0	0
labour (**)				4	5	20	40	55	310	800
									70	80
SUB-TOTAL (2)				*556*	*1,109*	*7,967*	*2,840*	*2,885*	*2,920*	*4,400*
Marketing Costs:										
· cold Storage/electricity				1,000	1,000	1,400	1,400	1,600	1,600	2,000
Local marketing:										
· transport				36	72	126	180	180	180	252
· agency fees				97.2	194.4	340.2	486	486	486	486
Export marketing:										
· transport:										
road				84	168	294	420	420	420	588
air/sea				840	1680	882	1,260	1,260	1,26	1,76
· agency fees				277.2	554.4	970.2	1,386	1,386	0	4
									1,386	1940.4
SUB-TOTAL (3)				*2,334.4*	*3,708.8*	*4,012.4*	*5,132*	*5,332*	*5,332*	*7,224.8*
TOTAL*(1 + 2 + 3)*	**78**	**84**	**89**	**2,979.4**	**5,373.8**	**6,478.4**	**8,574**	**8,733**	**8,873**	**12,148.8**

(*) Labour includes weeding, pruning, pollination, thinning and orchard maintenance.
(**) Labour includes sorting, cleaning, de-stoning, packing and packing house maintenance.

The calculations in Table 63 for marketing costs are based on the assumption that 30 % of the harvest will be marketed locally and 70 % will be for the export market. Estimated marketing costs are in the order of US$ 0.86 per kg. In the calculations for transport to Europe, air transport is used only during the first two years of production. Air transport is quite expensive, but since volumes to be exported are low in the initial stages of production, sea transport cannot be considered. Total operational cost as outlined in Table 63 amounts to US$ 1.446 per kg (Naute Project during 1997).

TABLE 64
Operational cost for a small date plantation (1 ha); (US$)

	YEAR									
ACTIVITY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Pre-harvest Cost:										
· water (***)	120	120	120	120	140	140	160	160	160	200
· fertilisers	24	24	24	24	24	24	24	24	24	24
· labour (*)	6	12	12	12	14	17	20	24	29	32
· mechanisation	10	10	10	10	10	10	10	10	10	10
· protection:										
bags: plastic					100		100		100	

shade net					400	400	400	400	400	400
pesticides	10	10	15	15	20	20	20	30	30	30
SUB-TOTAL (1)	*170*	*176*	*181*	*181*	*708*	*611*	*734*	*648*	*753*	*696*
Harvest Cost:										
· labour				*5*	10	30	60	80	100	120
· mechanisation				*5*	10	20	30	40	40	40
Packing Costs										
· packaging material:				35	70	130	180	180	180	250
· labour (**)				4	5	20	40	55	70	80
SUB-TOTAL (2)				*49*	*95*	*200*	*310*	355	*390*	*490*
Marketing Cost:										
· cold storage				40	40	60	60	80	80	100
· transport				120	240	420	420	420	420	840
SUB-TOTAL (3)				*160*	*280*	*480*	*480*	*500*	*500*	*940*
TOTAL *(1+2+3)*	**170**	**176**	**181**	**390**	**1,083**	**1,291**	**1,524**	**1,503**	**1,643**	**2,126**

(*) Labour includes weeding, pruning, pollination, thinning and orchard maintenance.

(**) Labour includes sorting, cleaning, de-stoning, packing and packing house maintenance.

(***) Higher water cost for small date plantation due to the fact that water is usually supplied from a borehole and pumped with a diesel engine at high cost.

In this scenario the small scale producer will sort and grade the fruit, but sell in bulk to a packing house. As a result, the expensive activities, i.e. pre-packing and export, are covered by someone else. This strategy will reduce production cost from US$ 1.446 per kg to US$ 0.236 per kg. Obviously the price to be received will also be much lower, as will be the risks involved in exporting.

3.3 Cash flow statement

The function of cash fl ow is to provide information on the timing and magnitude of cash (infl ows and outfl ows). Both cash fl ow statements here below summarise the cash fl ows for large (40 ha) and small scale (5 ha) date plantations, over a period of 10 years. For the calculations in Tables 65 and 66, the following average production potential per palm in kg is considered.

YEAR	LARGE SCALE	YEAR	SMALL SCALE
1 - 3		1 - 4	
4	10*	5	15
5	20	6	30
6	35	7 - 8	35
7 - 9	50	9	40
10	70	10	50

* For a well maintained large scale modern date plantation, production could start one year earlier than the small scale one and be over 100 kg/palm/year.

An estimated cashfl ow statement for the large scale modern date plantation is given in Table 65. The costs indicated are calculated as follows:

* gross income: - 30 % of production at US$ 2.4/kg

- 70 % of production at US$ 3/kg

* development cost: - plantation: 20 % own capital and rest as loan over 10 years at 18 %.

- infrastructure: established only in year 4 with 20 % as own capital and rest as loan over 10 years at 18 %.

TABLE 65
Cash flow statement for 40 ha date plantation (US$)

Year	Prod.	Gross Income	Development Cost		Operational	Management	Net	Balance
	kg	US$	Plantation	Infrastructure	Cost	& Overheads	Income	
1			44,000		3,120	40,000	-87,120	-87,120
2			40,000		3,360	40,000	-83,360	-170,480
3			40,000		3,560	40,000	-83,560	-254,040
4	48,000	135,360	40,000	96,600	119,176	40,000	-160,416	-414,456
5	96,000	270,720	40,000	89,000	214,952	40,000	-113,232	-527,688
6	168,000	473,760	40,000	89,000	259,136	40,000	45,624	-482,064
7	240,000	676,800	40,000	89,000	342,960	40,000	164,840	-317,224
8	240,000	676,800	40,000	89,000	349,320	40,000	158,480	-158,744
9	240,000	676,800	40,000	89,000	354,920	40,000	152,880	-5,864
10	336,000	947,520	40,000	89,000	485,952	40,000	292,568	286,704
11	336,000	947,520	40,000	89,000	485,952	40,000	292,568	579,272
12	336,000	947,520		89,000	485,952	40,000	332,568	911,840
13	336,000	947,520		89,000	485,952	40,000	332,568	1,244,408
14	336,000	947,520		89,000	485,952	40,000	332,568	1,576,976
15	336,000	947,520			485,952	40,000	421,568	1,998,544

The Table 65 cash fl ow statement suggests that net income is positive only as of year six, while the accumulating balance is negative up to year nine. Total costs in year 10 totals to US$ 1.95 per kg. Although costs can be recovered over the 15- year period with proper production techniques, planning and management, attention should be focused to improve the cashfl ow situation in years 1 to 5.

TABLE 66
Cash fl ow statement for 5 ha date plantation (US$)

Year	Prod. Kg	Gross Income US$	Development Cost	Operational Cost	Net Income	Balance
1			16,000	850	-16,850	-16,850
2				880	-880	-17,730
3				905	-905	-18,635
4				905	-905	-19,540
5	9,000	9,000		3,540	5,460	-14,000
6	18,000	18,000		3,055	14,945	945
7	21,000	21,000		3,677	17,323	18,268
8	21,000	21,000		3,240	17,760	36,028
9	24,000	24,000		3,765	20,235	56,263
10	30,000	30,000		3,480	26,520	82,783

Analysing costs at a smaller scale (Table 66), it can be seen that operational costs can already be covered in the first year of production (year 5 after establishment). The accumulated balance, however, is only positive in year 6. In calculating the cashflow, an income of US$ 1 per kg is assumed, considering that financing management and administration costs are taken into account. Investment in a 5 ha date plantation might thus result in a net income of US$ 26,520 in year 10 with a yield of 50 kg per palm at US$ 1 per kg.

When comparing the cost of production of 1 kg of dates for a large scale modern plantation and that for a small producer, one would like to suggest that a nucleus-regional packing

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CHAPTER XI: DATE PALM TECHNICAL CALENDAR

by A. Zaid and P. Klein
Date Production Support Programme

1. Introduction

This chapter highlights, in detail, the various technical steps needed to ensure the proper establishment of a date palm plantation and its management.

It is worth mentioning that since accurate information was available to the authors from their own experience in Namibia (Southern Hemisphere), it seemed appropriate to base the technical calendar on this region (Figure 89). Nnorthern Hemisphere readers could keep the difference in seasonal times in mind (i.e. fl owering is during July/August in the Southern Hemisphere and February/March in the northern hemisphere; fruit maturation and harvesting are during September/October in the Nnorthern Hemisphere and during February/March in the southern hemisphere).

2. Technical calendar for planting tissue culture plants - follow up during the first year

November

- Acquire the required amount of microsprayer supports (at a rate of 3 per plant);

- Prepare the required amount of protection units made of wire mesh and a shade net (1 per plant). No plant should be planted if no protection unit is available;

- Plant wind breaks (at least one year in advance); use Beef wood (*Casaurina cunninghummiana* or *Casuarina glauca*) which is characterised by rapid growth, high level of drought, and salt tolerance.

December

- Debusing and levelling;

- Layout of lines and rows;

- Ripping (± 1.2 m) in both directions on the rows;

- Install the irrigation system (secondary and tertiary pipelines only);

- Mark the exact position of plants;

- Dig holes (0.6 m^3), if soil has been cross ripped or 1 m^3 if soil was not ripped, and leave open till end of December;

- Try to localise old, well matured manure or any other organic material (i.e. maize hay, wheat straw, etc.) that will be used the next month.

January

- Place the irrigation supports (3 per plant) and connect the micro-jets (or drippers). The irrigation schedule is presented in chapter VII;

- Mix the well matured manure (3 kg per plant), gypsum (if needed) and NPK fertilisers with the soil removed from the hole;

- Put the mixed soil back in the hole;

- Start the irrigation cycle 2 to 3 times to allow soil to settle. The decomposition of manure will be initiated. When gypsum is applied, a short term leaching programme should be followed before planting;

- Enough time (4 to 6 weeks) should be allowed before planting to avoid the nitrogen negative effect period.

Fertilisation at planting:

The following amounts are to be used per planting hole:

- 3 kg of old kraal manure (± 3 spades full);
- 2 kg of gypsum (if necessary);
- 700 g double superphosphate;
- 500 g potassium chloride (or 625 g potassium sulphate); and
- 0.25 kg ammonium sulphate (and another 0.25 kg six weeks later).

February

- Tissue culture plants have been in the nursery for the past 8 to 12 months (depending on variety, their original size at reception from the laboratory, and on the care provided by the farmer). The plants should have been well irrigated (twice per week during winter and 3 times per week during summer; a close monitoring is to be ensured in case the substrate is made of bark), and fertilised according to the following programme: Mix 5 litre of SeaGro (5.5 %, 0.75 %, and 1.6 % of N,P,K,respectively) with 1,000 litres of water and apply at 140 ml per plant. Repeat once every two weeks until transplanting into the fi eld. For practical purposes, the plants could be irrigated with the solution by replacing a normal irrigation schedule;

- Select your planting material at the nursery; only plants with at least 4 pinnae leaves are to be transplanted in the fi eld;

- Inspect your plants and make sure they are free of diseases and pests. In the future plantation, use the Integrated Pest Management Approach (manual or mechanical weeding, light traps, etc.);

- Review and ensure the identifi cation of each plant; where different varieties are being planted, use different colour labelling for each variety;

- Each block, row and line is to be labelled. A map of the plantation (variety composition) is to be kept in the offi ce (and/or at home).

March

February and March are the best months for planting (no wind, no extreme temperatures and the average humidity is about 40 %). Let us suppose that our planting date is March15:

- Another irrigation before planting is advised. Irrigate to fi eld water capacity;

- Recommended spacing is 10 × 8 (10 m between rows and 8 between palms in a row); 125 palms per one hectare will be the planting density;

- Planting should be done early in the morning to avoid transplanting stress, and irrigation should be done immediately after transplanting;

- Bags should be cut from the bottom and progressively removed upwards, while the soil is put around the palm's substrate (to avoid roots damage); all distorted or damaged roots are to be pruned;

- The leaf base of the palm should be clearly out of the surface of the soil; planting must be to the depth of the plant's greatest diameter;

- A basin of 1.5 to 1.8 m in diameter and 20 to 30 cm deep is to be built for each palm. Hay or wheat straw is to be used for mulching;

- Irrigation cycle depends on the location. However, we recommend (from planting till end of August) 2 hours per cycle and twice a week. From September till March the next year it should be increased to 3 cycles per week and 2 hours each cycle. This irrigation calendar supposes the use of three drippers or microjets per palm at a rate of 32 litre/hour each. The palm will hence receive 96 litres per hour.

- At all times, the soil near the newly planted palm should be kept moist through light and frequent irrigation;

- The irrigation cycle is to be monitored (use tensiometers if possible), and frequent check-ups are essential to ensure the proper functioning of microjets or drippers;

- No leaf pruning is to be practised during the first two years (only leaves that touch the ground could be removed);

- The required number of male palms (5 for each ha) are to be planted separately in one block, preferably not in a windy spot and close to the pollen workshop;

- Weeding is to be properly implemented;

- Next year March: if needed apply 5 kg of gypsum per palm.

April

- April 15 (4 weeks after the planting date): apply 250 g potassium chloride per palm;
- April 25: apply if needed 2 kg of gypsum per palm;
- Apri 30 (six weeks after the planting date): apply 250 g ammonium sulphate per palm.

May

- May 15: apply the second 250 g potassium chloride per palm;
- End of May: assess your survival rate (should be at least 95%).

June

- June 15 (six weeks interval): apply the second 250 g ammonium sulphate per palm;

- Once the first year after planting is over, a fertilisation programme is to be applied till the first fl owering year (year 4 or 5 depending on variety, location and provided care). Full detail about the fertilisation programme can be found in Chapter VI.

July

- No offshoots should be left on a palm; they must be removed at an early stage to ensure vigorous growth and early fruit production. Removal of offshoots should be done twice per year (July and December). Make sure that the attachment point between the offshoot and the plant mother is treated with copper oxychlorid (use DEMIL DEX at 500 g in 25 *l* of PVA paint).

- After 4 years, the farmer must implement the following technical calendar.

3. Technical calendar for a date palm plantation older than 4/5 years

April/May

- Immediately after harvest, but no later than early May, the cleaning of the palms must be initiated. Old fruitstalks, leaves touching the ground and young offshoots are to be removed since they stress the mother palm, cause its decline and decrease fruit yield. No direct planting of these offshoots should be practised; they must be rooted in the nursery for at least one year;

- Removal of spines from about 20 to 25 outside leaves and cleaning of the palms to prepare for pollination;

- Leaves with symptoms of diseases need to be removed and burned;

- Apply fertilisation on the 1st of April;

- Apply potassium chloride fertilisation on the 15th of April;

- Apply the ammonium sulphate fertilisation (in April and in May);

- If leaching is required, it must be practised before the start of the monthly fertilisation;

- The palm's basin is to be weeded and mulched; and

- Attend to the general maintenance practices such as inspection of all water points (drippers, microjets, etc.), mulching, weeding, repair of basins, etc.

June

- Apply the ammonium sulphate fertilisation;

- If male flowers start production, harvest the pollen and dry it;

- Monitor a control programme against pests and diseases (avoid the extensive use of chemicals and base your approach on Integrated Pest Management; manual or mechanical weeding, light traps, phenomone traps, removal of diseased leaves, etc.).

July

- Pollination season starts and will continue until the end of August, sometimes until the end of September;

- An adult male palm produces between 500 to 1,000 g of pollen (an average of 700 g), which is enough for pollinating 47 female palms; It is clear that 15 to 20 g of pollen is the required amount of pollen to be used per female palm; approximately 2 kg of pollen are needed per hectare.

- Germination and humidity tests of stored pollen could be initiated at any convenient located scientific facility; if this is not possible try to use only fresh pollen;

- Use mixed pollen (old and fresh); on daily basis, the pollen (just the quantity to be used) is to be mixed with non- perfumed industrial talc (or wheat fl ower) at a rate of 30 to 50 percent depending on varieties.

- Medjool only requires a low quantity of pollen (10 % pollen/talc ratio = 1:g);

- Only skilled labourers should be used for pollination;

- Pollination should only be practised between 10:00 in the morning and 15:00 in the afternoon (not before, nor after). A minimum temperature of 18°C is to be respected;

- If it rains within 2 to 3 days after pollination, repeat the pollination;

- To pollinate, the female spathes are to be gently opened after they start cracking; cover-sheaths will be removed with no damage to the inside fl owers;

- The top 1/3 of the female inflorescence should be removed (1st thinning); do not squeeze the inflorescences while doing this.

- Pollination should be applied at least twice with 2 to 3- day intervals (to ensure a good fruit set);

- In places where low temperatures are expected during the pollination season, craft paper bags are to be used to cover the pollinated infl orescence. Several days later (8 to 10), the bags must be removed.

- A slight leaf pruning could also be practised depending on variety and on the palm's canopy;

- Make sure that the future enlarged inflorescence is not disturbed by surrounding leaves;

- Apply the Maxi-Fos fertilisation on the 1st of July;

- Apply the ammonium sulphate fertilisation on the 7th of July.

- Apply the potassium chloride on the 15th of July.

August

- Continue pollination;

- Two weeks after the last pollination, ensure a passage in each palm and below each infl ores-cence in order to assess the fruit set and to position (if a leaf or two needs to be cut, it must be done at this time); this is to prevent wind/leaf damage on the fruits;

- Start marketing contact with potential date traders;

- Ensure the availability of packing material;

- Initiate logistical planning (storage, transport, etc.);

- Apply the ammonium sulphate fertilisation.

September

Six to eight weeks after the first pollination, start the following:

- Bunch removal: Limit the number of fruit bunches per palm to the accepted norms depending on the palm's age and vigour. Use the formula: an average of 10 leaves per bunch. The bunches kept are the ones with the nice fruit set and well equilibrated around the palm (equally distributed around the crown). One fruit bunch during first year of production, 2 bunches the second year, and so on.

- Bunch thinning: Thin from the inside (± 1/3) but do not cut too close to the remaining inside spikelets; leave 5 to 6 cm to avoid drying and fungal attack. Thinning is variety dependent and should be done only after precise evaluation of the fruit set;

- The above thinning techniques should always lead to the following fruit distribution:

  * Barhee: 45 to 50 spikelets per bunch and 20 to 25 fruits per spikelet. The number of fruits per bunch will vary from 900 to 1,250; with an average of 15 g per fruit, the bunch weight will vary from 13.50 kg to 18.75 kg.

  * Medjool: 30 spikelets per bunch and 10 fruits per spikelet. The number of fruits per bunch should be about 300; with an average fruit weight of 20 g (as a semi-dry fruit from 18 to 28 g), the bunch weight will approximately be 6 kg.

- Positioning and supporting the bunches: Immediately, after bunch thinning is fi nished at the whole plantation, the operation of positioning and tying is to be practised. Be careful to gently position the bunch in order not to break the fruitstalk (use both hands). Each fruit bunch should be supported (to avoid its future breakage) by the use of two ropes attached to the upper and the lower leaf.

Note that all the above practises (pollination, thinning, etc.) are labour intensive (170 working days/year/hectare), and must only be handled by skilled labour. It is necessary to treat the fl ower/inflorescence with care from pollination till Hababouk stage.

- Apply ammonium sulphate fertilisation.

October/November

- Apply the Maxi-Fos fertilisation on the 1st of October;

- Apply the ammonium sulphate fertilisation for October and November;

- All bunches are to be covered with net bags (80 %) to protect the fruits from birds, wasps and insects. This period should correspond to the passage of fruits from Kimri to Khalal. Fruits at this stage are starting to turn yellow in colour (case of Barhee variety) and the nets are to be left on the bunches till fruit ripening and harvesting. This protection operation must be completed throughout the whole plantation before the Rutab stage is reached.

December/January

- Observe irrigation programme;
- Apply the Maxi-Fos fertilisation on the 1st of January;
- Apply the potassium chloride fertilisation on the 15th of January.

February

- If necessary, all dried and half dried leaves could be pruned during February to avoid the Rutab fruits from damage caused by these leaves during windy situations. It also helps the harvesting operation.

- Before harvesting (February preferably), leaves that touch the ground can be removed along with small offshoots.

March

- Harvesting season depends on variety, location and care; it could start early February;

- Make sure that fruits are matured and correspond to market needs (maturation test); bunches are tested for export standards;

- Good management of harvest, transport to the packing house and packaging process.

General

- Leaf pruning can be summarised as follows:

  * Immediately after harvest for the ones touching the ground;

  * During the second thinning operation and while positioning the bunch, 1 to 2 leaves per bunch are to be removed if required, to leave free space for the fruit bunch; and

- Weeding around the palm needs to be practised on monthly basis;

- Microsprinklers or drippers and palms's basin need to be maintained on regular basis;

- Maintain mulching practices;

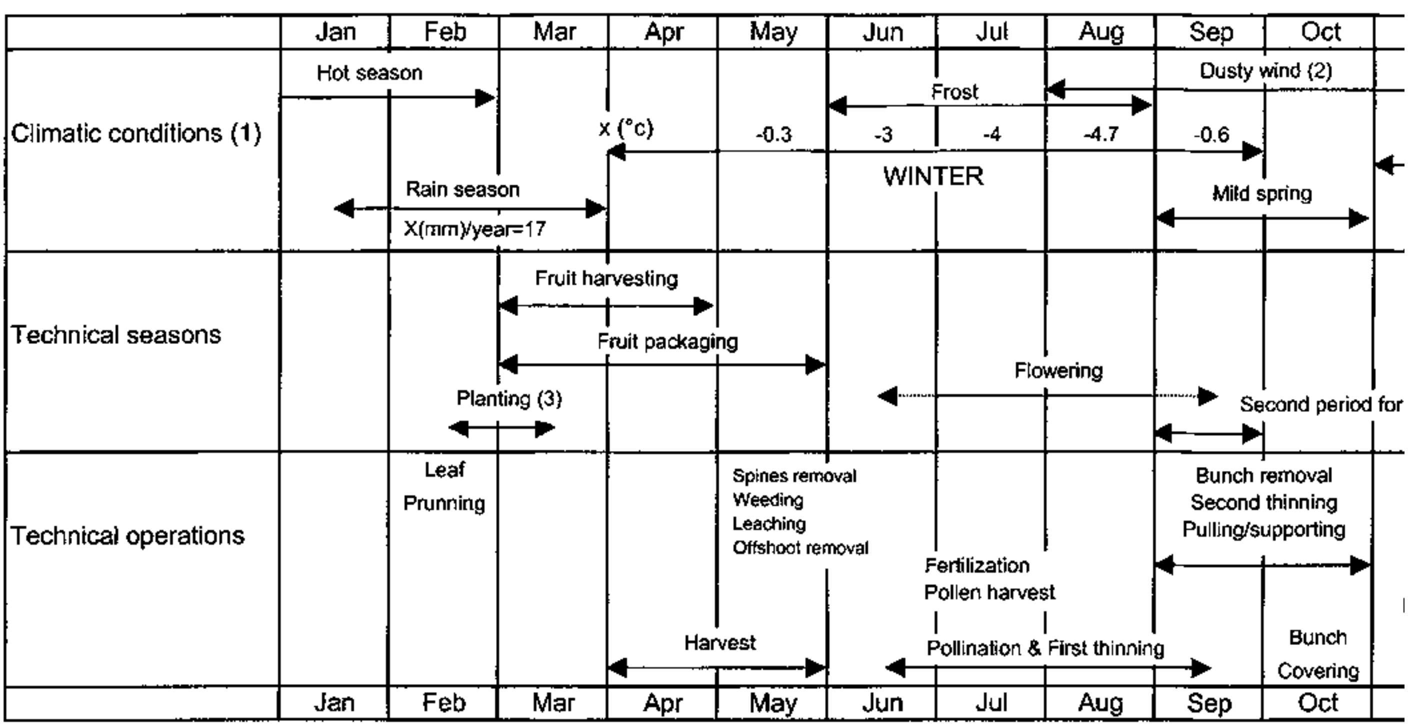
- Regular fi eld inspections for diseases and pests; and

- Plan in advence the labour requirements;

- Fertilisation Information

Table 45 listed in Chapter VI gives details about the fertilisation programme.

Figure 89. Date palm annual technical calendar: Model of Naute (Keetmanshoop), Namibia.



1) Minimum temperature statistics from 1948 till 1985 at Keetmanshoop Airport.

2) August wind direction: N-East and Sept/Oct/Nov: West (severe)

3) 15 February till 15 March is the best planting time(no wind, no extreme temperatures and humidity is relatively high - about 40%

4) Fertilisation and irrigation details are provided in chapter VI and VII, respectively.

CHAPTER XII: DISEASES AND PESTS OF DATE PALM

By A. Zaid, P. F. de Wet., M. Djerbi and A. Oihabi

1. Introduction

This chapter is an attempt to provide basic information on major diseases and pests of the date palm. It should serve as a brief reference and a source of information for extension specialists, date growers and anyone interested in the date palm phytosanitary status.

2. Fungal diseases of date palm

2.1 Bayoud disease

Origin, distribution and economic importance

The name bayoud comes from the Arabic word, "abiadh", meaning white which refers to the whitening of the fronds of diseased palms. This disease was first reported in 1870 in Zagora-Morocco. By 1940, it had already affected several date plantations and after one century, the disease has practically affected all Moroccan palm groves, as well as those of the western and central Algerian Sahara (Killian and Maire, 1930; Toutain, 1967).

Bayoud disease causes considerable damage that can sometimes take on spectacular proportions when the disease presents its violent epidemic aspect. Bayoud has destroyed in one century more than twelve million palms in Morocco and three million in Algeria. Bayoud destroyed the world's most renowned varieties that are susceptible to the disease and particularly those which produce high quality and quantity fruit (Medjool, Deglet Nour, BouFegouss). It also accelerated the phenomenon of desertifi cation (Figures 90a and b). The result is an infl ux of farmers who have abandoned their land and moved to large urban centres.

The continued spread of bayoud highlights the problem threatening the important plantations of Deglet Nour and Ghars in Oued Rhir, Zibans in Algeria and even in Tunisia, which is presently free of the disease, but has 70 % to 80 % of the date palm areas under varieties susceptible it..

The disease continues to advance relentlessly to the east, despite prophylactic measures and regular attempts at eradication undertaken in Algeria (Djerbi et al., 1985; Kellou and DuBost, 1947:Figure 91). It is evident therefore, that Bayoud constitutes a plague to Saharan agriculture and at the present expansion rate, it will certainly pose serious problems of human, social and economic nature to other date-producing areas of the world.

Disease symptoms

The bayoud disease attacks mature and young palms alike, as well as offshoots at their base (Saaidi, 1979).

External symptoms:

> The first symptom of the disease appears on a palm leaf of the middle crown (Figure 92). This leaf takes on a leaden hue (ash grey colour) and then withens, from bottom to top, in a very particular way: some pinnae or spines situated on one side of the frond wither progressively from the base upward to the apex (Figure 93). After one side has been affected, the whitening begins on the other side, progressing this time in the opposite direction from the top of the frond to the base.
>
> A brown stain appears lengthwise on the dorsal side of the rachis and advances from the base to the tip of the frond, corresponding to the passage of the mycelium in the vascular bundles of the rachis. Afterwards, the frond exhibits a characteristic arch, resembling a wet feather and hangs down along

the trunk. This whitening and dying process of the pinnae may take from a few days to several weeks.

The same succession of symptoms then begins to appear on adjacent leaves. The disease advances ineluctably and the palm dies when the terminal bud is affected. The palm can die at any time from several weeks to several months after the appearance of the first symptoms (Figures 94a and b). The rapid evolution of the symptoms depends mainly on planting conditions and on variety.

Internal symptoms:

A small number of disease infected roots, reddish in colour, are revealed when an affected palm is uprooted. The spots are large and numerous towards the base of the stipe. As they advance towards the upper parts of the palm, the coloured conducting fascicles separate and their complicated path inside the healthy tissues can be followed.

Palm fronds manifesting external symptoms exhibit a reddish brown colour when cut, showing highly coloured conducting fascicles. There is, therefore, a continuity of vascular symptoms that exist from the roots of the palm to the tips of the palm fronds.

The observation of symptoms is necessary to recognise the bayoud, but to identify this disease with certainty, samples of affected fronds must be analysed by a specialised laboratory.

Pathogen

The causal organism responsible for bayoud is a microscopic fungus which belongs to the mycofl ora of the soil and is named *Fusarium oxysporum forma specialis albedinis* (Killian and Maire, 1930; Malencon, 1934 and 1936).

Biology and epidemiology

Survival

Fusarium oxysporum f. sp. albedinis is preserved in the form of chlamydospores in the dead tissues of infected palm, especially in the roots which have been killed by the disease and in the soil.

Spread of Bayoud in palm groves

Contamination occurs regularly from palm to palm and more rapidly as the amount of irrigation increases. The appearance of the disease in locations far from the original infected area is caused primarily by the transport of infected offshoots or palm fragments harbouring the fungus.

Host plants

Many plants are often grown as intercrops in palm groves, notably lucerne (*Medicago sa-tiva L.*; alfalfa), henna (*Lawsonia inermis L.)* and vegetables. (Bult et al., 1967; Djerbi et al., 1985 and Louvet et al., 1973). These plants can harbour the bayoud organism without manifesting any symptoms (symptomless carriers).

Control of Bayoud disease

Chemical control

Soil treatment of this type of disease is destined, *a priori*, to fail and should therefore be avoided. Chemical control can, however, be feasible in the event of the discovery of primary sources of infection in a healthy area. In this case eradication techniques should be used: palms are uprooted and incinerated on the spot. The soil is then treated with methyl bromide or chloropicrin and the area closed off with replanting prohibited until further notice.

Cultural control

Since the factors that favour high yield in date palms (irrigation, fertilisation, etc.) are the same that favour the growth of the fungus, cultural techniques are not advised. However, a signifi cant reduction in the amount of irrigation can retard the advance of infection,i.e. stopping irrigation between the months of May and October, during the hot season in the northern hemisphere (Pereau-LeRoy, 1958).

Since the contamination occurs mainly by root contact, disease-free palms can be isolated by digging a trench of 2 m deep around them. Water should be provided by a trough bridging the rest of the grove to this isolated plot. Under these conditions these palms can be protected for more than 10 years (Djerbi, 1983).

Prophylactic measures

The essential task is to prevent the movement of contaminated plant material from an infected palm grove to a healthy one. This material, as has been previously mentioned, consists mainly of offshoots, palm fragments, manure and infected soil, and artifacts made from these materials. Legislation preventing the conveyance of contaminated vegetative material from one country to another, or from one region to another, has been passed by various countries such as Algeria, Egypt, Iraq, Libya, Mauritania, Saudi Arabia, Tunisia and USA.

Genetic control

The only productive means of controlling bayoud disease lies in continued research into resistant varieties. Many resistant cultivars have already been obtained in Morocco from three sources: selection of bayoud-resistant varieties from those already existing (local and introduced), selection of high-quality, resistant clones from the natural population of the date palm, and creation of resistant and high quality varieties through a hybridisation programme (Djerbi et al., 1986; Toutain, 1968).

In addition, the present success of date palm propagation by in vitro culture will make it possible to rehabilitate the Moroccan and Algerian palm groves that have been destroyed by bayoud. It will also be possible to reconstitute the palm groves presently threatened by Bayoud and create new date-growing areas with the help of high quality, resistant varieties.

In conclusion, bayoud disease is an epiphytic disease for which there is no known cure at present. Only preventive measures could protect healthy date plantations from this disease. Therefore, the following measures are imperative:

- Forbid the introduction of offshoots and all other plant material (palm fragments, artifacts made from date material, manure and infected soil) originating from bayoud infected countries or regions.

- Forbid the import of seeds and unprocessed products of symptomless carriers such as Alfalfa (Lucerne) and Henna from bayoud-infected countries or regions.

- Adopt legislation preventing the conveyance of the above plant material.

- Immediately report cases where symptoms similar to the ones caused by the bayoud appear.

- Information on bayoud and other major diseases and pests is necessary for the success of all above actions and must be available to all date growers.

2.2 Black scorch disease

Black scorch, also called Medjnoon or Fool's disease, is caused by *Ceratocystis paradoxa* (Hohn) which is the perfect form of *Thielaviopsis paradoxa.*

Black scorch has been observed on date palm in all date growing areas of the world. Symptoms are usually expressed in four distinct forms: black scorch on the leaves, inflorescence blight, heart or trunk rot and bud rot on palms of all ages. Infections are all characterised by partial to complete necrosis of the tissues. Typical lesions are dark brown to black, hard, carbonaceous, and, as a mass, give the petioles, fruit strands and fruit stalks a scorched, charcoal-like appearance (Figures 95a, b, c and d).

Decay is most serious when it attacks the terminal bud and heart leading to the death of the palm. Some palms recover, probably by development of a lateral bud from the uninjured portions of meristematic tissue. These palms show a characteristic bend in the region of infection. This is why it is called Medjnoon. They set normal growth back by several years.

According to Djerbi (1983), black scorch has been observed on 17 date varieties. Thoory, Hayani, Amhat, Saidy and Halawy varieties are highly susceptible. The disease has also been observed on Zahdi, Menakher, Baklany, Gantar, Halooa, Fteemy, Sukkar Nabat, Horra, Besser Haloo, Nakleh-Zianeh and Koroch varieties (Klotz and Fawcett, 1932). Medjool and Barhee varieties are also susceptible to the disease (Zaid's own observations).

Good sanitation is the first step in the control of black scorch. The affected fronds, leaf bases and inflorescences should be pruned, collected and immediately burned. The pruning cuts and surrounding tissues should be protected by spraying with Bordeaux mixture, lime-sulphur solution, copper sulphate lime mixture, dichlone, thiram or any new copper-based fungicides. Under a severe attack, affected palms are to be removed and burnt.

2.3 Brown leaf spot

Brown leaf spot as with other common date palm diseases, has also been observed in North Africa and the Middle East (Rieuf, 1968). Dark lesions are clearly delimited on green leaves, and on dying leaves the margin of the lesion remains reddish/brown as the centre becomes pale. Lesions also occur on the rachis, pinnae and spines (Figures 96a, b, c). Brown leaf spot is caused by *Mycosphaerella tassiana* (De Not) Johns.

Because it is a minor disease, no treatment is recommended. However, annual pruning of old infected leaves and their immediate burning is advised.

2.4 Diplodia disease

Diplodia disease, caused by *Diplodia phoenicum* (Sacc), has been recorded on 20 date varieties all around the world, although it appears to be most common to Deglet Nour. Symptoms are severe on offshoots and are characterised by death either while they are still attached to the mother palm or after they have been detached and planted out. The fungus may infect the outside leaves and fi nally kill younger leaves and the terminal bud;, or the central cluster may be infected and die before the older leaves. Yellowish-brown streaks extend along the leaf base (Figure 97).

On the leaves of older palms, the ventral mid-portion of the stalks is commonly affected, showing yellowish brown streaks, 15 cm to over one meter in length, extending along the leaf base and rachis. The upper part of the leaves however, may still appear green and unaffected.

Since the fungus usually enters the palm through wounds made during pruning or cutting when removing the offshoots, one precaution is to disinfect all tools and cut surfaces. Dipping or spraying the offshoots with various chemicals (benomyl, Bordeaux mixture, methylthiophanate, thiram and other copper-based fungicides), has been found effective against the disease.

2.5 Graphiola leaf spot

Graphiola leaf spot is caused by *Graphiola phoenicis* (Moug) Poit., which is a smut fungus. It develops sub-epidermal, in small spots on both sides of the pinnae leaves, on the rachis and on the leaf base (Figure 98). The numerous fruiting structures emerge as small-yellow/brown to black sori, 1 to 3 mm in diameter, with two layers. These sori are abundant on three year-old leaves, conspicuous on two year-old, but absent or infrequent on one year-old leaves. This is because of the 10 - 11 month incubation cycle for this pathogen. On a leaf, sori are abundant on apical pinnae, less abundant on the middle section becoming even less on the basal section.

The normal 6 - 8 year life of date palm fronds will be reduced to 3 years by *Graphiola* disease and heavily infected leaves die prematurely which consequently reduce yield of the palm.

Graphiola leaf spot disease is most common in Egypt (Delta region and Fayum) but absent in the less humid oases. In Saudi Arabia, it is abundant in Kattif, Demam and Jeddah, but absent in Iraq. Reports of this disease also originate from Algeria and USA. Around the world it is the most widely spread disease and occurs wherever the date palm is cultivated under humid conditions - mostly marginal date growing areas (Mediterranean coast) but also in the southern most humid regions of Mali, Mauritania, Niger and Senegal.

Control measures include leaf pruning coupled with treatment with Bordeaux mixture or any large spectrum fungicide (mancozeb, cupric hydroxide, cupric hydroxide + maneb, or copper oxychloride + maneb + zineb; 3 to 4 applications on a 15-day schedule after, sporulation, have been recommended). Genetic tolerance has been found in some varieties (Barhee, Adbad, Rahman, Gizaz, Iteema, Khastawy, Jouzi and Tadala).

2.6 Khamedj disease

Khamedj or infl orescencKe rot is a serious disease affecting most date growing areas of the old world. It causes damage on inflorescences in neglected palm groves in hot and humid regions, or in areas with prolonged periods of heavy rain, 2 to 3 months before emergence of spathes. The disease can reappear each year on the same palm with the same intensity and it is estimated that, in serious cases, 30 - 40 kg of fruits are lost annually (Chabrolin, 1928).

During 1948 - 1949 and 1977 - 1978 severe outbreaks occurred in Iraq at Basrah, affecting male and female palms and destroying 80 % of the harvest (Al Hassan and Waleed, 1977). Serious damage was also recognised in Katif in the Kingdom of Saudi Arabia in 1983, with losses ranging from 50 to 70 %.

The disease is caused by *Mauginiella scattae* Cav., which is always found in a pure state in affected tissues (Figure 99). However, *Fusarium moniliforme* and *Thielaviopsis paradoxa* may rarely cause inflorescence rot.

The first visible symptom of the disease appears on the external surface of unopened spathes and is in the form of a brownish or rusty-coloured area. It is most apparent on the internal face of the spathe where the fungus has already begun to infect the infl orescence. When the infected spathes split, they reveal partial or complete destruction of the flowers and strands. Severely damaged spathes may remain closed and their internal contents may be completely infected. The inflorescences become dry and covered with powdery fructifi cations of the fungus.

Transmission of the disease from one palm to the next occurs through the contamination of male inflorescences during the pollination period. The infection of the young inflorescence occurs early and happens when the spathe is still hidden in the leaf bases. The fungus penetrates directly into the spathe and then reaches the inflorescences where the fungus sporulates abundantly.

The frequent appearance of the disease in neglected date plantations indicates that good sanitation and effi cient maintenance is the first step in the control of Khamedj disease. The collection and burning of all infected inflorescences and spathes should be followed by treating the diseased palms with the following fungicides after the harvest and one month before the emergence of spathes: a bordeaux mixture or a copper (1/3), sulphate-lime (2/3) mixture or a 3 % dichlone spray or a 4 % thirame spray at the rate of 8 litres per palm or with benonyl and tuzet at the rate of 125 g/hl (Al Hassan et al., 1977).

Some varieties are particularly susceptible to Khamedj disease: Medjool, Ghars, Khadrawy and Sayer. Others manifest a good capacity for resistance: Hallawi, Zahdi, Hamrain and Takermest (Laville, 1973).

2.7 Omphalia root rot

Omphalia root rot was recorded in California, USA and in Mauritania by Fawcett and Klotz (1932) and Bliss (1944), respectively. It is also called a decline disease because of its association with declining date palms.

Four Mauritanian varieties (Ahmar, Marsij, Mrizigueg and Tinterguel) were found to be susceptible to this disease by Sachs (1967). Unlike other date varieties planted in California, Deglet Nour was found to have the lower infection rate.

Two species of Omphalia (*O. tralucida* Bliss and *O. pigmentata* Bliss) cause the disease and are widely spread in date plantations of Coachella Valley, CA-USA and in Kankossa (Mauritania) (Djerbi, 1983).

The premature death of fronds followed by retardation and cessation of growth are the main disease characteristics followed by necrosis and destruction of the roots. A completely non- productive stage is the result of the attack.

The use of Brestan or Dexon at the rate of one spray every two weeks for eight weeks was recommended by Sachs (1967) as a chemical control measure.

2.8 Belâat disease

Belâat disease was reported by several authors and from several North African countries (Algeria, Morocco, Tunisia, etc.) (Maire, 1935; Monciero, 1947; Calcat, 1959 and Toutain, 1967). The entire cluster of young fronds will whiten and die as a result of the attack, followed by the infection and death of the terminal bud (Figures 100 and 101). Accompanied by secondary organisms, the infection will progress downward in the trunk as a conical wet heart rot form, releasing an odour of acetic and butyric fermentation.

Belâat disease is caused by *Phytophtora sp.* similar to *P. palmivora* (Djerbi, 1983). Effi cient maintenance of date plantations is highly recommended to avoid attacks by this disease. Spraying with maneb or Bordeaux mixture at the rate of 8 litres/palm could control the disease at its early stages. Offshoots of affected palms usually remain healthy.

2.9 Fruit rot

Fruit rot damage varies from one year to another depending on humidity and rain and also on the time of these factors from the Khalal stage until fruit maturation (Figure 102). Even though losses vary from one country to another and from one variety to another, they can be easily estimated to be between 10 % and 50 % of the harvest (Darley and Wilbur, 1955; Calcat, 1959; Djerbi *et al*., 1986). Table 67 summarises these damage prevalent in different countries.

TABLE 67
Estimates of loss caused by fruit rot

Country	USA	Tunisia	Algeria	Morocco	Palestine
Loss value (%)	10 to 40	50	25	40	45
Main variety	Medjool, Deglet Nour	Deglet Nour	Deglet Nour	Medjool	Medjool, Barhee
Control measures	Covering with paper wraps Dusting with Fungicides	Paper wraps	None	None	None

Source: Djerbi, 1983.

The most common fungi causing fruit spoilage are the calyx-end rot caused by *Aspergillus niger* and the side spot decay caused by *Alternaria* sp.

Lowering the humidity inside the bunch, by the use of wire rings, and/or by removing a few fruit strands from the centre of the bunch, will facilitate ventilation and drying of wet fruit. Protection from rain or dew is reached by using paper covers in the early Khalal stage to cover the fruit bunch. Fungus spoilage could also be limited by dusting the fruit bunches during the Khalal stage with 5 % ferbam, 5 % malathion, 50 % sulphur and an inert carrier (40 %) (Djerbi, 1983).

3. Phytoplasmic diseases of date palm

3.1 Lethal yellowing

Lethal yellowing destroyed about 300,000 coconut palms in Miami (Florida, USA) in less than fi ve years (McCoy, 1976). Previously, the disease killed more than 15,000 coconut palms in Florida, (USA).

The host list of palm species attacked by lethal yellowing is large and includes *Phoenix dactylifera* L.; *P. canariensis* Hort., and *P. reclinata* Jacq. (Thomas, 1974).

Developing fruits of the coconut start dropping from the palm followed by the formation of new inflorescences which rapidly become necrotic. These first symptoms are followed by a rapid and generalised yellowing, leading to the death of the palm (Figure 103).

In date palm the fronds become desiccated and grey-brown instead of becoming yellow. A soft rot of the growing point occurs, converting the meristematic area into a putrid, slimy mass. The crown topples from the palm, leaving a naked trunk.

The causal agent is a mycoplasma-like organism. It is believed that the pathogen is disseminated by wind-born arthropod vectors. Removal of diseased palms and their offshoots, quarantine measures, the use of tolerant types of palms and the treatment with antibiotics are the main control measures.

3.2 Al Wijam

Nixon (1954) observed this disease in Al Hassa (Saudi Arabia). In Arabic, Al Wijam means poor or unfruitful. The disease is characterised by a retardation in terminal bud growth,and the whole crown of leaves formed after the occurrence of the disease have the rosetting symptoms. Newly formed leaves are reduced in size and marked by a faint narrow, yellow longitudinal line on the midribs (Figure 104). Leaves become chloritic and their life span is reduced. Death of leaves starts from the distal end and extends towards the base. Diseased spathes split open before their complete emergence and are reduced in size. The number and size of the bunches produced are also reduced year after year till the diseased palm fails to produce and dies.

Positive amplifi cation bands were obtained from DNA templates extracted from diseased tissue of date palm using the Polymerase Chain Reaction (PCR). These DNA tests offer basic support to the hypothesis that the cause of Al-Wijam disease is a Mycoplasma- like organism (Djerbi, 1999; personal communication).

3.3 Brittle leaves disease

Brittle leaves disease, also called "Maladie des Feuilles Cassantes" in French, was first observed in Nefta, Tozeur and Degache date plantations (Tunisia) and in Adrar, M'zab and Biskra (Algeria) (Djerbi, 1983).

Both adult and young palms including offshoots are attacked alike. A broad chlorotic striping of the pinnae followed by drying of the tip of the frond is the first symptom of this disease (Figures 105 and 106).

Yields drop signifi cantly as more fronds are affected and the retardation in terminal bud's growth becomes evident. Leaves are shorter and of irregular size.

The causal agent remains unknown and no fungi or other pathogens were isolated. However, recent investigations with PCR showed that the causal agent seems to be a Mycoplasma-like Organism (Djerbi, 1999; personal communication).

Chemical analysis of date palm leaves and soils showed that concentrations of all nutrients in the tissue were higher in leaves of unhealthy palms. The exception was the concentration of manganese, which was ten times lower in the unhealthy palms (Djerbi, 1983). In addition, the conductivity and the phosphorus concentrations of the soil with diseased palms are higher than that of healthy ones. These results suggest that the areas affected by the disease have a build-up of major nutrients and salts as a result of irrigation, which have contributed to the high electrical conductivity. High pH and conductivity may have caused lack of manganese in the soil.

Quarantine measures seem to be the only means of limiting the spread of the disease. Since manganese is defi cient in unhealthy palms, this nutrient could be brought to these palms either by spraying or by injection. Djerbi (1983) found a gradient of susceptibility within Tunisian varieties even though they all seemed to be equally attacked.

4. Diseases of unknown cause of date palm

4.1 Bending head

Also called "Le Coeur qui penche" in French, the bending head is a minor disease observed in Algeria, Egypt, Mauritania and Tunisia (Munier, 1955). The central cluster of fronds takes the form of an erect fascicle with a bent tip. The trunk bends and may even break.

Thielaviopsis paradoxa and *Botryodiplodia theobromae* Pat are fungi commonly isolated from declining palms (Brun and Laville, 1965). Effi cient maintenance and appropriate sanitation of the date plantation is the first control measure. Diseased parts of infested palms are to be collected and burnt in order to limit the spread of the disease.

4.2 Dry bone

Originally this disease was first reported by Fawcett and Klotz (1932) in USA. Other cases were found in Algeria, Egypt and Tunisia (Djerbi, 1983). According to Djerbi, the disease is characterised by whitish, irregular blotches and streaks on the leaf stalks, midribs and pinnae that become outlined by reddish brown margins. The name "dry bone" comes from the drying out of the surface of the leaf stalk with a hard, smooth and white appearance. Lesions, from one to several centimetres, involve only the epidermis and a thin layer of subjacent tissue.

According to Fawcett and Klotz (1932), a bacterium is commonly found associated with the lesions, and certain palms are more susceptible than others.

4.3 Faroun disease

Laville and Sachs (1967) reported this disease of unknown cause from Mauritania. Affected palms, present a parasol form produced by the old and mid-level fronds, while new fronds present a short rachis with an irregular arrangement of pinnae and spines. Leaves remain green during the first stages and then decline and become yellow. The terminal bud assumes a conical form and becomes a stunted rosette.

All these symptoms are accompanied by the abortion of the axillary buds, resulting in failure of fl owering for one or two seasons before foliage symptoms appear. Two to four years is the average duration of the disease from the appearance of the symptoms to the death of the palm. According to Djerbi (1983) no varietal resistance has been observed.

4.4 Rhizosis

Also called "Rapid decline", rhizosis is a minor but fatal disease of unknown cause. The first symptom is premature falling off of fruits. However, if the attack is sometime after fruit development, the fruit withers and shrivels on the bunch. A reddish-brown discolouration of pinnae appears on mature fronds and the disease progresses from the bottom to the top of the fronds which rapidly die.

Offshoots die with the diseased mother palm and the disease is hence self-limiting. According to Djerbi (1983), no varietal resistance has been observed.

5. Physiological disorders of date palm

5.1 Blacknose

Blacknose applies to the abnormally shrivelled and darkened tip of a date. Deglet Nour and Hayani seem to be the most susceptible varieties to this physiological disorder (Fawcett and Klotz, 1932).

Blacknose results from excessive checking of the epidermis, especially in the form of numerous small, transverse checks or breaks at the stylar end of the fruit. Pronounced shrivelling and darkening occur in proportion to the abundance of the checks and are related to humid weather at the Khalaal stage.

Given the fact that checking is induced by high humidity and rainfall, it follows that measures to avoid conditions that tend to increase humidity are to be taken. The conditions to be avoided include excessive soil moisture and the presence of intercrops and weeds, especially at the susceptible stage of fruit development. According to Nixon (1932), bagging the fruits in brown wrapping paper was found to inhibit the occurrence of blacknose checking. Over thinning can also increase the incidence of checking and subsequent development of blacknose.

5.2 Crosscuts

Crosscuts is a physiological disorder of fruit stalks and fronds reported from the United States, Pakistan and a few Middle East date growing countries such as Israel and Iraq (Bliss, 1937; Djerbi, 1980). In the United States more than 1,000 fruit bunches were damaged in a single plantation in 1934, up to a quarter of the crop was lost.

Crosscuts, or V- cuts, are clean breaks in the tissues of the fruit stalk bases and on fronds (Figures 107a and b). It consists of a slight to deep notch, similar to a cut artifi cially done by a knife. Fruits borne on strands in line with the break wither and fail to mature properly. Crosscuts result from an anatomical defect in the fruit stalks and fronds involving internal, sterile cavities leading to mechanical breaks during elongation of the stalk or the fronds. Crosscuts are commonly found in varieties having crowded leaf bases and its incidence increases as the palms get older. Sayer and Khadrawy varieties are especially susceptible to this disorder, and are no longer propagated in some countries (Carpenter, 1975).

Crop losses may be avoided by using non-susceptible varieties, or by reducing the number of fruit stalks in susceptible varieties.

5.3 Whitenose

Whitenose disease is commonly found in Iraq, Libya and Morocco (Hussain, 1974; Djerbi, 1983). Dry and prolonged wind in the early Rutab stage causes rapid maturation and desiccation of the fruit resulting in whitish drying at the calyx end of the fruit. The affected fruit becomes very dry, hard and has a high sugar content. Hydration may correct this condition in harvested fruits.

5.4 Barhee disorder

Barhee disorder is characterised by an unusual bending of the crown of Barhee variety. The disease was first reported in California (USA) by Darley et al. (1960) and later in Al Basra (Iraq) by Hussain (1974). It was also found at the Kibbutz YOTVATA (Israel) by Zaid (1996). Affected palms were found to bend mostly to the south and sometimes to the south-west.

At the Kibbutz Kineret (Israel), this phenomenon is severe and bending could reach an angle of about 90°. In Israel this bending disorder is also found with Dayri variety. Literature shows that it also affects Jahla and Aguellid varieties (Djerbi, 1983).

Neither the cause nor the control of this disorder is known. However, at Yotvata Kibbutz (Israel), growers are correcting this situation by fi xing a heavy iron bar to the opposite side of the bending (Figure 108); fruit bunches from the opposite side are tied to this bar in order to move the actual weight against the bending side. It seems that within 2 to 3 years, the bending is corrected. Bunch handling is also proposed to correct such an abnormality (Yost, 1968).

5.5 Black scald

Black scald, different from blacknose, is a minor disorder of unknown cause occurring in the United States (Djerbi, 1983). It consists of a blackened and sunken area with a defi nite line of demarcation. The disease usually appears on the tip or the sides of the fruit, and affected tissues have a bitter taste. The appearance of the disorder suggests exposure to high temperature, but the exact cause is not defi nitely known (Nixon, 1951).

5.6 Bastard offshoot

This is a deformed growth of date palm vegetative buds especially of offshoots fronds (Figures 109a and b). Mohamed and Al-Haidari (1965) stated that the bastard condition is due to infestation by the date palm bud mite *Makiella phoenicis* K. It may also be due to reduction in growth caused by an inequilibrium of growth regulators.

5.7 Leaf apical drying

This is not a disease but a physiological reaction to transplantation of adult palms (injury of their root system). All palms with these symptoms recover within two to three years after their transplanting (Figure 110).

5.8 Fertilisation injury

As shown in Figure 60, this type of injury is present only with young tissue culture-derived palm plants (first two years after fi eld planting) and when fertilisers (N, P, K) are applied too close to the palm's stipe. The nature of fertilisers is not the cause, but rather how close to the stipe the fertiliser was applied. If the damage is severe, it could cause the death of the young palm.

5.9 Frost damage

As stated in Chapter IV the date palm resists large temperature variations (-5 to 50°C) with a growth optimum between 32 and 38°C and a zero of vegetation of about 7°C. The vegetative activity will also decrease above 40°C and ceases around 45°C.

When temperature falls below 0°C, it causes serious metabolic disorders with some injury to date palm leaves characterised by a partial or total desiccation. Water of protoplasma freezes after coming out from the cells. During defrost, water invaded inter-cellular spaces and affected leaves turn brown and desiccated. The severity of damage is related to the intensity and duration of frost:

- At -6°C, leafl et ends become yellowish and dry up;

- At -12°C, leaves of external crown desiccate; and

- From -15°C, leaves of middle crown freeze and if low temperatures are suffi ciently prolonged, the central crown is reached and all foliage desiccates and the palm seems to be completely burned.

The relative stable temperature of terminal bud and trunk allows the date palm to resist frost in winter, and high temperature in summer. In fact, the terminal bud is protected by the fi brillium and the leaf bases; the internal temperatures of the trunk and terminal bud undergo less big variations than those of atmosphere; the difference is round 14°C less in summer and 12°C more in winter.

Frost injury to the date palm groves is not in direct loss of fruit on the palm but in freezing and loss of leaves so that the palm cannot support and mature the fruit crop the following year. Serious damage caused by frost was observed in plantations in Morocco (Guir, 1952; Tinghir, Tinjdad, 1965) and in USA (1873, 1940 and 1950) where temperatures of approximately -15°C occurred and frost caused a complete desiccation of leaves. In Morocco, palms were considered lost and the damage looked like a disaster to the local population. However, in spring, terminal buds started to grow although they were severely affected, and a good bloom was obtained (Djerbi, 1983).

The most practical and available protection for the date growers is to turn on the water and keep the date plantation wet when the temperature begins to get low enough (-5°C and below). A date plantation just irrigated or being irrigated when the temperature falls, has some heat stored, which gives protection.

Data are also available on principal date varieties and their susceptibility to cold:

Resistant: Zahdi.

Moderatly susceptible: Bentamoda, Bentkbala, Besser Halou, Hayani, Itima, Jouze, Khastawi, Mesh Degla, Sayer, Tadala, Tazizot and Thoury.

Susceptible: Ammari, Amri, Arechti, Barhee, Beid Hmam, Dayri, Deglet Nour, Horra, Khadrawy, Maktoum, Medjool, Menakher and Saidy.

Highly susceptible: Brain, Fursi, Hallawy, Hilali, Khlass, Khush Zebda and Ghars.

5.10 Lack or excess of water

The growth of the date palm is highly affected by variations in water availability and the water content of the soil. A decrease in yield, or complete failure in fruit production could result from these water variations.

To compensate for high evapotranspiration, the date palm requires a quantity of water from 1,500 to 2,800 mm/year. Prolonged water stress will signifi cantly decrease growth and yield, and if the drought continues for several years, date palm can dry up and die.

On the other hand, when the water table is high and drainage is inadequate and/or the leaching and transport of soluble salts is not complete, high evaporation rates tend to increase the concentration of salts in soil and in surface water. However, there are limits of salt tolerance and the date palm will not grow when soluble salt of the soil is above 6 percent. As stated in Chapter IV, the following shows the relationship between salts, growth and yield:

- irrigation with water of salinity up to 3.5 mmhos/cm (i.e. 2240 ppm) will not affect the yield, provided that the leaching requirement of 7 % is provided for.

- With an irrigation water of 5.3 mmhos/cm salt content and a leaching requirement of 11 %, yield reduction is only 10 %.

- When the salt content of the irrigation water reaches 10 mmhos (i.e. 6400 ppm) and a leaching requirement of 21 %, the reduction in yield is around 50 %.

The timing of leaching must be adjusted in each case, according to the quantities of soil and water, conditions of drainage, and characteristics of rainfall.

Although date palms are resistant to fl ooding, healthy growth of palms requires a well-drained soil, and it is clear that irrigation must always go hand in hand with drainage.

Serious losses, sometimes irreversible may occur in neglected date plantations (Figure 111). In such cases signs of decline appear on palms favoured by root penetration of numerous saprophytes and parasites that could lead to the death of palms (Djerbi, 1983).

6. Major pests of date palm

The date palm and its fruits are subject to attacks by several pests that are, in most cases, well adapted to the oasis environment. Damage caused by pests is considerable and leads to heavy economic losses.

6.1 White scale

White scale, caused by *Parlatoria blanchardii* Targ., is widely present in most date palm growing areas of the world except in USA, where it was eradicated in 1936, and in some countries of the southern hemisphere (Namibia and RSA).

It is considered a serious pest in Algeria, Kuwait, Libya, Mauritania, Morocco and Tunisia. Iraq, Oman, Saudi Arabia and Sudan consider this pest a moderate one, while Egypt, Jordan, UAE and Yemen consider it a minor pest.

Damage by white scale is very serious on young palms between two to eight years of age, but even under severe attacks, the palm and its offshoots do not die.

Nymphs and adults suck the sap from the leafl et, midribs and the dates. Under each scale insect, a discoloured area appears on the leafl et. Heavy infestation causes leafl ets to turn yellow and contributes to the premature death of the fronds (Figures 112, 113 and 114).

Respiration and photosynthesis are almost stopped resulting in early death of the infested leaf. Damage on fruits is easily noticeable and the production is not marketable. The cycle of *Parlatoria blanchardii* Targ. is summarised in Figure 115. The number of generations developed during one year varies from three to four depending on temperature.

The natural enemies of *Parlatoria blanchardii* are: *Hemisarcoptes malus, Chrysoperla vulgaris, Cardiastethus nazarenus, Coccinellidae* (29 species), *Nitidulidae* (5 species), *Mycetaeidae* (1 species), *Aphytis mytilaspidis,* *Cybocephalus nigriceps, Cybocephalus rufi frones, Chilocorus bipustulatus var. iraniensis* and *Chilocorus sp.* (FAO, 1995) (Figure 116).

Natural enemies and pruning normally keep pest populations at tolerable levels. In the 1970s the coccinellid *Chilocorus bibustulatus* var. *iraniensis* was introduced into Mauritania and Morocco, but permanent establishment failed and efforts were discontinued. In the 1980s, attempts were made to introduce the coccinellids into northern Sudan, but they were not successful either. In 1993 the coccinellids were released in Oman, but there is

no information on their establishment. The introduction of coccinellids is currently being investigated in Tunisia.

Chemical control appears to be conducted occasionally in young plantations. Mineral oils are used (Djerbi, 1994).

6.2 Red scale

Red scale, *Phoenicococcus marlatti*. cockerell, is exclusively a pest of palms, particularly date palms, with other palms as host plants (e.g.: Doupalm, Canary Island palm and the California fan palm). It is probably found wherever date palm is cultivated, but with no great threat (Dowson, 1982). The extent of its damage is known to be less than that caused by the *Parlatoria* scale.

Leaves of date palm are often found to be clotted over with thin, minute, greyish scales with darker centres (Figures 117a and b). The darker spot is oval in outline and is the body of the insect itself. The individual scale is seldom larger than a small pinhead, roundish in shape, and deep pink to dark red in colour, but partly or entirely covered with a white waxy secretion that forms a cottony mass (Nixon and Carpenter, 1978).

All exposed portions of the palm can be attacked by the pest. Heavy infestations could cause complete coverage of the leaf surfaces by scales, which will result in interference with the metabolic functions of the plant. Attacked leaves and underlying tissues may be damaged to a depth of a few millimetres and will consequently be killed in severe cases.

The red date scale usually stays out of the light and is found massed on the white tissues at the bases of the leaves and fruitstalks, where it is protected by fibre and other leaf bases. Frequently, the scale is found on roots underground. The red scale is not as easily detectable as most other scales because of its natural tendency to hide. Red scale is not suspected until the base of the green leaf is cut and subsequently observed. Stickney *et. al.* (1950) provided a comprehensive study of the insect's biology.

P. marlatti. passes its lifecycle in a protective covering of wax that it secrets. The female produces numerous eggs under the protective scale. After the eggs hatch, the nymphs crawl out and move about freely, feeding at various positions. Once a suitable location on the host plant is selected, nymph's will insert their needle-like mouth parts to suck the sap. When they start to feed, layers of wax, forming the covering of the scale over the body, are secreted.

Soon after beginning to feed, adults will moult. Later on, males are incapable of feeding and will mate with the females and die. The female, once fertilised, increases rapidly in size and produces eggs before dying within the scale.

The pest breeds actively during the summer months and hibernation starts in early winter. A complete life-cycle takes approximately 55 days during summer and 158 days during winter. Three to fi ve generations could be found annually.

It is worth mentioning that the scale appears to cause considerable damage to plants growing under favourable conditions. Areas where the climate is milder or more humid may also face severe scale attacks.

Even though this scale insect is regarded insignifi cant, and with no economic impact, the first measure is to cut away all attacked leaves and burn them in order to stop the spread of the pest. Infested palms, offshoots or even tissue culture-derived plants, which are still at the hardening phase, must be sprayed with malathion 370 - 450 g or with parathion 120 g a.m. dissolved in 450 litres of water.

Since the scale is a sucking insect, the use of ultracide or dimenthoate when the pest is mobile is also recommended (Djerbi, 1994). Infested offshoots could also be subjected to a temperature of 50°C for 65 hours in an insulated room. General predators, such as *Pharoscymnus anchorago* (Fairmaire), are considered as active predators.

6.3 Bou Faroua

Bou Faroua, also called Goubar or Old World date mite, is caused by *Oligonychus afrasiaticus* McGregor, and *O. pratensis* Banks. This mite is present in all date growing areas, and damage is severe in neglected plantations.

Immediately after fruit set (Hababouk stage), mite eggs are deposited to produce larvae which will feed on the fruits and later cover these with a web retaining sand particles. The cycle length is about ten to fi fteen days depending on temperature. Mites will rapidly multiply causing the drop-off of the fruits. Affected mature fruits are of no commercial value (Figures 118 and 119).

Chemical analysis of infested and fully matured dates shows that the water soluble substances such as sugar are less in infested dates (Hussain, 1974). Under Iraq's climate, the Old World date mite has six overlapping generations during the fruiting season of palms (Hussain, 1974). The mite population on dates reaches its peak during the middle of July. The first appearance of mite on immature dates is during the first week of July. Even though they are found on all parts of the date, the majority of mites congregate near the calyx area, where most of the eggs are laid. Mite and eggs are also found on fruit stalks. The mites migrate to the palm crown during the last week of August. Hussain (1974) states that the fi bres and frond bases taken from infested palms during the winter months show adult and nymph mites. This mite does not hibernate on the leafl ets, date palm seedlings, offshoots or on the many species of vegetation in the plantation.

Dusting date bunches early in July with sulphur at the rate of about 100 - 150 g per palm is effective (Djerbi, 1994). The Iraqi variety "Sayer" is relatively resistant to mite attack.

6.4 Caroub moth

Caroub moth, also called "Ver de la Datte" in French, is caused by *Ectomyelois ceratoniae*. Zeller, and is found in all date growing areas. The larva of the Caroub moth attacks dates in plantations, packing houses and stores. Eggs are laid on the dates and hatching begins four days later. The larval period is about three weeks in warm months and eight weeks in colder months. The pupal period is about fi ve days.

Taking into account the moth's life cycle, it is recommended to protect the fruit bunches, to clean the plantation from wind-fallen fruits and to fumigate harvested and stored dates. The use of pheromone traps will not only help to determine the emergence of moths but also to estimate the population level. The rate of infestation could be lowered by spraying the infested fruits with *Bacillus thuringiensis* (Djerbi, 1994).

6.5 Rhinoceros beetle (Oryctes rhinoceros Linné)

The adult beetle is a stoutly-built insect about fi ve centimetres in body length and shiny black in colour with a reddish under-surface covered with short, fi ne hair. Its tibiae are furnished with thorn-like spines. This insect has earned the name of rhinoceros beetle because of the presence on its head of a horn-like structure, which is conspicuously longer in the male (Figure 120).

The adults feed on tender leaves, inflorescences and fruit stalk of the fruit bunches of date palm, (Figures 121a, b and c) whereas the grubs thrive on decomposing dung and decaying vegetable matter like stumps and trunks of palms. This insect is also a pest of coconut and other palms.

Within a week of the emergence of the females they start laying eggs. The whitish-brown eggs are laid singly in dung heaps and decomposing vegetable matter. The eggs hatch out into fat soft-bodied pale-yellowish curled larvae in about 10 to12 days. The larvae become full-grown in about 4 or 5 months and they take another 6 to 7 months in hibernation before they transform themselves into pupae. The full-grown larva is a stout fl eshy creature measuring about 7 cm in length with brownish head and dirty white appearance. The full-fed grub pupates in the dung heaps, etc., in a specially prepared oval chamber made of soil or excretory matter. The adult beetles emerge from the pupae in about 3 to 4 weeks and fl y to nearby palms and start feeding on them causing damage. There is only one life-cycle during the year.

Contrary to other pests, only the adult beetles are responsible for causing damage to the palms. The pest has been found to be more destructive to young plants. They remain hidden during the daytime and become active at night, when they fl y about and reach the tops of date palms. They drill large holes close to the base of the growing heart-leaf and enter the stem. They feed on the softer tissues of the growing heart-leaf and cut right through it, with the result that further growth stops and the palm ultimately dies. The beetle also causes damage by boring into tender fronds, chewing tissues and throwing them out as a fi brous dry mass (Figure 122). Fronds may hence break and if the growing point is bored the plant dies off. Most of the damage occurs during the rainy season.

The adult beetles should be attracted and destroyed by putting up mercury-vapour light traps at regular intervals in infested plantations.

The light trap is based on the fact that some insects are very active at night and are attracted by the light. This method of mechanical control is presently included in Integrated Pest Management.

The degree to which insects are attracted varies according to the type of traps as well as to the nature and power of light. It was shown that the mercury-vapour light is the best tool to attract insects.

The advantages of using light traps are::

- to obtain information on the number of captured species;

- to predict the occurrence of an outbreak of an insect-pest; and

- to use it as a mechanical control method since it can reduce the number of insects as well as production losses.

The insect collector (D) should be half filled with diesel, kerosene or paraffin; (Figure 123).

6.6 Red palm weevil and African palm weevil

The red palm weevil (RPW), *Rhynchophorus ferrugineus* Oliv., also called the Indian palm weevil, is well known in the Middle East where it causes severe damage on date palms (Table 68). The RPW was first noted in the Arabian Peninsula in the mid 1980's and in Egypt in 1992 (Figure 124). The weevil was first observed in Rass El Khaima, United Arab Emirates in 1985. Approximately, 5 to 6 % of palms in the Middle East region are infested with the RPW with an annual rate of infection of about 1.9 (Table 69).

TABLE 68
Distribution of red palm weevil in the Near East

Country	First Recorded	Area/Location Infested
Qatar	1985	Doha
UAE	1985	Rass El Khaima
Saudi Arabia	1987	Katiff
Egypt	1992	Salheya, El-Tal El Keber and El-Kassasin
Kuwait	1993	Throughout
Oman	1993	Buraimi, Mahadha, Masandam Governorate

Source: FAO, 1995

TABLE 69
Evolution of affected date palm palms

	YEAR		YEAR	
UAE	1990	1,300	1995	44,000
KSA	1987	Less than 1,000	1996	120,000

The rate of infestation is about 2.02 (1300 x^5 = 44000) and about 1.70 (1000 x^9 = 120,000) for the United Arab Emirates (UAE) and the Kingdom of Saudi Arabia (KSA), respectively. The average rate of annual infestations could be 1.9.

(Infestation year n = infestation year (n-1) × 1.9).

The RPW was wrongly classifi ed as a coconut pest. Indeed, as early as 1970, the RPW was found in India attacking date palms (Khawaja and Akmal, 1971). The first warning came from Dr. Djerbi (1983) who was the first to realize the danger and to invite date growing countries to conduct studies on the biology of this pest, and on appropriate control measures. According to Dr. Oehlschlager (1998), there are fi ve species of palm weevils in the genus *Rhynchophorus* that are economically damaging to palms (Table 70). Up to December 1998, the following countries are offi cially declared as having the RPW infestation: Australia, Burma, China, Egypt, India, Indonesia, Iran, Iraq, Malaysia, Pakistan, Papua New Guinea, Philippines, Saudi Arabia, Sri Lanka, Taiwan, Thailand, Tanzania, UAE and Vietnam. According to Zaid (1999), three more countries are added to the above mentioned list (Jordan, Israel and Palestine):

* On April 21,1999, Zaid identifi ed by e-mail scanning, the photo of the first red palm weevil found in Jericho (Palestine).

* On May 6, the weevil was found in Jordan (in Shunae), few kilometres north-east of Jericho.

* On May 14, another weevil was found in Israel, along the Jordanian border at Moshav Yafi t (15 km north of Jericho).

TABLE 70
Rhynchophorus species damaging palms

Species	Palm Hosts	Region
Rhynchophorus ferrugineus	Date	Middle East
Rhynchophorus vulneratus	Coconut	South East Asia
(Same species)	Oil	South East Asia
Rhynchophorus bilineatus	Coconut	Papua New Guinea
Rhynchophorus cruentatus	Sabal	Florida
Rhynchophorus phoenicis	Coconut Oil, Date	Tropical Africa
Rhynchophorus palmarum	Coconut Oil	Central and South America

Source: Oehlschlager, 1998

The African palm weevil (APW), (*Rhynchophorus phoenicis F.*), was found by Zaid (1999) at two date plantations, one in the RSA and one in Zimbabwe (Figures 125 and 126). To the author's knowledge, it is the first time that this pest has been reported to attack date palms (*Phoenix dactylifera L*). It is also the first time that the genus *Rhynchophorus* has been reported to attack date palms in RSA and Zimbabwe.

The APW is suspected to originate from a local palm host commonly called Lala Palm (*Hyphaene coriacea*). However, in general, this species is known to occur naturally in southern Africa and is also widely distributed in Africa. It attacks a variety of palms in the genera of *Phoenix*, *Elaeis*, *Borassus*, *Hyphaene* and *Raphia*. The biology of the APW (*R. phoenicis*) is well known and summed up in Lepesme's "Les Insectes des Palmiers".

Infestation is often not apparent until extensive damage has already been caused and the palms are beyond recovery (Figures 127 and 128). In these infested plantations, we were looking for wilted/yellow inner leaves. When the observer got closer, a characteristic rotting odour could smelt. Small round holes at the sites of removed offshoots were also a clear indication of the presence of the weevil. Chewed up date palm fi bres were extruded (Figure 129), and a brown fl uid was oozing out of the holes on the stem. Cocoon, weevil and pupal fi bres are frequently found in the palm leaf base (Figure 130).

The following control measures are highly recommended: quarantine, plantation sanitation, chemical treatment, regular surveys, pheromone mass trapping and the use of nematodes. Furthermore, the control of the red and African palm weevils requires all these steps which are of equal importance. Not respecting even one of these measures will lead to infestation of date plantations.

Quarantine

It is imperative that all imports of date palm offshoots from infested areas (Middle East and Asia) to uninfested areas be prohibited. Other imports of palms into uninfested areas are to be carefully screened and put in quarantine so as not to introduce another species of *Rhynchophorus* or even another strain of *R. phoenicis* into the region. Even within the sub region of a sub continent the movement of palm plant material must be monitored through effective quarantine regulations.

Plantation sanitation

Prevention of the infestation is essential, and the practice of good cultural techniques will protect the date plantation from infestation by weevils. Date palms are not to be stressed and appropriate irrigation and fertilisation programmes are to be respected. Removal of offshoots is to be properly implemented and the cut surface on the mother palm treated with PVC paint or a copper sulphate product. Soil is to be put around the base of the palm to protect the cut.

Over 80 % of weevil infestation occurs at the base near the offshoots or where offshoots have been removed. Palms that are stressed or damaged are vulnerable to attack and semi-chemicals emanating from these palms attract adult weevils.

Sanitation measures, such as the removal of dead palms or palms beyond recovery, are essential, as they are the ideal breeding places for the rhinoceros beetles that generally pave the way for entry of the palm weevil into young palms. Wounding of the palms, like cutting steps into the stem to facilitate climbing should be avoided. When the leaves are pruned, the grubs may tunnel their way into the stem through the cut end of the periole where eggs will be laid. Treatment of cut surfaces with PVC paint will ensure the control of infestation. Heavily infested date palms that can not be saved and the first infested palms of a healthy plantation are to be uprooted, burnt and buried outside the plantation to a depth of one meter. Growers must make sure that all weevils in the destroyed palm are killed. Many people do not like to be aggressive with phytosanitation, because of the investment in the palms, but the cost - if a weevil epizootic gets going - can accumulate to the loss of the whole plantation. Cut stumps and useless parts of the palm need to be destroyed in order to kill the early stages of the weevil. The holes and cuts made by the rhinoceros beetle constitute a favourable entry point to the weevil. These rhinoceros beetles must be attracted and destroyed by putting up mercury vapour light traps at regular intervals in the plantation.

Chemical treatment

In case the whole plantation is infested, the grower could extend the life of the palm and resulting production by practising the following:

- cuts and holes made by the rhinoceros beetle should be treated (potassium cyanide, carbon bisulphate, etc.);

- young galleries made by the weevil should be sealed with mud and aluminium phosphate application (poisonous fumes);

- the grubs should be destroyed within the holes by injecting the above mentioned poisonous fumes.

To kill adult weevils inside the date palm, injection of insecticide into the trunk or fumigation could be practised. Phostoxin tablets are placed in infested trunks then sealed with gypsum or cement. No further injections into palms have been carried out in Saudi Arabia and Egypt since 1994, because they were found to be ineffective. There is no evidence from any country that chemical spraying/injecting has any effect on the rate of weevil infestations. Adult weevils can disperse about one km/day, which makes the process of chemical spraying a difficult one. Chemical treatment has proven to be positive only on cut and injured surfaces which, without this chemical treatment, will offer entry points to the weevil.

Regular surveys

Infected and non infested areas need to be regularly surveyed, not only to detect and record new weevil infestations, but also to assess the health of uninfested plantations and the effectiveness of the adopted control measures. The frequency of these surveys depends on the life cycle of the weevil. Once a month during cold months, and twice a month during the early part of the warm season and summer time.

Pheromone mass trapping

The trapping and destroying of adults is a recent method of controlling the weevil. In the Middle East, where the attack by RPW is severe on date palm, pheromone-baited traps have been used for monitoring and for the reduction of the weevil population.

In 1993, a male produced aggregation pheromone was reported for *R. ferrugineus* and a pheromone-food trap was effective to capture large numbers of *R. ferrugineus* (Hallett et al., 1993a). Although males produce an aggregation pheromone that should attract equal numbers of males and females, the sex ratio of captured weevils is usually 3 - 4:1 in favour of females (Hallett et al. 1993b). It is worth mentioning that this mass trapping is successful only when combined with good sanitation and chemical control measures. It allows the reduction of the weevil population and the numbers of fl ying adults.

The use of pheromones have started in UAE (1993), in Oman and the Kingdom of Saudi Arabia (1994). Pheromone/food traps need to be placed where infestation is suspected/confi rmed at one (1) trap for each 100 meters. Traps need to be placed in the ground. According to Oehlschlager (1998), the best trapping results are obtained if: - the pheromone lure contains pheromone and plant produced synergists; - food (such as date palm stem pieces, date fruit, sugar cane, bananas and apples) is kept wet by frequent addition of water; and - traps are shaded to keep them wet.

Use of Nematodes

The natural enemies of the weevil do not play a significant part in the control of its populations. However, in the Middle East the use of an entomopathogenic nematode (*H. indicus*) of *Heterorgabditis* species or *steinernema* sp. is being investigated. Third stage infective juveniles of the nematode in a symbiosis with *Xeonorhabdus* bacteria attack the weevil (grub stage only).

6.7 Desert Locust (Schistocerca gregaria Forskal)

The desert locust occurs in all date growing areas of the Near East and North Africa and causes severe damage. Heavy migrations into date plantations are sporadic but may be devastating. The locust feeds on leaves and fruits of the date palm and may destroy the palm's canopy and leave the palm totally naked (Figures 131a and b). Young locusts feed on younger plants and small offshoots.

Swarms of locusts are usually measured in terms of square miles and occur throughout the Old World date-growing areas (Comelly, 1960; Perreau-Le Roy, 1958). In fact, a swarm of 50 square miles represents about 10,000 tons of locusts. In 1954 and during a two-week period, approximately 10,000 square miles of locust swarms invaded the Souss-Valley of Morocco and caused extensive damage to plantations and other crops (Djerbi, 1983). A similar disaster affected Israel in 1958 - 59 with a locust invasion that lasted 14 days.

To recover from a severe locust attack, a date plantation needs at least three years - under optimal growing conditions - to reconstitute its canopy. Within such period the fruit yield is of course heavily affected. Chemical control is effective if applied properly and well timed to kill locusts before they attack date palms. The use of aerial spraying on both ground and flying swarms of locusts (subspecies: gregaria) has been successful since 1959.

6.8 Rodents

Two types of rodents cause damage to date palm: The black rat (*Rattus rattus*) and the house mouse (*Mus musculus* L).

The black rat and the house mouse are usually in the field and storage area, and feed exclusively on date fruits. Besides damaging date fruits, rodents could also cause the following:

- establishment of underground galleries that threaten the traditional canal irrigation system and sometimes damage it;

- feeding on offshoot roots which affects their survival (Figures 132a and b). It also feeds on roots of old palms causing them to fall down if feeding was only on one side of the palm and wind was severe;

- feeding on recently emerged infl orescences.

There is only one control measure, that is by using poison. A mixture of zinc phosphate at 30 to 50 g with 1 kg of millet fl our and 3 % of cooking oil. The paste is to be placed around the palms at the entry to the galleries. A chemical product "Finale" gave excellent results at the Eersbegin project (Namibia). It is a highly active anticoagulant bait at 0.025 g/kg as an active ingredient. The death of rodents takes 4 to 12 days. The chemical was recently used (July and August 1997) in both the Eersbegin and Naute date plantations (Namibia) with a sound success rate against *Mus musculus*.

6.9 Termites (Microcerotermes diversus)

Termites usually feed on cellulose matter and the attack starts from the root zone and base of the offshoots by making vertical canals through it, or building soil-canals on it, allowing them to reach the stem. Where termites are found, they usually cause the death of newly planted offshoots. They may also make galleries in the trunks of weak palms and cause them to collapse.

Control measures could be started by removing and burning destroyed offshoots. In case of a slight attack, it is recommended to clean the offshoot of soil canals and spray it with a termite killer (Dursban or Hostathion). It is also advised to turn over the surrounding soil to about 50 cm deep in order to destroy these canals and treat them with a nematicide product (which will certainly kill all termite species).

6.10 Other pests of date palm

Because they are minor pests and/or do not cause damage of any economic importance, the following pests are not detailed in this chapter. The reader is invited to read more specialised references such as Hussain (1974) El Bekr (1972), and Djerbi (1983).

- Fig Beetle, also called Green Fruit Beetle, *Cotinis texana* (Casey);

- Indian Meal Moth, *Plodia interpunctella* (Hbn).;

-Almond Moth, *Ephestia calidella;*

-Lesser Date Moth also called Hmira, *Batrachedra amydraula,* Meyr (Figure 133);

-Dubas, *Ommatissus binotatus* var. *Lybicus,* De Bergevin (Figures 134, 135 and 136);

-Raisin Moth, *Cadra figulilella,* Greg;

-*Arenipses sabella* Haps;

-Stem Borer, *Jebusaea hammerschmidtii* Reiche (Figure 137);

-Fruit Stalk Borer, *Oryctes elegans;*

-Frond Borer, *Phonopate frontalis,* fahraeus;

-Date Stone Beetle, *Coccotrypes dactyliperda* F.;

-*Apathe monachus* Fabricius;

-Inflorescences Pest, *Carpophillus obseletus,* Erichson;

-Merchant Grain Beetle, *Oryzaephilus mercator* (Fauv);

-Mealy Bugs, *Muconellicoccus hirsutus* Green;

-Saw-Toothed Grain Beetle, *Oryzaephilus* surinamensis (L.);

-Oriental Wasp, *Vespa orientalis* L.;

-Yellow Wasp, *Polistes hebroeus* F.;

-Spotted Yellow Wasp, *Polistes gallicus* L.;

-Palm Bud Mite, *Mackiella phoenicis* K.;

-Bettle Mite, *Mycobatus sp.;*

-Palm False Spider Mite, *Tenuipalus eriophyides,* Baker (Figure 138);

-Leaflet False Spider Mite, *Raoiella indica* Hirst.;

-Other pests of stored dates: *Tribolium castaneum, Tribolium confusum, Trigoderma granarium* and *Cryptolestes ferrugineus.*

6.11 Nematodes

Root-knot nematodes *(Meloidogyne spp.)* are widely distributed in date palm plantations, but the amount of damage caused to fruit bearing palms has not been determined (Carpenter, 1964). Nematodes are spread most readily by offshoots, which, if growing below the soil surface, may be infested while attached to the mother palm. Nurseries provide a second source of infestation of offshoots. Root-knot nematodes have such a wide range of cultivated and weed hosts that their control in date plantations has not been attempted. Dowson and Pansiot (1965) state that nematodes in the Old World date palm plantations do not appear to have been studied. It is possible that much of the unhealthy growth of palms, generally attributed to other causes, may be due to nematode attack.

6.12 Weeds

Weeds are plants that grow with date palms and act as competitors for food or serve as alternate hosts for insects and diseases (Figure 139). Numerous studies have established that weeds cause more damage than insects and fungi combined. They cause damage through reduction in yields, loss of nutrients and water, shading effect, increase in the cost of production and decrease in the quality of fruit and by acting as alternate hosts to other harmful organisms.

The most common weeds are: Haifa *(Imperata cylindrica),* Bermuda grass *(Cynodon dactylon), Cyperus spp., Chenopodium spp., Juncus* sp. and Johnson grass. Many other weeds of minor importance can be found in a date plantation.

A big obstacle in the adoption of effective weed control measures is the general lack of awareness of the impact of the damage caused by weeds. Various control attempts have been conducted to reduce weed damage. These include hoeing, ploughing, and chemical control. Improved weed management should be emphasised (FAO, 1995).

For further information, the reader is referred to the following references:

- Date Palm and Dates with Their Pests (Hussain, 1974);

- Diseases of the Date Palm (Djerbi, 1983);

- Bayoud Disease of Date Palm (IAEA, 1996); and

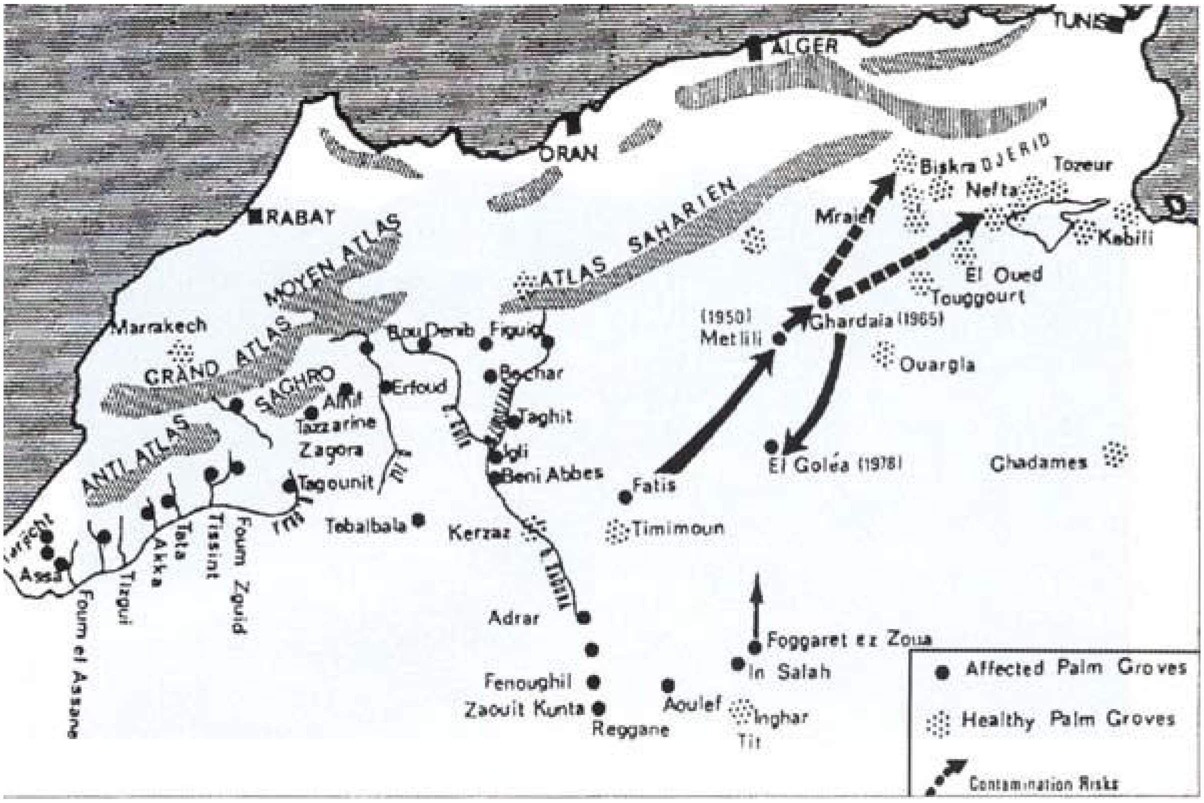
- Technical Leaflets Produced Within the Framework of the Date Production Support Programme UTF/NAM/004/NAM (1995-1999).

Figure 90. Spread of Bayoud disease in Moroccan date plantation

A - During early years of attack

B - Later when most palms die and desertifi cation takes over

Figure 91. Spread and distribution of Bayoud in Algeria (1982)



(Source: Djerbi, 1983)

Figure 92. Bayoud symptoms appear on one or more leaves of the middle crown.

Figure 93. Unilateral progression of the whitening and dying process on one side of the frond.

Figure 94.

A - Bayoud symptoms advance to the central cluster;

B - The palm dies when the terminal bud is affected

Figure 95.

A - Black scorch (*Thielaviopsis paradoxa*) symptoms on the attacked young frond;

B - See dwarfi ng effect on a young frond of one year old tissue culture-derived Medjool palm at Naute (Namibia)

C - Effect on four year old tissue culture-derived Medjool plant;

D - Late stage of attack**.**

Figure 96. Brown leaf spot caused by *Mycosphaerella tassiana* (De Note) John at three different stages of attack:

A - early;

B - medium;

C - late.

Figure 97. Diplodia disease caused by *Diplodia phoenicum.*

Note the characteristic of the symptoms at an early stage of infection.

Figure 98. Fruiting structures called sori of the Graphiola leaf spot.

Note it is on both sides of the pinnae.

Figure 99. An open spathe showing the attack by *Mauginiella scaettae*

Figure 100. An adult date palm with a dead terminal bud fully destroyed by Belâat Disease

Figure 101. Conical wet heart rot of the terminal bud caused by *Phytophtora* sp. (Belaât)

Figure 102. Early stage of checking - Fruit rot caused by the high humidity around the bunch

Figure 103. Lethal yellowing in Florida on coconut palms (*Cocos nucifera* L.)

(Courtesy of Dr. McCoy)

Figure 104. First symptom of Al Wijam disease.

Note yellow streakings on date palm rachis

Figure 105. Date Palm leaves showing different degrees of attack by the "Brittle Leaves" disease

Figure 106. Declining date palms affected by the "Brittle Leaves" disease

Figure 107. Cross cuts symptoms appear as clean breaks:

A - in the tissue of the fruit stalk's base

B - on fronds. **(Case of Jarvis Male)**

Figure 108. Barhee disorder.

Note the iron bar fi xed to the opposite side of bending

Figure 109.

A - Bastard offshoots on a tissue culture-derived Barhee palm;

B - A close-up on the same palm

Figure 110. Symptoms of leaf apical drying caused by transplanting adult palms

Figure 111. Salt stress shown on a seedling date palm at Guanikontes (Namibia)

Figure 112. Full coverage of the palm leafl et and rachis by the white schale (*Parlatoria blanchardii* Targ)

Figure 113. Full coverage of date fruits with *Parlatoria blanchardii* Targ

Figure 114. ***Parlatoria blanchardii*** **Targ**

Note female (1.8 mm of length × 0.7 mm in width) and male (1 mm in length × 0.4 mm in width) scales.

Figure 115. Cycle of white scale (*Parlatoria blanchardii* Targ.)

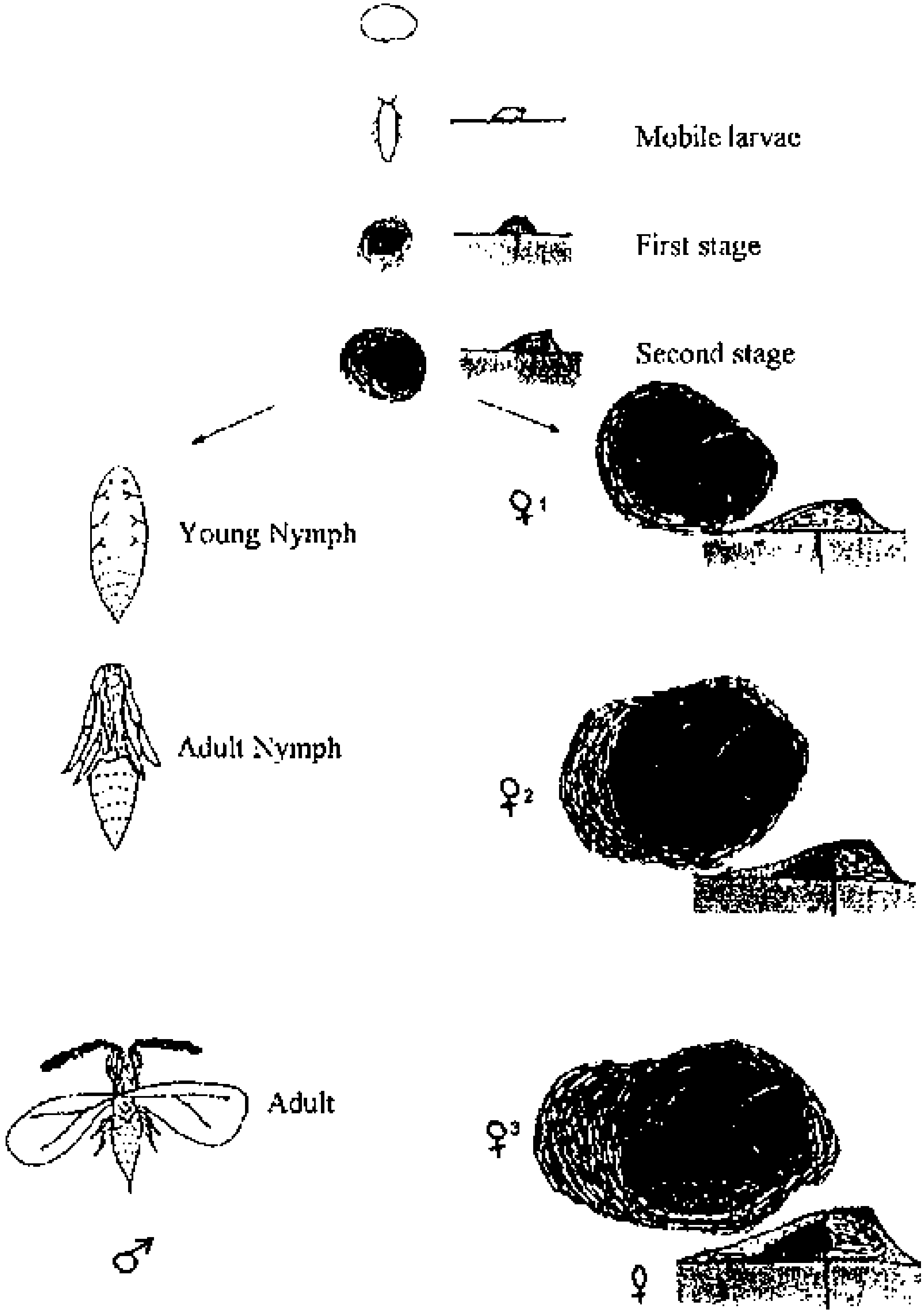


Figure 116. Biological control of the white scale using *Chi-locorus bipustulatus* (Courtesy J. Brun)

Figure 117. Red scale attack on tissue culture-derived plantlets, caused by *Phoenicococcus mar-latti*;

A - early stage of attack;

B - fi nal stage

Figure 118. Bou Faroua disease.

Note the silky web surrounding the fruits

Figure 119. Bou Faroua disease (*Oligonychus afrasiaticus*)

Note the abundance of fi laments covering the fruits.

Figure 120. Rhinoceros beetle: *Oryctes rhinoceros Linné*

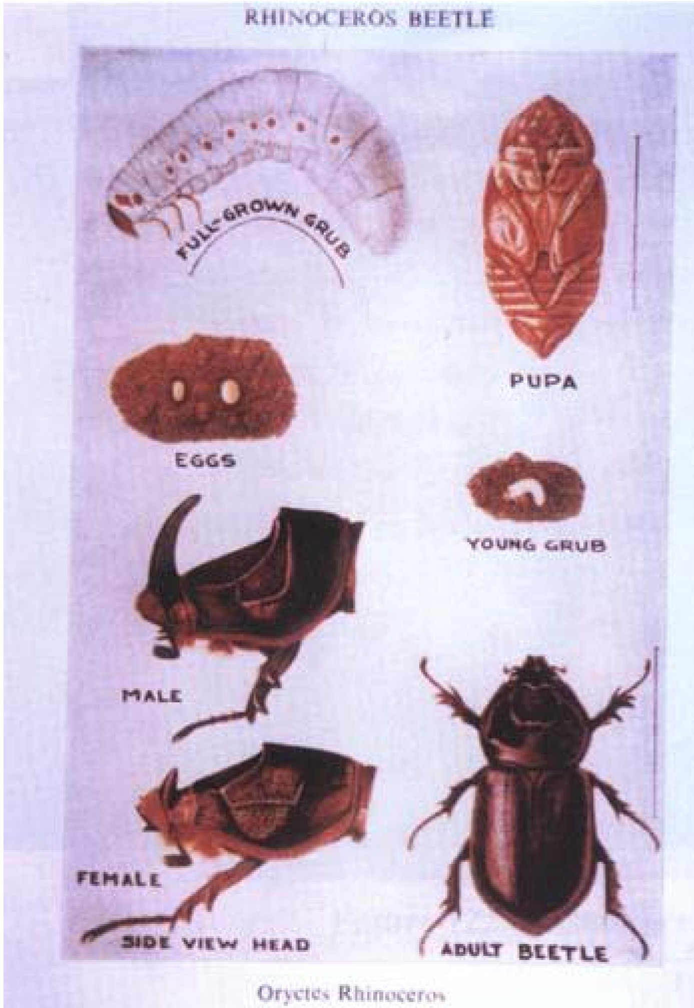


Figure 124. Red Palm Weevil: ***Rhynchophorus ferrugineus Oliv***

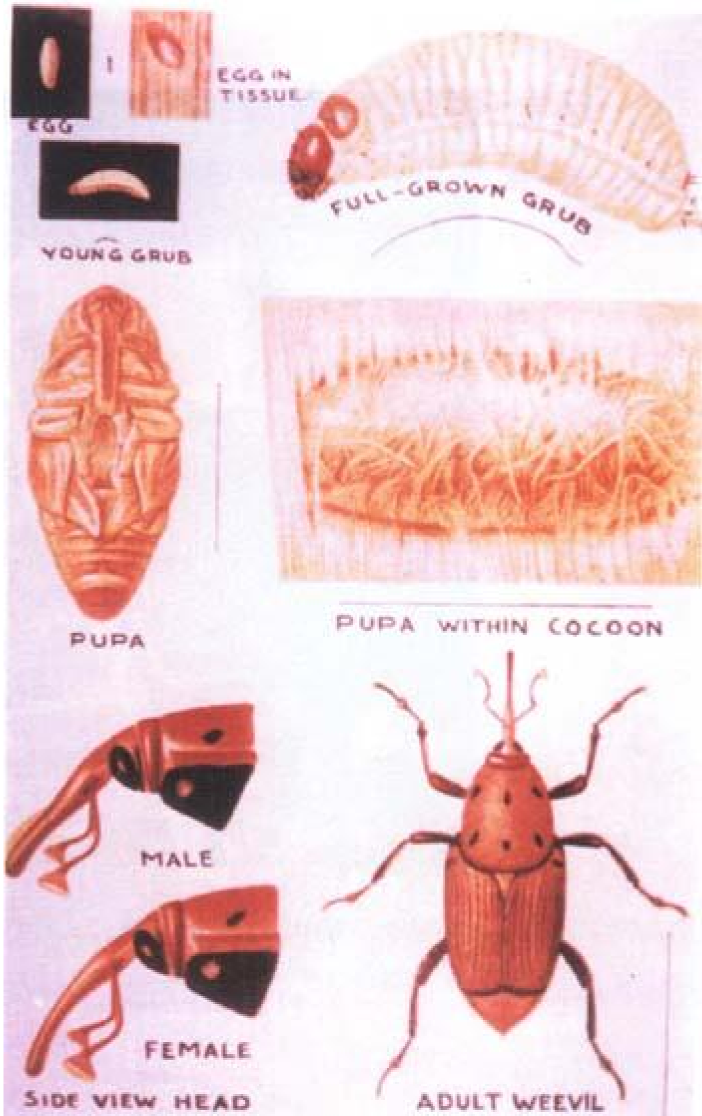


Figure 121. Damage caused by rhinoceros beetle to:

A - young infl orescence;

B - fruit bunch;

C - palm frond

Figure 122. Tissues are thrown as a fi brous dry mass

Figure 123. Mercury-vapour light trap

a - Impact metal panels
b - Funnel
c - Roof
d - Insect collector
e - Mercury vapour light bulb

Figure 125. Male (left) and female (right) African Palm Weevil (*R. phoenicis F*)

Note the difference in sizes between the two sexes; also note that the male rostum is hairy

Figure 126. From left to right: young grub, full grown grub, pupa and adults (male and female)

Figure 127. Date palm (Medjool variety) heavily infested by African palm weevil (*R. phoenicis F.*)

Note the palm is beyond recovery

Figure 128. The build up of galleries by weevils (grubs and adults) resulted in the destruction of the whole stem of the date palm

Figure 129. Chewed up date palm's fi bres being extruded. A characteristic rotting odour could be smelt.

Figure 130. At the palm leaf base several cocoons are lodged

Figure 131. Desert locust attack on date palm tissue culture-derived palms

A -Two-year old Medjool;

B - Six-year old Barhee

Figure 132. Underground galleries made by rodents.

A - At early stage;

B - later stage of attack **(Eersbegin, July 1997)**

Figure 133. Lesser date moth, also called Hmira, *Batrachedra amydraula* Meyr.

Figure 134. Dubas, *Ommatissus binotatus* var. *Lybicus*, De Bergevin.

Figure 135. Dubas larvae of *Ommatissus binotatus* var. *Lybicus* at different stages on a leafl et of date palm.

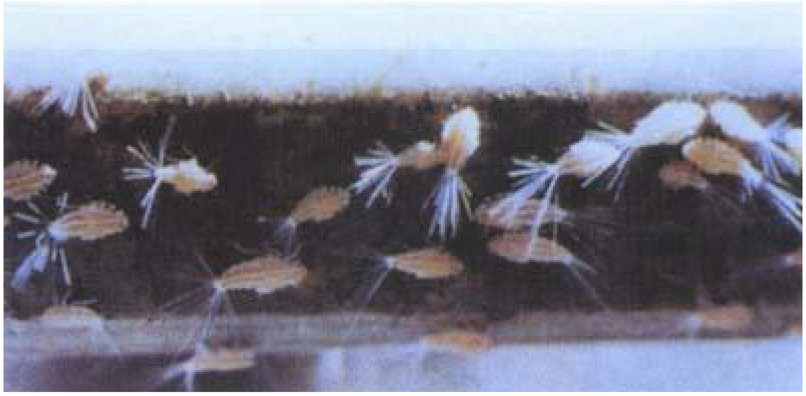


Figure 136. Dubas adult female (Length: 5.5 mm).

Figure 137. Stem Borer, *Jebusaea hammerschmidtii* Reiche. Note the intensity of damage on this seedling date palm trunk.

Figure 138. Palm false spider mite, *Tenuipalus* eriophyides. Baker.

Figure 139. Weeds infestation on one-year old tissue culture-derived Medjool plant.

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BACK COVER

This publication, which was produced within the framework of the Date Production Support Programme in Namibia, updates and complements technical information included in earlier FAO publications: *Dates: handling, processing and packaging* (1962) and *Date production and protection* (1982). It should serve as a reference volume for research workers and a source of much more detailed information for extension specialists, date growers and anyone interested in the date palm industry. The 12 chapters of the book cover the botanical and systematic description, origin, geographical distribution and nutritional value, economic importance, climatic requirements, orchard management, harvesting, and diseases and pests of date palm.