

Proceedings

Workshop on “Irrigation of Date Palm and Associated Crops”

In collaboration with

Faculty of Agriculture, Damascus University

Damascus, Syrian Arab Republic, 27-30 May, 2007

Food and Agriculture Organization of the United Nations,

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Foreword

The Near East Region represents the origin of date palm development, dating back to 4000 BC, and holds a vital socio-economic heritage. At present, the region hosts around 800,000 ha of date palm representing 1.5% of the total irrigated area in the region and 90% of the world production of dates.

In most countries of the region where date palm is grown, water scarcity and quality deterioration are constraining its sustainable development. The scarcity level varies from one country to another but the date sector is generally characterized by traditional practices, leading to very low productivity and the wastage of high amounts of irrigation water at the field level. The sector also faces several other problems and constraints such as the lack of adequate pest and disease control.

To assist countries in addressing these issues, FAO has given a particular attention to the date palm sector over the past few years. The creation of the Date Palm Global Network since 2003 and its continuous support have increased communication and exchange of experiences among date producing countries. Furthermore and in response to several appeals by FAO Member Countries, FAO Regional Office for the Near East has taken the initiative of assessing the experience in date palm irrigation in view of elaborating practical guidelines on water management for date palm production and developing technical capacities to adequately manage date palm irrigation. The process started with pilot studies on the irrigation of date palms and associated crops in all major date producing countries in the region and was followed by a workshop on the subject, organized in collaboration with the Faculty of Agriculture, Damascus University, Syrian Arab Republic, in May 2007. In addition to invited experts who conducted the studies, the workshop was also attended by representatives of several national institutions as well as regional and international organizations involved in research on crop water management.

The workshop was dedicated to taking stock of the country assessments and experiences of the participating organizations, sharing experiences between countries regarding success stories, identifying the major constraints facing the irrigation of date palm and making recommendations for follow-up activities and cooperation with a view of assisting Member Countries to address the issues identified.

The proceedings of this workshop presented here are arranged in two parts. The first part provides a state of the art summary of irrigated date palm production in the Near East Region, with information from the country studies, highlighting the actual knowledge of date palm irrigation with consideration of water requirement, water use, productivity, irrigation agronomy, irrigation methods and institutions. The second part presents summaries of the country papers (Algeria, Egypt, Iran, Libya, Morocco, Oman, Saudi Arabia, Tunisia, United Arab Emirates and Yemen), harmonized and structured as follows: i) General overview, ii) date production, iii) water resources, iv) water requirements, v) irrigation and agricultural practices vi) and research and institutions. The original country studies will be included in the electronic version of the proceedings in a CD.

The issues and challenges related to the irrigation of date palm and associate crops were widely discussed during this workshop, with special consideration to agricultural water use efficiency (technical, agronomic and economic aspects). The workshop made a set of relevant recommendations, with a specials inference to the need to develop and implement a project that would compile existing information and knowledge as well as good practices and research results from the various countries and bring them together in the form of a practical manual on the irrigation of date palm, with due consideration to the main factors where this crop is grown, with a view of optimizing water use and economic profitability. To guide the process, participants to the workshop split in two working groups and elaborated the profiles of two regional projects. A compilation of these profiles is summarized in Annex I.

Acknowledgements

The workshop would not have achieved its objectives without the collaboration of many. The experts made great efforts for gathering data and information, producing country reports and actively participating to the workshop deliberations. Mr. Melvyn Kay, FAO Consultant, prepared the country syntheses presented in these proceedings based on the information provided in the lengthy original country papers. The representatives of ACSAD, ICARDA and FAO made useful presentations that enriched and enlarged the scope of the discussions. The participants from research institutions and the host country brought their experiences and views to the discussions. Sincere thanks are extended to all.

The University of Damascus in general and its Faculty of Agriculture in particular made excellent arrangements for the smooth organization of the workshop. Specials thanks are expressed to the management of both and to the staff that contributed one way or another.

Thanks are also due to FAO Officers, staff and resources persons for their efforts throughout the lengthy process, from launching the idea of the study on date palm to the editing of these proceedings.

Questions and queries on this publication can be addressed to:

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Recommendations

The participants recommended that countries should provide guidance for future policies and actions and create awareness and momentum for addressing the issues related to the irrigation of date palm and associated crops identified by the workshop.

Very little is known about actual water requirements of date palms and how the crop responds to deficit irrigation and to low quality water. These and other aspects of water management for date palm irrigation should have more attention in research programs in the Near East region.

With the data presently available, care should be taken when interpreting estimates of production, number of palm trees, and water use. There are several unknown factors which can affect the estimates made of productivity.

Realistic in-depth assessments of the current levels of irrigation water use, the performance of irrigation systems and the way farmers and system managers manage irrigation are needed.

Water shortage in the region is continuously increasing and negatively affecting particularly date palms which constitute the basis of ecosystems in desert oases. As such, date palms are essential for the production of other crops and their sustainability can be achieved only if the available water resources are managed adequately which is not the case at present.

New technologies designed to improve water use efficiency and date palm productivity exist but are largely unknown among date palm growers. This implies the need for capacity building among farmers and by implication of the institutions that support them.

Enhanced network capabilities on date palm production and information exchange can greatly improve capacity building at all levels in the region and should be sought.

There is an urgent need for the implementation of a project that would compile information, existing knowledge, and good practices and research results from the different countries and bring it together in the form of a practical manual on the irrigation of date palm, with due consideration to the main factors where this crop is grown, with a view of optimizing water use and economic profitability. The project would also provide and opportunity for the provision of training and institutional capacity development in the field of date palm irrigation.

1 Irrigated date palm production in the Near East

1.1 Introduction

History shows that dates have been a traditional crop for many centuries in the hot, arid regions of the developing world, especially the Near East. Not only have dates provided abundant food and nutrition for people and animals, the palms themselves have provided materials for building and thatching roofs and for household utensils. Dates also play an integral role in the daily cultural and religious life of people in the region. In Iran for example, growing dates bestows authority on farmers and gives them a sense of pride. Dates also perform an important socio-economic role. Date palm cultivation is a labour intensive industry which makes a valuable contribution to improving and sustaining livelihoods in poor rural areas. Agro-industries surround the main date producing areas to process and pack dates for local markets and for export and this creates jobs, particularly for women. In Egypt the date industry supports over one million people and it is estimated that a 40ha commercial date plantation requires some 8,000 working days a year. All this can help to stem the flow of people from the rural areas into the cities.

But the association of date palms with aridity has led to misunderstandings, often held among farmers that palms can grow and bear fruit in drought conditions and do not require much water. There is of course truth in the resilience of date palms to survive through prolonged dry periods but the reality is that palms do need considerable amounts of water to flourish and produce marketable fruit, particularly for export. The misconceptions about water come from the fact that many date palm plantations are located in oases or along field margins and so they get their water from the naturally occurring shallow groundwater or seepage from canals. But whatever the source of supply – be it naturally occurring or from irrigation – for every cubic meter of water used by date palms there is one cubic meter less for other purposes. So in the Near East, where water is in short supply and water poverty is common place, the amount of water allocated for date palms is of strategic significance for the management of national water resources. For farmers, who rely on date production for their livelihood, it is vital that they make best use of every cubic metre of water and maximise their productivity.

In spite of the importance of dates in the region there is surprisingly little information available and published on the amount of water consumed by date palms, the effectiveness of on-farm water management practices, and the quality of water management support services available to farmers to promote the productive use of water. Each country pursues its own research on water use and farmers adapt irrigation technologies to suit their local needs but very little is published so that others may benefit from the experience. To find out more about what is happening across the region, FAO commissioned country studies in Algeria, Egypt, Iran, Libya, Morocco, Oman, Saudi Arabia, Tunisia, United Arab Emirates, and Yemen.

This part of the report is a synthesis of the information obtained from these country studies. It attempts to address the key questions of date palm irrigation – How much water do date palms need? What are the critical water demand periods? How tolerant is date production to poor water irrigation quality? What are the most appropriate irrigation methods to use? What are the best soil and water management practices for farmers to adopt in order to ensure high levels of water use efficiency? But equally important are questions about the support that farmers need to grow dates productively. What institutional structures are in place or are needed to improve the capacity of farmers to take responsibility for water management and to adopt modern and efficient irrigation practices?

1.2 Date production

1.2.1 Market challenges

Some 6.7 million tonnes of dates are grown annually, principally in the Near East where production has been increasing rapidly since the early 1990s (Table 1). Egypt, Iran, and Saudi Arabia now account for almost half the total world production. Only in Iraq (because of the trade embargo and the conflict) and Morocco (because of phyto-sanitary problems) has output decreased.

Most dates (over 90%) are grown for local consumption and are extremely important as a subsistence crop. The remaining 10% (over 500,000 tons) are exported annually – the main net exporters from the region being Iran, Tunisia, Algeria, and Saudi Arabia. Tunisia and Algeria have focused on the high value confectionary market in Europe. In 2006 Tunisia exported some 30% of production (43,000 tons) to Europe. Iran and Saudi Arabia have concentrated on the bulk export of low quality dates mainly to Asian countries such as India.

* Table 1 Main date producers in the Near East (000s tons)

	1991	2001	% change	2006	% world production
World production	3,717	5,353	43	6,700	
Egypt	603	1100	67	1600	21
Saudi Arabia	528	712	35	970	18
Iran	634	900	42	960	18
Iraq	566	400	-29	Not known	Not known
Algeria	209	370	75	520	9
Sudan	140	177	26	330	6
Oman	135	260	93	244	4
Libya	Not known	Not known	Not known	150	2.4
Tunisia	Not known	105	Not known	133	2.4
Morocco	107	32	-31	64	0.8
United Arab Emirates	Not known	30	Not known	50	0.7
Yemen	Not known	Not known	Not known	29	0.6

NB: This table is compiled from various FAO sources together with data provided in the country reports.

Is this growth in demand for dates going to continue? The future looks uncertain. The home market for dates in the Near East may well continue to grow steadily in some countries, particularly to offset the loss in production in Iraq, once a major producer. But there are concerns in some countries (Iran and Oman) about the low price of dates in the local markets and the sustainability of production beyond using dates as a subsistence crop. There are also questions about the international market. Will the market for low value dates continue to grow through increased demand from countries such as India? Will the high value end of the market continue to flourish in the Near East as more sophisticated producers in the USA and the southern hemisphere enter the market?

Only time will provide the answers to these questions but clearly the limited availability of water resources will impact on the ability of countries in the Near East to respond to any increases in the future demand for dates both in terms of quantity and quality.

1.2.2 Challenges facing primary producers

Looking at date production from a producer's point of view, an invited group of scientists, specialists and representatives from the Gulf Cooperation Council (GCC) countries met in 2004[1] to discuss the challenges facing primary producers. They highlighted several priority research areas to support date palm development:

- Identification, classification and finger printing of the local varieties
- New techniques for variety improvement including gene transfer to improve adaptability to salinity, drought and pest resistance
- development of proper IPM programmes
- Improvement of agro-management techniques **especially in the area of irrigation**, fertigation, pollination, fruiting and mechanization of tree services

[1] A regional workshop on date palm development in the Arabian peninsular, Abu Dhabi and UEA (ICARDA 2004)

- Development of post-harvest techniques to improve marketing at the off season period and techniques for utilizing date palm traditional and new value-added products
- Build up of an expert system for date palm production
- **Capacity building of NARS and growers in the area of date palm agro-management**
- **Enhance networking capabilities for the exchange of information, databases, services derived from the project activities**.

The importance given to each of these issues by the different GCC countries (Table 2) indicated that crop management, which includes irrigation water management, is high on the list of priorities. The meeting suggested that very little is known about actual water requirements of date palms, and how they respond to deficit irrigation and to low quality water. They also concluded that new technologies designed to improve water use efficiency and date palm productivity where largely unknown among farmers. This highlighted the need for improved capacity building among farmers and by implication the institutions that support them. The need for enhanced network capabilities on date palm production, and information exchange was also identified as important to improving capacity.

*Table 2 Priorities for different themes as ranked by GCC country representatives (1 stands for highest priority)

Topics	Bahrain	UAE	Kuwait	Oman	Qatar	KSA	Ave
Propagation & crop management	2	1	3	3	3	2	2.3
Crop Protection & IPM	3	2	2	2	2	1	2
Post Harvest & processing	4	1	4	1	4	4	3
Biotechnology & germplasm Conservation	1	2	1	-	1	3	1.3
IT & expert system	5	2	5	-	5	5	3.66

Source: ICARDA 2004

1.3 Concerns about water

Countries in the Near East region suffer from severe water shortages with some 16 countries below the internationally accepted 'water poverty limit' of 500m^3/capita/yr compared with a global average of 7,000m^3/capita/yr. They have rising populations demanding more water per capita and they rely heavily on irrigated agriculture, which in many cases absorbs more than 80 percent of the available water resources for economic growth, employment and food security. Over the past half century planners have responded to water shortages by increasing the supply. They commissioned water resources studies, projected future demand on an unconstrained basis, looked for supply augmentation options, and implemented schemes through public agencies often at subsidized prices. But this policy of making more water available is no longer viable today. Many countries are now consuming most of their renewable and even non-renewable water resources. Competition from domestic and industrial water users and the environment is growing and this is putting pressure on agriculture to 'release' water for other uses rather than use more. As supply options reach their limits attention is shifting from supply to demand. Can the water demand from agriculture be reduced? Can existing supplies be used more efficiently and productively on the farm? What steps are needed to encourage this? What are the implications of this for farmers and irrigation managers? As one workshop delegate put it – the emphasis now is not on 'more crop per drop' but on 'more crop per less drop'.

These concerns over water and its generally poor management in the agricultural sector is good reason to focus on those crops that consume significant quantities of water and ask if there are ways in which it can be used more effectively to increase the productivity of water i.e. to improve the productivity of each cubic meter of water. The advent of climate change and concerns about 'exporting' water crops only adds to these uncertainties.

From the country studies a conservative estimate of the number of date palms in the region is 120 million (Table 4). It is estimated they use between 13,000 and 26,000Mm^3 of water each year – an average of 19,500Mm^3. This is a significant amount of water – equivalent to one third of the Nile water allocation for Egypt (55,000Mm^3) and more than the entire Nile allocation for the Sudan. A significant amount of water is also 'exported'. For example, Tunisia exports 43,000 tons of dates to Europe, which effectively means exporting 42Mm^3 of water that was used to grow them.

In these circumstances a focus on date palm irrigation is justified to inform future water policy in water-short countries. Dates are a long-term crop and farmers cannot easily opt in and out of dates in response to the vagaries of the climate and available resources in the same way they can with annual crops. So long term planning for date production and water use is essential.

1.4 Water requirements and productivity

Palms need water to grow and produce dates whether they are irrigated or not. They use valuable and scarce water resources – some take up shallow groundwater from naturally occurring oases while others require irrigation often pumped from deeper groundwater or from surface streams.

There are few data on date palm water use published internationally. An FAO source lists the main date producing countries together with estimates of annual water consumption (in m^3/ha) (Table 3).

* Table 3 Annual water consumption for dates (m^3/ha)

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	25,000 - 32,000
Morocco	13,000 - 20,000
South Africa	25,000
Tunisia	23,600

Source: FAO Date Palm Cultivation (2003)

* Table 4 Water use and productivity of date palms from country studies

Place	Production (1000 t)	Area of date palms (ha)	Ave yield (t/ha)	No of palm trees (million)[3]	Ave yield (kg/palm)	Annual gross water use (m^3/ha)[4]	Annual gross water use (m^3/palm)	Productivity (kg/m^3 of water)
Egypt	1160	95,000	12.2	11.5	102	10,280-14,880	86-124	2.28-3.31
Saudi Arabia	970	150,800	6.7	22.62	43.2	18,180-42,600	150-350	0.15-0.37
Iran	960	239,000	4.2	28.68	34.7	12,270-19,720	102-164	0.21-0.34
Algeria	520	147,900	3.5	16.5	31.5	5,200-25,400	43-210	0.14-0.67
Iraq[1]	400	Not known	Not known	12.7	35	Not known	Not known	Not known
Sudan	330	Not known	Not known	9.4	35	Not known	Not known	Not known
Oman	244	31,350	4.5	7.4	35.6	21,950-29,320	183-240	0.15-0.21
Libya	150	29,000	5.2	3.5	42.8	7,200-29,700	60-247	0.18-0.72
Tunisia	133	33,000	4.2	4.5	29.6	12,000	100	0.28
Morocco	64	13,700	4.7	2.1	29.6	12,600-23,900	105-200	0.21-0.4
UAE	50	18,500	2.7	2.2	24.7	15,500-20,740	130-173	0.20-0.26
Yemen	29	13,740	4.2	1.6	18	20,000-26,000	176-217	0.13-0.16
Total	5,010	771,990		122.7				
Average[2]			4.2		32.6	13,500-24,400	112-203	0.18-0.37

[1] Data from Iraq and Sudan are not available but in view of their importance as date producers, an estimate of the number of trees has been made on the basis of production in 2001 in the case of Iraq and 2007 for Sudan.

[2] Averages do not include Egypt which reports yields much higher than the other countries for reasons given in the text.

[3] The number of productive palms may be less than the total number of palms grown in some countries. In the absence of clear data on this, the table lists the total number of palms in each country. The exception to this is Morocco. Only half the palms are productive because of disease and so only the number of productive palms is listed. Where the number of palms is not given an estimate was made assuming 120 palms/ha.

[4] A range of water use data are available for each country. Although not confirmed it is likely that the higher figure may include intercrops as well as date palm water use.

In contrast to the dearth of published information, the country studies provide much more data on water consumption and also production. These are summarized in Table 4 with estimates of production, number of palm trees, and water use. From these data the average productivity per hectare of land, of individual palms, and of each cubic meter of water were estimated.

Care is needed when interpreting these data as there are several unknown factors which can affect the estimates made of productivity.

- Egypt reports very high average yield compared to other countries. This is said to be due to good access to water by palms growing along the Nile valley and that more than half the production is soft dates which means fruits contain 40-50% water at harvest. For this reason average production figures do not include Egypt as this would distort the picture for the rest of the region.
- The figures quoted for planted area do not always make clear the density of planting. This is particularly important for tree crops and in the case of palms the planting density can vary from as little as 100 palms per hectare up to 200 palms per hectare. Where this is not stated in the country studies an average of 120 palms per hectare is used to estimate the number of palms.
- In most countries dates are not always planted as plantations in a regular grid layout. Rather they are planted along canals and field margins. In Egypt for example some 6 million productive palms are planted in this way. This makes an assessment of the area planted to dates rather problematic.
- Not all the date palms in a country are productive. In Morocco for example, there are 4.8 million trees but only 2.1 million are considered to be productive. In Iran only 199,000ha out of a planted area of 239,000ha are productive. But not all countries provide data on productive and non-productive palms and so only total palm numbers are quoted (with the exception of Morocco whose palms have been ravaged with disease and are unlikely to recover in the medium term).
- Many countries plant an intercrop between the palms and do not usually differentiate between water for the palms and water for the intercrop. So it is likely that the higher figures given in Table 4 include the water use by intercrops as well as date palms.

All these factors, only serve to confuse the picture of water use by date palms but it is considered that Table 4 provides the best estimate available at this point in time. It provides a useful guide and benchmark for what is happening in the region.

One way of overcoming the confusion about data on water use created by planting density and intercropping would be to quote the amount of water used by individual palms rather than as a water duty in cubic meters per hectare.

1.4.1 Productivity

Date production is usually quoted in tons or in terms of productivity to land in tons/ha (Table 4). But as water is the limiting resource it is more pertinent to examine the production of dates to water rather than to land. In Table 4 productivity to water is calculated using the average yield in tons/ha divided by the annual gross water use in m^3/ha producing a value in kg/m^3 of water. This illustrates where the best value for each cubic meter of water can be obtained. The highest productivity is in Egypt at 1.28-3.31kg/m^3 of water. This is significantly greater than all the other countries for reasons given earlier. The range for other countries produces an average of 0.18-0.37kg/m^3 which provides a useful benchmark to guide decision-making on water use.

An assessment of the average productivity per palm is also shown in Table 4. This is based on estimates of the number of productive palm trees in each country and the total production. Egypt again shows the highest productivity per tree. There are some 11.5 million palms producing some 1.1 million tons of dates and this produces an average yield of 102kg/palm. This is a very high figure compared with the world average of about 50kg/palm. The average for the rest of the countries is 32.6kg/palm.

At a more local level two studies, one in Saudi Arabia and a second in Oman, both reported that maximum production occurs when palms are given their full water requirements but maximum productivity occurs at a much lower level of water supply – sometimes as low as 50% of the water requirement is given. This result could have significant implications for planning future water resources for date palms particularly when water is short and the market for dates is not good.

1.4.2 Calculating water requirements

Most countries assess date palm water requirements using some form of theoretical calculation, such as the Penman formula or Class A pan data. Some make assumptions about the efficiency of the irrigation method to arrive at gross water requirements. This is because very few actual data are available from field or lysimeter experiments – which are not so surprising considering the challenges of growing mature date palms in a lysimeter over many years.

The data available on crop water use varies considerably from one country to another and even within a country, principally as a result of the differences in climate. Algeria for example, reports that water demand for mature trees varies from 1,260mm/yr in Batna, a significant date growing area in the north, to 3,130mm/yr in Adrar in the much drier south. This equates to an annual water demand of 12,600m^3/ha and 31,300m^3/ha respectively – an average of 22,000m^3/ha. Figures are quoted for maximum water demand in July of 580 l/day/palm in Batna and 1,190 l/day/palm in Adrar based on a typical planting of 120 palms/ha.

Egypt also reports considerable variation in water demand across the country. Dates grown in Lower Egypt use an average of 10,280m^3/ha whereas in Upper Egypt average consumption rises to 14,880 m^3/ha.

Estimates of water use for Morocco have increased over the years. In 1993 FAO suggested a theoretical water supply of 8,000-14,000 m^3/ha for palms planted at 100 palms/ha. Later, in 1997 local scientists amended this to 12,600-13,900 m^3/ha. Although not specifically stated it is assumed that these are gross water requirements and some value for irrigation efficiency is implicit in them.

Saudi Arabia water use estimates range from 18,180m^3/ha for drip irrigated palms to 42,600m^3/ha for surface irrigation. This difference is attributed mainly to climate differences but there is also the assumption that drip irrigation will use less water than surface irrigation. But Saudi Arabia also reports a lack of data on irrigation requirement for dates. This stems from the fact that most date palm plantations are located either in oases or along beaches where the water table is high, or in the vicinity of lakes. In such regions, sufficient water is available year round to render irrigation unnecessary.

CROP COEFFICIENTS

Few data are also available on crop coefficients beyond those quoted in FAO I&D No 56 – Crop Water Requirements. Here date palm crop coefficients are given as 0.9-1.0 for mature palms. Saudi Arabia and UAE report values ranging from 0.7 to 1.0 depending on the time in the growing season (Table 5).

* Table 5 Crop coefficients for date palms in Saudi Arabia and UAE

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Saudi Arabia	0.80	0.85	0.90	0.95	1.00	1.00	1.00	1.00	0.90	0.85	0.85	0.80
UAE	0.7	0.73	0.8	0.9	0.9	0.9	0.9	0.9	0.85	0.75	0.73	0.7

1.4.3 Irrigation efficiency

All countries factor in some form of irrigation efficiency to assess gross water requirement but most use standard values quoted in textbooks rather than actual local field measured values. Typical values are shown in Table 6. Surface irrigation is rated the least efficient with bubbler and drip showing higher levels of efficiency. This assumption takes no account of the management of the systems which are often the main reason why systems are inefficient. For example, drip irrigation is considered to have the highest level of efficiency yet several country studies refer to the misuse of water with this method as farmers say they are dissatisfied with the apparently inadequate amount of water it provides for mature palms (see section 1.6)

In Saudi Arabia water application efficiency is highly controversial. There are large uncertainties about how much water is applied to each crop and the overall water consumption at farm level. In the modern farms specializing in date palms intercropped with citrus trees at Al-Hassa, the irrigation efficiency is reported to be low. This is in spite of the fact that modern irrigation equipment is used to apply water to a very high standard – 40,000m^3/ha/yr corresponding to over 300 l/tree/day. This is a common problem in many countries but one that is not discussed in any depth. It highlights the need for realistic in-depth assessments of the current levels of irrigation water use, the performance of irrigation systems and the way farmers and system managers manage (or mis-manage) irrigation.

* Table 6 Gross water requirements indicating levels of irrigation efficiency in UAE

	Gross water use (mm/yr)		
Irrigation method	Surface	Bubbler	Drip
Assumed irrig efficiency	65%	80%	90%
7 year old palms	1,990	1,623	1,443
Mature palms	2,074	1,685	1,550

1.5 Irrigation agronomy

1.5.1 Planting density

The most common way of expressing water use is in cubic metres per hectare (m^3/ha). But this is of little value if the planting density is not known or not specified. The denser the planting the more water will be needed. Planting density does vary considerably from country to country and within countries. In the UAE traditional date palm planting is on a 10m×10m grid (100 palms/ha) but in some cases, like the Libyan coastal regions they are planted on a 20m×30m grid. This enables each palm to exploit a large soil water volume which can help to protect the palm in times of water shortage. Increasingly though new plantings are more intensive such as 7m×7m grid (200 palms/ha) and in some cases on a 5m×5m spacing (400 palms/ha). Saudi Arabia reported that planting should allow sufficient space for sunlight on a mature crop canopy and sufficient working space within the field. Spacing of 7m×7m is recommended in new plantations but wider spacings are used in the old oases where it is common to grow some other crops such as vegetables and fruit in between the date palms.

So when quoting water use by palms in terms of m^3/ha it is essential to quote the planting density as well.

1.5.2 Intercropping

Farmers in many countries practice intercropping between the palms and they do not separate out the water needs of dates from the intercrops. Rather they irrigate the intercrop and assume that the nearby palm trees take water as well.

In Iran plantations are irrigated together with other annual and perennial crops and there are no measuring devices to separate the water quantity used by dates and other crops.

Traditional Moroccan for palm plantations is to crop at three levels: palm trees, fruit trees and low crops which are generally, cereals, legumes, forages and vegetables.

All this adds to the complexity of determining date palm water requirements as well as being a source of confusion when date palm water requirements are quoted, often with a ‘hidden’ assumption that intercropping is taking place as well.

In Saudi Arabia new date palms are planted for intensive date production without intercropping. This situation requires more precise knowledge of the water requirements of dates and is ideally suited to drip or bubbler irrigation

1.5.3 Experiments with water

Few experimental data are published on date palm irrigation but the country studies do refer to some interesting experimental work that throws additional and more practical light on the actual water use by palms and their response to irrigation.

IN EGYPT

A study of the effects of irrigation on tree growth, fruit yield and quality at Aswan was undertaken in 1983 and showed that increasing irrigation frequency increased the size, weight, moisture content and the total soluble solids of the fruits. It also reduced the fruit maturity period by about 15 days. The final recommendation was to irrigate 12 times a year.

Field observations of palms confirmed their tolerance to drought even when they were neglected. But leaf growth and fruits do begin to suffer when the soil around the roots reaches wilting point. Date palms growing in deep soil with high water holding capacity were reported to produce average yields even without irrigation for 2-3 months (June–September) with little effect on leaf growth. When irrigated again the leaves grew normally. Date palm trees in areas where the ground water table is high did not require any external irrigation.

Some limited research work demonstrated that drip irrigation increased crop yield to 100kg/tree. Another experiment compared drip with sprinkler irrigation with yields quoted at 145kg/tree for drip irrigation while 109kg/tree for sprinkler.

IN LIBYA

Several long term experiments were conducted in the 1950s and 1960s to assess the impact of water management on date palm production. When crops were stressed through lack of water it appreciably reduced the vegetative growth but date yields were not significantly affected. Only when vegetative growth stopped were yields reduced. In irrigation trials that extended the time between successive irrigations from 2-8 weeks yield and leaf growth were not significantly affected provided the palms received adequate water during the irrigation period.

In another irrigation study on mature palms the results showed that so long as the moisture content of the soil remained above the wilting range, neither yields nor leaf-growth rates were significantly reduced by water shortage. When the soil was allowed to remain in the wilting range for several weeks there was significant reductions in leaf growth rate and in fresh weight per fruit. Flowering emergence in the following spring was delayed. But there was no significant reduction in yield because the shortage occurred when the fruit was mature or ripening.

One field experiment showed that it was possible to use drip irrigation on mature palms. After two years yields were more pronounced and this was explained by the increased weight of individual fruits.

Another long-term experiment compared sprinkler and drip methods on mature palms. Drip was considered superior to sprinkler irrigation as bunch production, fruit size, and total yield all increased. The advantage was explained by higher water availability and this may be the reason why the previous drip experiment also showed increased yields.

These experiments demonstrated that drip irrigation can have advantages in marginal conditions of saline water, high water table, and atmospheric dryness. They also demonstrated that watering only part of the root system of mature palms did not adversely affect crop yield and quality – rather is increased yield in some cases.

IN OMAN

Experiments between 1997 and 1999 looked at different levels of water stress on mature 8-year old palms. They demonstrated that increasing water stress depressed yields but increased the productivity of water. This was considered to be an important result in an area where there is considerable over-pumping of groundwater and salt water intrusion in coastal areas as well as an over-supply of dates for the market. It was suggested that aiming for increased productivity to water rather than overall production could not only mean higher prices for farmers but also lead to a more realistic market in dates that did not require government subsidies. Researchers however, did acknowledge that this level of control over irrigation was not always possible for those farmers using aflaj irrigation were the supply is shared on a time basis and this reduces the flexibility for managing water deficits.

In experiments comparing basin and bubbler irrigation on mature palms farmers were observed to adjust their irrigation practices to the production stage of the crop showing that indigenous knowledge can be a very valuable source of information. It was suggested that this needs documenting for wider dissemination.

1.5.4 Tolerance to salinity

Many countries reported the use of long standing experimental work on the tolerance of crops to saline water and soil conditions that affect many crops. But some provided more detailed information about the tolerance of date palms.

IN EGYPT

Date palms can tolerate irrigation water salinity better than any other fruit tree but the crop yield will be affected depending on the concentration of salts. Studies suggest that date palms can produce full crop production if they are irrigated with saline water up to 2,000ppm. The yield will be reduced by about 10%, 25%, and 50% if the irrigation water salinity rises to 3,000, 5,000, and 8,000ppm respectively.

IN IRAN

Date palms can tolerate salinity levels of 6,000-7,000 ppm but this does reduce date quality and quantity. Date palm plantations can be irrigated with water with EC of 3.5dc/cm without any reduction in crop performance. Date palm trees can tolerate flooding and water logging conditions because they have air voids in their rooting system. However, long durations of inundation can have negative effects.

IN LIBYA

Several experiments were a 5-year experimental study in the 1960s assessed the impact on date production of irrigating and leaching with salty water. Irrigation water contained 10kg of salt per millimeter of water applied to one hectare of land. Water was applied at 1.8, 3.0, and 4.2m/yr for irrigation and leaching. For the application of 3m of water/yr salt removal was adequate, but with 1.2m it was not. In the first three years yield and quality were unaffected by differences in water supply, but in the last two years yields was lower in the 1.8m irrigation treatment.

In another experiment young date palms were irrigated for one year with water containing 253 (control), 6,000, 12,000, 18,000 and 24,000ppm of salt. Leaf growth rate was halved by the 6,000ppm treatment and decreased considerably further at higher concentrations.

1.5.5 Irrigation scheduling

Research in Saudi Arabia, where most water is pumped from wells, shows that effective irrigation scheduling can save on average 20-30% of the water and energy used. An experiment carried out in the Hail region to evaluate an automatic irrigation scheduling technique for conservation of water on a wheat crop for three seasons showed an overall saving of 24%. However, it was considered that the cost and level of technical support needed to run this system was prohibitive.

In Saudi Arabia, like most other countries in the region, the use of instruments to measure and monitor soil water and their use in irrigation scheduling is limited to research centers, educational institutions, and some of the large agricultural companies. Farmers typically are not only unable to use these rather costly techniques but also the systems of irrigation they use are often too rigid to allow for this level of water control. The extension services needed to support their use is also not available to most farmers.

1.5.6 Indigenous knowledge

Several country studies provided advice on water management based on indigenous knowledge and experience of both farmers and researchers which generally supports experimental findings.

An example from Egypt suggests the following guidance to get the best response from irrigation:

- Irrigate before pollination in order to stimulate the growth of the fruit bunches
- Irrigate when the fruit bunches are developing, at stalk pending, and when fruit is maturing.
- Reduce irrigation amount and frequency near crop maturity to lower crop moisture content and avoid deterioration.
- Irrigate only in the early in morning or late evening to avoid the heat.
- Stop irrigation for about 40 days at the end of November especially if the dates are being intercropped with clover or other annuals.

In Saudi Arabia farmers are advised that the critical stage for newly planted palms is in the first six weeks and for mature trees it is during fruit development and from the end of fruit set until the fruit reaches its full size.

1.6 Irrigation methods

Various irrigation methods are used throughout the region and are described in some detail in the country studies (Table 7). Flood or surface irrigation is cited as the most common method and this comes from the long tradition of using such methods. Egypt for example still irrigates about 90% of its date palms with surface methods particularly on the old lands. This seems to be the trend in most other countries as well. Egypt also points out that many palms are not grown in groves or plantations but along the borders of farms and are managed as part of the farm cropping system. This may be true in many countries, particularly were palms are grown in oases and other areas of shallow groundwater.

Modern irrigation systems (MIS) are growing in popularity for date palms but they are not widely used. Sprinkler irrigation is not commonly used although micro sprinklers play a growing role in some countries, particularly on sandy soils where palms are commonly grown. Drip and bubbler irrigation are also used, and like micro sprinkler systems they can 'grow' as the palms mature and need more water.

Drip irrigation is a method that most interests governments because of its reputation for reducing the irrigation requirement. But care is needed to manage this system properly and it can also prove costly to install. Drip irrigation efficiency is as much a function of how well it is managed as it is the system itself. When it is badly managed efficiencies can be very low. Most countries are now experimenting with drip irrigation and many have already successfully installed systems for evaluation. Increased yields are also quoted for drip systems but this may be a function of the improved control over water rather than the method *per se*. Drip irrigation trials can also be confused by nutrient applications. Drip systems are ideal for feeding nutrients into the irrigation water and so the response may be as much to fertilizer as it is to water.

In Algeria localized irrigation was first introduced in the 1980s and its acceptance grew substantially between 2000 and 2005 from 0.3% (320ha) to 38% (56,000ha) encouraged by government subsidies. Farmers are reported to have modified the systems because they felt that they were not delivering enough water. This similar point was reported from Libya were farmers do not believe that drip delivers enough water to the crop.

Bubbler irrigation appears to be more acceptable from a farmer point of view as farmers can see the water during irrigation. It is a method that is growing in use and it produces much higher discharges which reduce blocking problems. Basins are usually constructed around the palms to confine any excess water that lies on the soil surface and so the method is seen as a good step along the pathway of improving existing surface irrigation systems.

But there are many places were irrigation methods are used that do not fit into these neat categories. In oases natural ground water supplies most of the water for crops and in some coastal areas rising tides are used to push water into date palm plantations. In other places, such a Yemen, various systems of harvesting rainwater either from surface runoff or from underground sources are described. These have often developed over many years into highly sustainable 'irrigation systems'.

The main concern among farmers about MIS is that they do not believe that they provide enough water for the palms, particularly older palms with extensive root systems. In Iran farmers are concerned that switching to drip may cause problems as the root system may not be able to respond to the new and localized method of applying water. This is a strong belief amongst date growers which has affected the take-up of MIS. Also some plantations are already unproductive or produce inferior quality dates and so investing in expensive MIS is not a viable option for many farmers. They also lack capital to invest and the knowledge about MIS to use it effectively.

In Oman the uptake of MIS is poor for reasons similar to those in Iran, although cost is not such a problem as farmers get back 25-75% of system costs in subsidies for installing drip and bubbler irrigation. However, they much prefer to install these systems to irrigate vegetables rather than dates as this is more profitable.

Yemen reports that MIS have been installed on the large farms to cultivate palm trees. They are well designed and were meant to reduce water losses but in the absence of technical expertise to run the systems water losses are reported to be excessive.

* Table 7 Date palms using different irrigation methods

Location	Date palm area (ha)	Surface	MIS
Egypt	95,000	90,000	5,000
Iran	239,000	228,296	10,704
Saudi Arabia	150,800	Not known	Not known
Algeria	147,900	91,900	56,000
UAE	18,500	Not known	Not known
Oman	31,352	30,117	1,235
Tunisia	33,000	Not known	Not known
Libya	29,000	29,000	Negligible
Morocco	13,700	12,100	1,600
Yemen	13,740	Not known	Not known

1.7 Research and advisory services

Most countries do not have research and advisory services specific to date palm production. Rather it is included as part of the support services provide for agriculture as a whole. The country studies describe the irrigation situation in each country together with the way in which their irrigation research and advisory services are organized. But almost without exception the studies do not present any detailed analysis of services and their performance. They do however emphasize the inadequacies of existing services and the need for improvement. This seems to be a general criticism across the region.

Saudi Arabia comments that technical support services for irrigation are essentially non-existent, with the exception of limited extension services in the Al-Hassa oasis and those provided by some of the Agriculture Directorates. The current situation of irrigation management reflects the existing legal and institutional setups. More specifically, the level of technical assistance and provision of extension, training and advisory services to farmers is generally low. Linkages between governmental institutions in charge of irrigation and farmers are rather weak and the capacity of these institutions is limited in terms of manpower and technical know-how.

Egypt is an example of a country with a long established system of support for farmers. It has a long tradition of irrigation and water resources and (irrigated) agriculture being managed by separate ministries. The Ministry of Water Resources and Irrigation manages the large water distribution networks delivering water down to tertiary level where farmer groups take over responsibility for its management on the farm. Farmers in the Nile valley have long experience of irrigation and the system of supply relies on them pumping water from the canals into their fields. The underlying philosophy is that as water (which is free) must be pumped and the farmers must buy the fuel, they will use it sparingly. But this philosophy is compromised when fuel is subsidized or when water is in command (above ground level) as it is in the new lands.

The Ministry of Agriculture supports farmers directly through its extension service but this concentrates on crops and fertilizer and not so much on water management. There appears to be little or no direct support to farmers in water management except for an Irrigation Advisory Service that was recently set up to facilitate the organization of Water User Associations.

In Iran most irrigation is under governmental control. Irrigation services are provided by government to farmers in the form of hardware such as land leveling and canal lining and software such as training and advice. The latter is the responsibility of the Ministry of Agriculture extension service but it is reported to be very limited in scope and in some cases non-existent. Extension agents have very little knowledge of irrigation practices and target other mainstream agricultural issues.

Morocco has well established formal large-scale government run irrigation schemes (approx 800,0000ha) and informal smallholder 'private' irrigation schemes (approx 500,000ha). There is a well established government-based institutional structure to support the large-scale schemes and this is in a process of change from a prescriptive system to one where farmers have more say in all aspects of decision-making. But like other countries the agricultural extension service does not address irrigation issues. This is left to a separate group within the Ministry of Agriculture – the Administration du Génie Rural. It is not clear however, just how these services inter-relate or how effective they are, particularly as irrigation is undergoing a process of management transfer.

In Tunisia the Ministry of Agriculture is the main player providing the lead and support for irrigation development and its management. However, in common with other countries the main services are in support of agricultural inputs other than water. Training in irrigation is organised for farmers and there is extensive use of TV and radio, which are judged as a very successful way of getting information to the extensive rural areas. But there is concern about the ageing population of farmers who have poor education and the constraints this brings to the introduction of new developments. Few farmers, it is reported, actively seek information from the support services.

In Yemen extension has been the subject of considerable investment over the last 25 years but little is reported to have taken place in the provision of irrigation services and as a result they are practically non-existent. Farmers seldom visit extension centres to enquire about methods and issues related management of water for irrigation at the field level. Improvements in irrigation have focused on conveyance systems and the introduction of modern methods of irrigation such as drip, bubbler and sprinkler techniques.

1.8 In summary

The country studies and this synthesis set out to clarify our current knowledge of date palm irrigation. It started with the misconceptions among many farmers and indeed the wider public about how dates seem not to need much water to grow and bear fruit as they tend to grow in hot arid countries. The reality is very different. An estimate based on information supplied by the country studies suggests that the number of date palms growing in those countries is in excess of 120 million and they are using an average of 19,500Mm^3 of water each year – approximately equivalent to one third of Egypt's annual share of the Nile water. And every cubic meter of water used by date palms means one less cubic meter for other purposes. So in the Near East, where water is in short supply and water poverty is common place, the amount of water allocated for date palms can have strategic significance for the management of national water resources. For farmers, who rely on date production for their livelihood, it is vital that they make best use of every cubic meter of water and maximise their productivity, particularly when markets are over-supplied with dates and prices are low.

In spite of the importance of dates in the region there is surprisingly little information available and published about the amount of water consumed by date palms, the effectiveness of on-farm water management practices, and the quality of water management support services available to farmers to promote the productive use of water.

WATER USE AND PRODUCTIVITY

The question of how much water do date palms use is a crucial one, particularly in water-short countries, both for individual farmers looking to maximize their income and for governments who wish to plan the best use of their limited water resources. So it is disappointing to see that there are few published data on water consumption by date palms and the data that are available in the country studies are mostly theoretically based. They rely on climatic data and an accepted method of calculating crop water requirements, such as the Penman method, and in some cases standard reference values are used for irrigation efficiency for the different methods of irrigation.

The data that are available are also confusing. Some quote net water requirements and some gross use. Most quote water use m^3/ha but do not state the palm planting density nor do they say if the water use refers to both the palms and/or any intercropping, which is common place in many countries. Ideally it would be best to express water use per palm rather than per hectare as this would overcome much of the confusion.

Estimates for water use may be questionable but from an irrigation agronomy view point the body of knowledge is growing steadily – the best times to irrigate and the tolerance of date palms to salinity and aridity. Some reports included water use experiments undertaken on a field scale, some in the 1960s and 1970s and some in more recent times, which do add to our knowledge of irrigation agronomy. But these tend to lack the precision needed from a water management perspective – just how much water to apply and when.

More reliable field data would obviously be beneficial to back up this information and to confirm the theoretical estimates for water use but this may not be practicable in the short term. The least that is needed is for researchers to be very clear about what they are calculating and the assumptions they are making. This may provide sufficient and adequate data for planning purposes. The assessments made in this synthesis go some way to achieving this but the data base needs to be much more robust.

From the perspective of individual farmers more detailed knowledge of water needs and agronomy is important. This report provides some of this knowledge but more is needed. A potentially fruitful source of this information is local indigenous knowledge acquired over many generations by farmers. Several reports refer to this important and yet untapped knowledge base. A very useful project would be to systematically gather this information from the various countries and bring it together in the form of a best practice guide for date palm irrigation.

Limited research in the region has also demonstrated the difference between production and productivity. Although maximum production can be achieved by providing the full water requirements of palms maximum productivity to water can be achieved with significantly less water – often as much as 50% less. In water-short areas and where dates are in plentiful supply it is productivity that should drive date-water policy and not production.

IRRIGATION METHODS

Although most countries are now investigating ‘modern’ irrigation systems (MIS) they still only represent a small portion of date palm irrigation. In Iran for example, of the 239,000ha of irrigated palm plantations only

4.5% is drip irrigated. This may change in the future as pressure on water resources increases but it will take some time to achieve significant coverage.

Governments are keen to improve the take up of MIS as they see it as a way of saving water for use elsewhere. But one of the main concerns about MIS comes from farmers. They are not so concerned about the technicalities of the systems or the cost (as they tend to be heavily subsidized by government) but the fact that they simply do not believe that systems such as drip and bubbler provide enough water for the palms, particularly older palms with extensive root systems. Until the psychological barrier is removed it is unlikely that MIS take up will improve in the near future. So it is incumbent on those responsible for water management research and extension to make sure that they focus on changing attitudes among farmers. In the meantime they should not neglect the need to improve the more traditional surface irrigation methods.

INSTITUTIONS

If farmers are to acquire water management skills, and those relevant to date palm irrigation, they will undoubtedly need support. But how can this be provided when irrigation advisory services either do not exist or the performance of those that do is disappointing? If the tradition of government provision continues how the services can be structured, delivered and paid for when most government departments are looking to cut expenditure rather than increase it?

This is not a new problem and it is not likely to be resolved simply to improve data palm irrigation. It is a much larger problem of which date production is only a part.

There is a need first of all to gather information about advisory services to establish the current state of play. What irrigation advisory services are available? Are they essentially scheduling services, do they train farmers and do they provide on-farm advisory support? How are they organised? Are they top-down services supplied to farmers or do farmers have some say in the advice they need and when they need it? How well do these services work and who evaluates them – the farmers or government? Who pays for the services and are they cost effective?

As the current trend in irrigation is towards farmer participation and to hand over operational responsibility from government to farmers, advisory services need to reflect these changes? Does the government continue to provide them or should private services become the norm? Should they be more demand-oriented and should farmers be expected to pay for them as they are expected to pay for operation and maintenance?

Answering these questions will go a long way to improving the irrigation of date palms.

2 Algeria country paper

2.1 Introduction

Date production in Algeria is extremely important for subsistence in the south of the country. For many centuries millions of people have grown dates as an important source of food and nutrition. Moreover, date palms and their fruits are an integrated part of the culture and the ecological diversity of the desert areas.

Unfortunately, the Algerian date palm faces serious difficulties. Production is poor and this impacts on farming incomes. Low yields are mainly the result of poor extension services to farmers. Diseases also contribute to the problem and the Bayoud disease is prevalent in the west, south, and parts of the western centre of Algerian Sahara. Poor marketing on a national and international scale is also a problem because of a lack of adequate organizations.

2.2 Date production

In spite of the difficulties that date production faces, Algeria ranks 5th in the list of producer countries producing 0.52Mtons in 2005 from some 10.4 million trees. In the early 1980s Algeria had some 11.5m date palms but following a programme of planting over a 15-year period from 1985 this has now risen significantly to 16.5m. Similarly the area planted to date palms increased from 83,400ha to some 102,000ha – an increase of almost 9000ha/yr. The production impact of this additional planting has yet to be fully realized as many of new trees are still too young to bear serious quantities of fruit.

On the basis of the 2005 data the average yield across the country was almost 50kg/tree. However, within this there are considerable variations from 96kg/ha in Biskra to 13.5kg/ha in Indouf. There are also variations in production with varieties. This is compared with production figures from other countries – USA, 70kg/tree and Egypt, 60kg/tree.

2.3 Historical perspective

The presence of date palms in Algeria goes back to the Neolithic era as seen in paintings in Tassili region. The crop was developed in the south of the country by the Phoenicians. But according to other sources dates were brought by Arab nomadic Bedouins coming from the east for trade during the 7th century. Since the Middle Ages many palm plantations were created on the tracks of the caravans and they were used as halts or commercial bases like El Golea and Ouargla.

Date palm cultivation in Ziban and Oued Righ is very old but the tradition is very alive there. In 1850, Oued Righ had at least 500,000 palm trees and during the colonial occupation (1830-1962), new plantations (160,000) came to reinforce the production. This dynamism was based on the universally famous Deglet Nour variety.

2.4 Oases

Oases cover 148,000ha – 57% in the North-East of the Algerian Sahara (Zibans, Oued Righ, El Oued and Ouargla) and 43% in the West (M'zab, Touat, Gourara and Saoura).

Date palms are mainly grown in these oases and they fall into three groups:

- Modern plantations located in the Oued Righ valley and the region of Ziban. These are commercial production farms.
- Traditional palm plantations characterized by the lack of alignment of trees. These are reserved mainly for family consumption and productivity is not good.
- Marginal palm plantations of modest importance. The exploitation of these palm plantations is only secondary (Ahaggar, Saoura and Djanet).

In the south intercropping of palm trees with fruit trees, and cash crops is not common. But it does occur in the valley of M'zab and also around Biskra, Bechar and Adrar. The importance of the intercrop for small-scale farmers for subsistence and local markets outweighs the date production which has low commercial value.

SOCIO-ECONOMICS

The oases fulfill a double function – feeder and habitat. The microclimate generated by the palm trees makes possible the cultivation of fruit trees, fodder, vegetables and familial small livestock (sheep, goats and even some cows). This would not survive separately outside the oasis. The oases are thus of economic importance for the inhabitants. They can exploit the space, climate, water, products, and by-products.

The life of the oases population is centered on the date palm. For the country, it constitutes the second entry in foreign currencies after oil and is consequently the first agricultural production for export.

Nowadays, the Saharan population is about 3 million and will reach 3.2 million in 2010. In 1967 the Algerian Sahara counted only 890,000 inhabitants. One decade later the population reached 1,272,000 then 1,855,000 in 1987. Between 1987 and today the Saharan population almost doubled.

Biskra, Ouargla, Ghardaïa and Bechar are great cities of more than 150,000 inhabitants. In comparison to these urban demographic trends, agriculture does not occupy more than 21% of the active population against 75% twenty years ago.

The various reorganizations and land reforms engaged by the Government from independence (1962) to the mid 1980s resulted in relative stagnation of agricultural activity in the oases and an almost total stop on private investments in the date sector

The economic revival since 2000 is pure oxygen for the date palm farmers and others involved in the date sector, as we know that more than 1 million people – 40% of the Saharan population – now earn their living from agriculture.

ECOLOGICAL AND ENVIRONMENTAL ASPECTS

The oasis is a real protection against the climatic risks: sun, heat, winds and sand erosion. Its ecological and environmental role is significant because it complements the urban environment, contributes to regional climatic equilibrium, and safeguards vegetation and animal species.

SOCIO-CULTURAL ASPECTS

The date is associated to the Arabo-Islamic culture. It is several times cited in the Koran and almost all the date producers are part of this culture. During the period of harvest of dates in the Saharan cities, life is decorated by the presence of dates in the markets.

To offer dates is an excellent means of expressing friendship and love. Thus, the oases inhabitants offer dates to their close relations and to friends, especially when they come from the cities to the north.

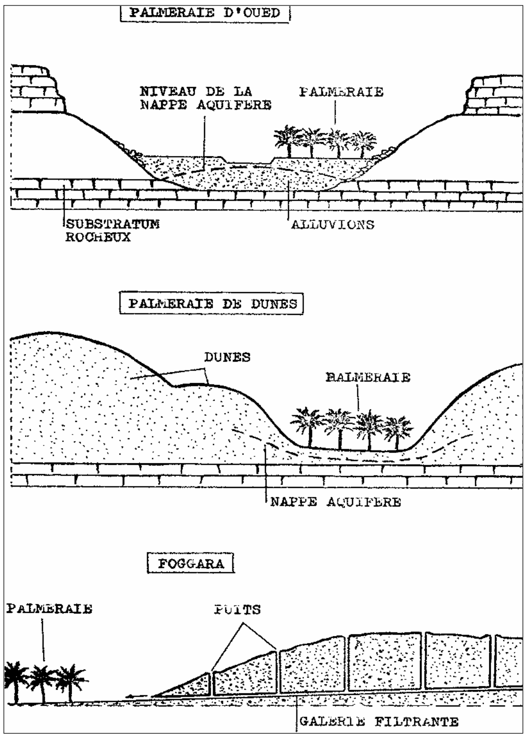
2.4.1 Changes in the oases

Since 1983 new systems of production have been introduced which are to the long term detriment of the oases? This concerns the exploitation of the oases to grow irrigated cereals and fodder using center pivots and the cultivation of potatoes and vegetables in glasshouses. The region now exports these products to the north of the country and even abroad. This has improved livelihoods but it is at the expense of the sustainability of the oases systems and was sometimes done with little respect for the old community practices.

2.4.2 Methods of exploiting oases water

In the Sahara, the availability of water determines the different irrigation systems and different cropping systems. Each oases cropping system has its characteristics because of the diversity of the modes of exploitation of the water and the type of cropping practices.

There are several ways in which oases use available water resources (Figure 1).



* Figure 1 Different type of oasis in the Algerian south

DAMS AND SEGUIAS

This approach exploits flood flows in wadis. Water is collected by dams made of date palm trunks (stips) or stones. Water is fed into channels (seguia) that take water to the gardens. The oases of Sidi Okba in Zibans (Biskra) use this approach to exploit the wadi El Abiodh.

SPREADING FLOOD WATER

In the valley of M'zab, rainfall is rare – annual 56 mm. The wadis drain the plateau of the Dayas and the Mozabite ridge suddenly bringing great quantities of water which flood the palm plantations. This is usually accounts for two days of flooding a year with flows up to 300m^3/s.

To make better use of this water the farmers construct a series of dams to retain water and allow it to infiltrate and replenish the groundwater.

IRRIGATION FROM WELLS

Shallow underground water is collected by a well and drawn to the surface using animal power and conveyed in channels to the farms. In Ouargla, there used to be between 250 to 300 wells of this kind but they have now all but disappeared because of falling water tables and the use of motor-driven pumps since the 1950s.

GHOUTS

A Ghout is a farming technique for the palm trees, specific to the region of Oued Souf (El Oued). This traditional method of farming involves clearing a large area and lowering the ground level some 10m to get close to the water table. Palms are planted in the depression so their roots can reach the groundwater. No additional irrigation in needed.

In a Ghout, the date palms are planted in groups of 20 to 100 palm trees in the center of an artificial basin 10m deep and a diameter from 80 to 200m so that the bottom is within 1m of the water table.

FOGGARAS

Foggaras are galleries for collecting and the conveying underground water by means of a system of gently sloping galleries dug into the hillside. One foggara needs on average 2,000m of drainage gallery to extract 1 l/s. Ancestral systems are used to collect and distribute water to gardens and palm trees.

There are significant numbers in Adrar (Gourara, Touat and Tidikelt). Some 560 foggaras among the existing 1400 have been restored. The overall length of all the galleries is estimated to exceed 1,000km.

DEEP PUMPING FROM AQUIFERS

Pumping the deep aquifers for irrigation started with the exploitation of oil and the appearance of the motor-driven pumps and electrification. Water is pumped directly into the irrigation channels or is stored in reservoirs. The irrigation is done by flooding.

2.4.3 Water requirements

The Saharan area is characterized by a desert climate defined by one hot season where the relative humidity of the air is generally lower than 15% with dry, hot winds charged with sand and a cold season when temperatures are 25°-30°C.

The climatic water demand expressed by potential evapotranspiration is 2500mm/yr and rainfall is below 100mm. In good conditions, an adult palm tree has a canopy of about 150m^2 and it can under dry summer conditions consume about 70l/hr which is approximately 700-800l/day.

In 2005, the arable irrigated surface in the south was estimated to be 222,572ha – 36% of the 612,290ha of arable irrigated surface in the country. The palm tree occupies 147,906ha. Some 82% is flood irrigated; 1% is bour (ghout), and 17% is micro irrigation).

Date palm requirements are determine theoretically using climate data and FAO CropWat 4. There is considerable variation in evaporation across the country. It varies from 1,260mm/yr in Batna in the north of the Sahara to 3,130mm/yr in Adrar, which is one of the most arid areas. Table 8 summarizes the mean values.

* Table 8 Mean annual potential evapotranspiration (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
82	104	160	205	261	297	326	302	216	159	99	75	2285

Assuming a crop factor of 0.9 for dates in the winter and 0.95 in the summer the water requirement for dates is shown in Table 9. The average water requirement is estimated to be 1.15 l/s/ha but this varies from 0.13-0.8 l/s/ha in Batna and from 0.4-1.65 l/s/ha in Adrar. These flows represent a consumption of 580 l/day/tree in Batna and 119 1l/day/tree in Adrar.

* Table 9 Mean water requirements for date palms (based on 120 trees/ha)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
l/day/tree	198	280	388	513	630	783	831	771	570	407	247	180
l/s/ha	0.27	0.35	0.54	0.69	0.88	1.05	1.15	1.07	0.77	0.57	0.33	0.25

2.5 Productivity

Data available on the productivity of water based on theoretical water requirements and in some cases actual flow measurements are shown in Table 10.

* Table 10 Productivity of dates to water

Varieties			Deglet Nour (Fine dates)		Ghars and similar (Soft dates)		Degla Beida and similar (Dry dates)		Date palm in general	
	Water use (m^3/tree/yr)		Productivity (kg/m^3)		Productivity (kg/m^3)		Productivity (kg/m^3)		Productivity (kg/m^3)	
	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual
Adrar	261	158					0.108	0.177	0.108	0.177
Batna	106		0.736		0.345		0.378		0.383	
Biskra	175	192	0.414	0.376	0.268	0.243	0.411	0.373	0.394	0.357
Bechar	178	133					0.196	0.261	0.196	0.261
Tamanrasset	184						0.108		0.108	
Illizi	196		0.142		0.170		0.182		0.174	
Ouargla	155	208	0.394	0.293	0.305	0.227	0.392	0.292	0.355	0.264
Tindouf	194				0.070				0.070	
El-Oued	158	183	0.357	0.308	0.205	0.177	0.342	0.295	0.365	0.314
Ghardaia	170	195	0.306	0.266	0.286	0.248	0.242	0.210	0.272	0.236
Algeria	176	178	0.353	0.349	0.289	0.286	0.219	0.217	0.283	0.280

2.6 Irrigation methods

2.6.1 Flood irrigation

Surface irrigation is the mode of irrigation practised since the creation of the oases. It is practised in more than 82% of the date palm plantations. The most water wasting is often observed in the palm plantations where this mode of irrigation is practiced.

Farmers irrigate, on average, every ten days in winter and every two days in summer while trying to adjust watering with the needs.

With the artesian drillings farmers irrigate too much in winter as they do not worry about the moisture of the soil. Marsh land surrounding the farms is often a consequence of this.

A study by ITDAS (Technical Institute of the Development of Saharan Agronomy) in 2005 showed levels of water use 20-30% higher than date palm requirements in many areas of the country. Only in two areas, Bechar and Adrar was it less than the requirement.

* Table 11 Ratio of annual water demand and supply for irrigation in regions of Algeria in 2005

Station	ETP Penman – Monteith (mm)	ETM (mm) Kc (mean) = 0.9	Actual irrigation D (mm)	D/ETM
Biskra	2144	1930	2314	1.2
El Oued	2035	1832	2200	1.2
Touggourt	1982	1782	2280	1.3
Ghardaia	2144	1929	2350	1.2
Ouargla	2358	2123	2500	1.2
Bechar	2301	2071	1600	0.8
El Golea	2301	2071	2000	1.0
Adrar	3230	2907	1900	0.7

2.6.2 Micro irrigation

The necessity to introduce modern irrigation methods is the consequence of the mismanagement of water resources which results from the use of the traditional techniques.

It was introduced in the 1980s by the INRA agricultural research station of Sidi Mahdi in Touggourt. It was used in some parcels of palm trees, vines, and vegetables under greenhouses.

* Table 12 Principal characteristics of localized irrigation

Characteristics	January	July
Monthly needs for the palm tree/ha	$1200m^3$	$3000m^3$
Daily needs (120 trees/ha)	$40m^3$	$100m^3$
Daily needs per palm tree	$0.3m^3$	$0.85m^3$
Frequency of the irrigation	3 days	3 days
Discharge	500 l/h	500 l/h
Duration of an irrigation	5 hrs	1 hr and 45min

The use of localized irrigation was largely improved by the farmers themselves, because they consider that the quantity supplied by drip irrigation was insufficient. This improved system consists in bringing water using PVC pipes from a reservoir built on an elevated place some 2-3m above level of the basins surrounding the palm trees. Pipes used are 6-10mm dia to distribute flows from 100-200l/hr. Since 2000, this system is used in all the young plantations created with a government investment programme.

2.6.3 Comparing flood and micro irrigation

Since 2000 localized irrigation, considered as the most economic method, is encouraged and subsidized by the government. In 2005 it was observed that the area irrigated by flood methods decreased by 9% compared to 2000. This fact is related to two things, the deterioration of a certain number of palm trees, and the conversion of some plantations from flood irrigation to localized irrigation.

In 2005 the system of localized irrigation covered 38% of the total surface planted to date palms whereas in 2000 it was only 0.3%.

* Table 13 Development of localised irrigation for date palm irrigation

Flood irrigation (ha)		Localized irrigation (ha)		Total (ha)	
2000	2005	2000	2005	2000	2005
101,227	91,910	323	55,996	101,550	147,906

2.7 Institutions

The organization responsible for the distribution of water is the National Office of Irrigation and Drainage (ONID). They manage 6% of the irrigated area in the south of the country. The remainder is done by the farmers themselves.

2.8 Constraints

Agriculture in the oases is facing some problems. The Campaign against the propagation of the bayoud disease, the control of certain diseases due to fungus or moulds, and the control of the date parasites continues. There is also the problem of sand invasion and drought, water mismanagement, salinity, and bad maintenance of the hydraulic equipment. In addition there are also socio-economic problems such as technical aid and training, farmers' organization, financing, upstream and downstream organization of the market.

The water requirements for the Saharan agriculture vary greatly between the regions and the seasons; irrigation is a necessary practice in all the Algerian oases. The techniques of surface irrigation by gravity prevail in these areas. The great imperfections of the irrigation are observed especially in the control of water losses, generated in the water conveyance from the source to the palm tree and also in the definition of the doses and the frequencies.

Irrigation scheduling is done empirically from observations acquired through experience.

The main constraints posed with the irrigation of the date palm and the associated crops are related to the water management and the organization of the farmers.

Extension services are ineffective and insufficient, not by the number of structures or personnel, but by the results. There is also a lack of scientific documents published on the irrigation of the date palm.

References

ABDELGAWAD G & SOUICI D (2005) Final Report about research program for the utilization of brackish and saline water in North Africa. IFAD, ACSAD and ITDAS: 103pp.

ABDOUS B, BESBES M, FEZZANI C, LATRECH D, MAMOU A (2005) Système Aquifère du Sahara Septentrional «SASS» gestion commune d'un bassin transfrontière (principaux résultats). Colloque international sur les ressources en eau souterraines au Sahara, CIRESS, Ouargla: 6-14.

Agriculture et développement (2006) Revue de vulgarisation et de communication N°03, édité par l'Institut National de la Vulgarisation Agricole: 30pp.

ANRH (1998) Ressources en eau souterraines au Sahara Septentrional: 13pp.

ANSARI T (2005) Le système traditionnel d'exploitation des eaux souterraines (foggara). Colloque international sur les ressources en eau souterraines au Sahara, CIRESS, Ouargla: 26-35.

BALDY Ch (1986) L'agro météorologie et le développement agricole des régions arides et semi-arides. INRA Ed. INRA Ed. INRA, Paris: 115pp.

BELGUEDJ M (1992) Le développement agricole dans la région des Ziban (Biskra, Algérie). Université de tours, DEA – Géographie et aménagement du monde arabe: 53pp.

BELLABACI H (1988) Inventaires et étude des variétés du palmier dattier dans le sud algérien. Annales agronomiques VOL. 12 n°1, T2, année 1988.

BEN KHALIFA A (1985) Etude de la variabilité des cultivars traditionnels du palmier dattier (Phoenix dactyliféra L.) du Touat et du Gourara. Mémoire de DES, USTHB, Alger.

BEN KHALIFA A & RA BRAC DE LA PERRIERE (1987) Rapport de mission dans les palmeraies du Tidikelt. URZA, Alger: 25 pp.

BENNADJI A & BENNADJI H (1998) Création d'oasis dans les Sahara algérien: le projet de Gassi Touil. Sécheresse; 9: 289-298.

BOUCHEMAL S & SPIGA N (2006) L'utilisation de l'eau par l'agriculture dans la wilaya d'Adrar : quel devenir? In Journées internationales sur la désertification et le développement durable : CRSTRA, Biskra : 55-61.

BOUZAHER A (1990) Note technique: Création d'oasis en Algérie. In Dollé V. (ed.), Toutain G. (ed.). *Les systèmes agricoles oasiens.* Montpellier : CIHEAM-IAMM: 325-328.

CHEHMA A & LONGO HF (2002) Possibilités d'utilisation des sous produits du palmier dattier pou l'engraissement du dromadaire et du mouton. Journal algérien des régions arides. Ed. CRSTRA : 11-23.

CHEHMA A & LONGO HF, BADA A, MOSBAH M (2002) Valeur alimentaire des sous produits du palmier dattier, de la paille d'orge et du drinn chez le dromadaire. Journal algérien des régions arides. Ed. CRSTRA: 33-44.

DEMMAK A & BEKHOUCHE H (2005): Le phénomène de remontée des eaux dans la vallée de Oued Souf. Colloque international sur les ressources en eau souterraines au Sahara, CIRESS, Ouargla: 82-85.

Direction des Services Agricoles de Biskra (DSA) (1967) Etude de l'aménagement de la palmeraie de Sidi Okba : 25-37.

DUBOST D (1983) Rapport préliminaire sur les essais d'irrigation localisée du palmier dattier à la station expérimentale de Sidi Mahdi (Touggourt). Bulletin d'agronomie Saharienne ; n°5 : 29-60.

DUBOST D (1983) Contribution à l'amélioration agricole des eaux chaudes du continental intercalaire (albien) dans la cuvette du bas Sahara algérien. Bulletin d'agronomie Saharienne; n5: 61- 109.

DUBOST D (1992) Aridité, agriculture et développement: le cas des oasis algériennes. Sécheresse; 3 (2): 85- 96.

DUBOST D (2002) Ecologie, Aménagement et développement Agricole des Oasis Algériennes. Edition du Centre de Recherche Scientifique et Technologique sur les Régions Arides : 423 pp.

DURANT JH & GUYOT J (1955) L'irrigation des cultures dans l'Oued Rhir. Trav. Inst. Rech. Sahar., XIII: 75-130.

GUYOT J & ROHMER R (1961) Etude des qualités physico-chimiques des eaux de la nappe albienne. Rapport SES: 4 pp.

Institut National des Sols de l'Irrigation et le Drainage (INSID) (2002) Conclusions de la mission effectuée au niveau des wilayas de Biskra et El Oued: 14pp.

Maghreb date Palm Project (2003) Analyse diagnostic du secteur du palmier dattier en Algérie. IPGRI, PNUD, FEM, INRA Algérie, INRA Tunisie et INRA Maroc: 60pp.

MATALLAH A (1969) Note sur les variétés de dattier cultivées en Algérie. ED. INRAA, 26pp. ronéotypées.

MESSAR E.M (1996) Le secteur phoenicicole algérien : situation et perspectives à l'horizon 2010. ICIHEAM- Option Méditerranéennes: 23-44.

MOULLA A.S, GUENDOUZ A, REGHIS Z, CHAID Z, LARBES M, OUAREZKI S, REZKA A, (2005) Un aperçu de quelques résultats d'hydrologie isotopique importants obtenus au Sahara algérien. Colloque international sur les ressources en eau souterraines au Sahara, CIRESS, Ouargla: 159-169.

OUENNOUGHI M & DUBOST D (2005) Le voyage forcé des dattiers en Nouvelle-Calédonie. Sécheresse ; 16 (4) : 241- 246.

PERENNES JJ (1979) Structures agraires et décolonisation. Les oasis de l'oued Rhir (Algérie). Ed. O.P.U. L'Harmattan, Alger/Paris: 372 pp.

REMINI B (2005) La problématique de l'eau en Algérie. Collection hydraulique et transport solide: 182 pp.

SOUICI D & BENABDI S (1997) Contribution au projet du schéma directeur de développement des régions sahariennes en Algérie : ressources en eau, irrigation et zonage agricole. Université de Montpellier II, DU – Gestion intégrée de la ressource en eau: 63pp.

TABOUCHE N (1999) Etude de la répartition spatiale des teneurs en fluorures des eaux souterraines du Sahara septentrional, Thèse de Magister en sciences hydrauliques, université de Biskra, Algérie.

TESSIER M (1965) Les crues d'oueds au Sahara algérien de 1950 à 1961. Trav. Inst. Rech. Sahar. XXIV: 7-9.

TOUTAIN G DOLLE V FERRY M (1990) Situation des systèmes oasiens en régions chaudes. In Dollé V. (ed.), Toutain G. (ed.). Les systèmes agricoles oasiens. Montpellier: CIHEAM-IAMM: 7- 18.

3 Egypt country paper

3.1 Background

The date palm is one of Man's oldest cultivated plants. The earliest records mentioning palm culture indicated that the dates were domesticated before 3000 BC in Mesopotamia, although it has been suggested that date culture might reach as far back as 5000 BC.

In Egypt agricultural operations on date palm, like pollination, are known at least since 2500 BC proved by ancient texts. Plantations nowadays are spread out all over Egypt, wherever water is available.

Date palm culture in Egypt is nearly always associated with other crops. Its status follows the general characteristics of irrigated agriculture in Egypt. The total number of productive date palm is about 11.5 millions trees.

* Table 14 Date palm production in Egypt (2005)

Location	Area (fed)	No of productive palms	Production (ton)	Productivity (kg/tree)
Delta area	28,466	4,960,625	601,716	121.3
Middle Nile valley	12,478	2,062,382	171,750	83.3
Upper Nile valley	12,235	2,302,202	188,123	81.7
Total all over Delta and the valley	53,179	9,325,209	961,589	103.1
Total outside the Nile valley	32,904	2,077,760	198,098	95.3
Grand Total	86,083	11,402,969	1,159,687	101.7

The Nile valley is the biggest oasis in the world. The date palm plantations in the Nile delta constitute about 1/3 of the productive date palms of the country. Half of Egypt's total number of palms is found between Cairo and Aswan, in the strip of cultivated land along the Nile River and the Fayoum depression. The remaining 25% are found in the western part of Egypt, from the Nile to the Libyan border. It is a vast desert plateau, which is cut from the South East to the North West by a succession of depressions.

Date palms are also present but in smaller numbers in South and North Sinai, along the Red Sea, and in Matrouh Governorate. The total number of productive date palms in these areas is estimated to be 600,000 palms.

The date palm can be expected to maintain a dominant place in Egyptian agriculture because of its excellent adaptation to the harsh climatic conditions of the country. Its traditional use as a primary source of food and by-products, and its ecological benefits in oasis agriculture makes it the important fruit tree and the best crop to be cultivated.

Agriculture concerns only 3% of the total area of Egypt but it provides work for 37% of the country's labour force. The majority of the farms are very small, about 95% of ownership is of less than 5 Fadden (1Fadden = 0.42ha).

3.2 Water resources

Egypt has no effective rainfall except in a narrow band along the Northern coastal area where the average annual rainfall is 200mm. It is less than 50mm/yr at Cairo and close to zero at Aswan.

For this reason the River Nile is the main source of water for Egypt. In, general, the natural amount of water at Aswan is about 84 Bm^3/yr, the Egyptian share is 55.5 Bm^3/yr and 18.5 Bm^3/yr for Sudan, while 10 Bm^3/yr is lost through evaporation and leaching.

Egypt also has several important underground aquifers which are exploited for irrigation.

* Table 15 Underground aquifers in Egypt

Location	Amount (Mm^3/yr)
Nile valley	7,482
Coastal basin	31
Eastern and western desert	3,984
Sinai	300
Total	11,761

This means the total amount of ground water which can be used for irrigation is about $12Bm^3/yr$; only $5Bm^3/yr$ is used and so there is about $6Bm^3/yr$ more available.

There are difference between the deep ground water (non renewable) and the ground water aquifer underlying the Nile valley and the Delta, which is entirely recharged and is dependent on deep percolation of irrigation water and seepage from the irrigation system.

3.3 Date palm agriculture

Irrigation has been practised throughout the Nile valley since the earliest times. Until the middle of the 19th century, this was facilitated by natural inundation by the flood water. But over the past two centuries considerable changes have taken place along the Nile River including the construction of barrages and dams that have radically changed and improved the control of irrigation in the country. The total land area irrigated now stands at 7.8 Mfeddans (Table 16).

* Table 16 Land use in Egypt

	Area (1000s fed)	% of total area
Total area	238,445	
Land area	237,616	99.40
Agriculture area	7,836	3.8
Arable land	6,726	2.82
Permanent crop (incl. dates)	1,109	0.46
Permanent pasture		
Non arable & non permanent	229,180	96
Arable & permanent crops	7,836	3

There are an estimated 6 million productive date palm trees planted separately all over the country(not in groves), bordering the farms or even in the middle of the farms, managed with the cropping pattern in the farm.

Egypt is one of the main producers of dates with annual production reaching 1,100,000 tons in 2005. The average yield of the date palms is about 102kg/palm calculated on the basis of bearing palms. This figure is very high compared to the world average that is of about 50kg/palm. The reason for this high yield is two-fold:

- Good access to water. Palm trees in Egypt benefit nearly always from the irrigation of associated crops and because, in many places, the water table is close to the surface.
- More than half of the production is soft dates, which means the fruits contain around 40-50% water.

Date palm culture is nearly always associated with other crops. Its status follows the general characteristics of the agriculture in Egypt.

Date palms are particularly well adapted to saline soils and an excessive rises in the water table, but data are missing to evaluate the effects precisely. A principal role of date palms is to reduce the evapotranspiration of other plants grown under the palm's canopy.

Most of the date palms grown in the Delta and Nile valley are irrigated from the river Nile directly in groves or in-directly if they are grown separately around field margins of annual or perennial crops.

3.3.1 Socio-economic importance

The date palm plays an important socio-economic role in Egypt and supports about 1 million families. Unemployment is high in the rural areas and the flow of people to the cities is an increasing social problem. Agricultural development in terms of increased date production may assist the Egyptian Government's efforts to reduce migration. Date palm cultivation is a labour intensive industry which can contribute to job creation in the oases and areas of date palm plantations. Agro-industries can be developed for processing and packaging of products creating more jobs and generating income, particularly for rural women. Under a fully mechanized date industry an average of seven working days are needed annually per ton of date fruits produced. This calculation is based only on field activities and does not include packaging and processing. To highlight the importance of job creation in the date palm sector, a commercial date plantation of 100 feddan requires 8,000 working days per year.

3.4 Water requirements

Most date palm farmers in the Arab countries, including Egypt, care little about irrigation. They believe that date palms can grow and bear fruits under drought conditions and do not require much irrigation. But all experiments and studies show that date palms must fulfil their water needs in order to grow and produce quality fruit and yield.

Average values of water use for dates in the different parts of Egypt are shown in Table 17.

* Table 17 Average annual ET crop for date palms in the different regions of Egypt (m^3/fed)

Crop	Lower Egypt	Middle Egypt	Upper Egypt
Dates	4,547	5,391	6,253

These values are calculated and based on climate data combined with crop coefficients. But more reliable estimates of crop water requirements are needed.

In general, the date palm irrigation water requirements need more advanced studies using up-to–date calculations under different environmental conditions.

3.5 Irrigation agronomy

Date palms in Egypt do not receive the attention they deserve regarding irrigation, and fertigation, and other agricultural practices and these results in a low level of productivity.

Research in Egypt has shown that 85-90% of a palm's hairy roots are concentrated in the top 2m of soil. This is the main zone where most water is stored following irrigation and where most water is absorbed by the palm.

If date palms are exposed to long periods of drought, the leaf growth is reduced and accordingly the yield and fruit quantity and quality will be severely affected. This is particularly true if the drought is in summer months or at the time of fruit growth and maturity.

Research by Allam et al (1973) studied the effect of irrigation on the tree growth, fruit yield and quality, time of fruit maturity for Sakoti variety in Aswan governorate. The trees were 24 years old and grown in a sandy soil. Palms were irrigated 6 times a year as a control and then 12 and 24 times a year. The time between irrigation was 2-8 weeks. Increasing irrigation frequencies increased the size, weight, moisture content and the total soluble solids of the fruits. But increasing irrigation decreased the total sugars and sucrose and increased the reduced sugars percentages. It also reduced the fruit maturity period by about 15 days. The final recommendation was to irrigate the Sakoti variety at Aswan 12 times a year.

When planting new off-shoots the irrigation frequency of new offshoots planted in sandy soil should be every two days and every 4-5 days in light soil until their root systems have developed. The plants should then be irrigated twice every week in sandy soil and once every week in light soil.

For mature date palms, the rooting depth is about 5m with a radius of 3m. Dates follow the classic water abstraction pattern, namely 40% from the first 50cm, 70% from the first 1.0m, 90 % is from the top 1.5m, and only 10% is from the last layer or 1.5-2.0m and deeper. For young date plantlets this depth can vary from 25-50cm and the radius from 10-30cm, 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 that irrigation 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) may be more effective at delivering water to the root zone than non- localised methods (e.g. flood irrigation).

After planting small tissue culture-derived date palms, the volume of soil from which it can extract water is very small. Sufficient water may be applied, but it may not all be available to the plant. It is thus necessary to ensure that enough water reaches the area where the roots are found. 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 palms do not suffer from water deficiency. Even more care should be given if the palm is planted in a very sandy soil.

The date palm tree should be irrigated before the time of pollination in order to stimulate the growth of the fruit bunches and pollination process will be earlier.

The irrigation should be carried out at the time of developing fruit bunches and stalk pending and at fruit maturing.

The irrigation frequency should be regulated during the fruit development from kemri stage up to khlal stage.

The irrigation frequency and quantities should be reduced at the stage of full maturation to protect the fruit from deterioration and started to be black in colour because of the extra moisture content of the fruits.

At the end of harvesting, the irrigation should be scheduled for the new fruiting development.

The time of irrigation should be early in morning or at evening and stopped during mid day in summer hot days.

It is recommended that irrigation should be stopped for about 40 days starting at the end of November especially if the under cropping is clover or other annuals.

3.5.1 Tolerance to drought and water logging

Date Palm trees can tolerate the two extremes of drought and water logging and so they can be considered as a halophyte and also as a xerophyte plant. They can grow in harsh environmental conditions of the desert, like the oases, and also grow well around the lakes of the northern Delta where the shallow ground water is very close to the surface.

In-spite of their neglect date palm trees can tolerate drought much better than most other fruit trees. But if the soil around the root system reaches wilting point the growth of the leaves and the fruit will be affected. Date palms growing in deep soil with high water holding capacity can produce average yields even with no irrigation for 2-3 months (June–September) the leaf growth will be affected little, but after irrigation the leaves grow normally. Date palm trees in areas where the ground water table is high do not require irrigation. This is the case in the Northern part of the Delta.

The plant can survive in water logged conditions because it has large vacuole cells which can store oxygen through an inter-aeration system from the stem tissues down to the root zone.

In spite of the tolerance of date palms they do prefer controlled irrigation in order to grow and bear the best yields and quality fruits.

3.5.2 Tolerance to salinity

Date palms can tolerate irrigation water salinity better than any other fruit tree but the crop yield will be affected depending on the concentration of salts.

Studies suggest that date palms can produce full crop production if they are irrigated with saline water up to 2,000ppm. The yield will be reduced by about 10%, 25%, and 50% if the irrigation water salinity rises to 3,000, 5,000, and 8,000ppm respectively.

3.6 Irrigation methods

Egyptian farmers have traditionally irrigated by dividing their field into small basins of not more than 10×10m. These basins provide the farmer with reasonable water control and allowed application of reasonably uniform amounts of water even when fields are somewhat unleveled. This method of irrigation for date palm is used mainly in the old lands, especially in the northern part of the Delta and also in Aswan. Basins with furrows are used widely in the Delta.

Furrow irrigation is often used to irrigate new offshoots and after four years basins are used.

Sprinklers are used for many crops but not usually for date palms. Drip, bubbler and micro irrigation systems are used but little research has been reported on the benefits of these systems.

However, some limited research work on the use of drip produced some encouraging but limited data. In an experiment on full grown date palms of Zahdy variety four drippers where used for each tree providing a total application of 8gal/h/tree. The rate of irrigation is 50 gallon/day/tree in winter and 150-175 gallon/day/tree in summer. All the treatments increased the crop yield up to 100kg/tree. Another experiment compared drip with sprinkler irrigation. The water requirement for irrigation was 150-200m^3/day/tree using 12drippers/tree. The yield was 145kg/tree for drip irrigation while 109kg/tree for sprinkler.

3.7 Irrigation research

Since the 18th century the irrigation authorities in Egypt have collected data on the Nile Basin which has enabled investigators to carry out many studies related to irrigation and to the means of utilizing and developing Egypt's water resources.

In more recent times the Ministry of Public Works and Water Resources has upgraded research and established a "Water Research Center" in 1975 to study outline and long term issues relating to irrigation and the use of water resources for agriculture. There are 12 other institutes that also undertake research that is of importance to irrigated agriculture.

Water shortages in the country as the population grows are encouraging researchers to look for more efficient methods of growing crops.

References

Allam HM, Hussein F and Abdalla KM (1973) Seasonal requirements of water by Sakkoti dates grown at Asswan. Moshtohor, Fac. Res. Bull 39: 1-10.

Al-Homad A and MA Kassem (2003) Determination of water Requirements and irrigation scheduling for Date Palm offshoot. KSA, King Saud University, college of Agric. Qaseem Branch.

International conference on Date Palm (2003) Center for agricultural water use efficiency Research-Irrigation of date palm with saline and effluent water. http:/mop.textstore.co.il

Egyptian code of the re-use of Treated Waste Water in Agriculture 2005 Building and Housing Research Center.

FAOSTAT (2005) Area under Date Palm in North Africa.

FAO (2005) Final Report: Rapid assessment study: Towards integrated planning of irrigation and Drainage In Egypt.

Ghulom Hussein et al (1993) Water requirement of young date palm tree under flood irrigation in Al-Hassa. Saudi Arabia the third symposium on Date Palm, King Faisal University, Date Palm Research Center.

Liebenberg PJ and A-Zaid (?) Date Palm Irrigation, Date Palm cultivation, FAO Corporate Document Repository

Mahmud TH (1958) Processing and marketing aspects of the date industry in the Coachella valley. California. MS of arts thesis in Geography. University of California-Los Angeles 298pp.

Popenoe P (1924) The date palm in antiquity. Sci. Monthly 10:313-325.

Riad M (?) The date palm sector in Egypt CIHEAM-Options Mediterranean's, Ministry of Agriculture and land Reclamation Cairo, Dokki, Egypt.

4 Iran country paper

4.1 Background

Date palm has a long history in Iran and it is said that the origin of this crop belongs to regions near Persian Gulf. It is a crop that survives in harsh climatic conditions and can tolerate high levels of soil and water salinity. It is called the food crop of dry and poor regions. In at least three big provinces of Iran (Sistan and Balouchestan, Kouzestan, and Boushehr) more than 50% of perennial plantations are planted to dates palms. Its good nutritional value, its resistance to harsh conditions, a historic interest from farmers, and its various edible and non-edible uses has made this crop one of the most important and socially justified agricultural crops in the country.

4.2 Agriculture and water resources

Iran has a mean annual rainfall of 250mm, which amounts to a potential water resource of some 413Bm^3/yr. The usable water is about 135 Bm^3. Some 93%, equivalent to about 86Bm^3, is consumed by agriculture.

The total irrigated area in 2004-05 was 9.18Mha. According to government statistics the area under perennial crops is about 2.6Mha. Date palms account for about 239,000ha (Table 18) (about 9% of perennial crops) and they are ranked as the third fruit crop in the country. Total water consumption of date palm plantation is estimated to be about 3Bm^3. Out of a total date palm plantation area approximately 199,000ha is considered to be productive and about 40,000ha are unproductive. Almost 98 percent of plantations are irrigated with the remainder rain-fed. Almost all the plantations are located in six eastern, southern and south-eastern provinces of the country. Average yield from the irrigated date palm plantations is about 5,459kg/ha.

* Table 18 Area of date plantations and annual water use from different sources

Province	Plantation area (ha)	Amount of water used (Mm^3)	Underground (Mm^3)	Surface (Mm^3)
Boushehr	34,785	491.65	417.90	73.75
Sistan & Balouchestan	37,819	491.65	417.90	73.75
Fars	29,361	381.69	305.35	76.34
Kerman	54,437	707.68	636.91	70.77
Hormozgan	39,118	508.53	457.68	50.85
Khouzestan	37,741	490.63	147.19	343.44
Other area	5,601	72.82	54.62	18.21
Country	238,862	3,144	2,437	707

4.2.1 Date palm growing areas

Some 98% of the date palm plantation area is located in six provinces in the south southwest and southeast of the country. Some important issues related specifically to irrigation methods, practices and problems are described briefly below.

BOUSHEHR

In this province four permanent rivers provide irrigation water for date plantations. However, the annual flow in these rivers does not meet the real need of the plantations and the water quality is also not good. Flood irrigation, which is very inefficient, is practiced widely. Large ponds with water depths up to 1.0m are used to irrigate 30–60 date palm trees at one time. This irrigation method was copied (mistakenly) from methods used in the southern region were large basins were constructed to catch rainwater rather than for formal irrigation.

With introduction of heavy soil moving machinery this poor and inefficient irrigation method was extended even further. Rising water tables and poor drainage are also a problem in places, as is the lack of research into the irrigation problems facing farmers in this province.

SISTAN AND BALOUCHESTAN PROVINCE

Both surface and ground water resources supply water for date palm orchards. Underground resources are extracted by deep and semi deep wells, while surface water comes both from rivers and qanats.

Flood and basin irrigation are used in Saravan and Iranshahr but because of water shortages farmers have resorted to efficient methods of rain water harvesting. In some places, small structures are built from local materials and runoff water flowing along seasonal water courses is diverted into irrigation basins.

In this region there is a strong cultural relationship with date palm trees. Farmers who own more date palm trees and who plant more of this crop are considered more superior to others and this gives them a feeling of pride and superiority.

In this province like some others, inter-cropping with date palms is common. Date palm trees cannot provide all the basic needs and because they are normally planted 10×10m it takes years (generally more than seven years) for the trees to bear fruit. So the space between date palm trees is cropped with annual, biannual and perennial crops. This way the farmers maintain a good income.

FARS PROVINCE

The main irrigation water resource in this province is surface water and to a lesser extent groundwater. The quality of ground water varies within the region and the quantity is limited. The main irrigation method for date palms in Jahrom area is basin and trickle irrigation. The irrigation interval for basin irrigation is usually around ten days. Due to severe water shortage in this area trickle irrigation is more popular. It is the only place in the country in which the date palm growers have been convinced to invest in modern irrigation techniques.

Most trickle irrigation systems have been implemented at the farmer's expense and government financial contribution is minimal. This area could well act as a pilot for the introduction of modern irrigation techniques as the farmers are more informed and conditions are better prepared for extension of new and scientific ideas than in other provinces.

KERMAN PROVINCE

This province has low precipitation and scarce water resources. Except for areas in Bam and Jiroft that have limited surface water resources most other places rely on ground water.

The main date palm growing townships in the province are Bam, Jeeroft and Kahnooj. The famous Mozafty variety of date palm is widely grown in Bam and this place is well known for its dates. Deep and semi deep water wells, qanat and river flows, form main water resources for date palms. The most popular and widely practiced irrigation methods are basin and flood irrigation, although modern methods are gaining in popularity.

HORMOZGAN

This province does not benefit from permanent rivers with high discharges. The most important rivers are Minab and Mehran rivers. Because of hot climates, a large part of river flows evaporate. Date palm growing areas are in Hjiabad, Minab, Bandar Lengeh and Roodan. Date palm plantations are old and unproductive and farmers have little incentive to invest in infrastructural affairs of these plantation. The most widely practiced irrigation method in the province is flood irrigation, by pumping from water wells, springs and qanat. The irrigation interval in young plantations in the Bastak area is once every other day and in old plantations once every seven days. During winter months, irrigation interval is 20 days.

KHOUZESTAN

This area is close to the Persian Gulf and as a tradition most plantations were irrigated by tidal methods. During high tide at night, water levels in the rivers near the sea coast rise and water flows under gravity into rows of date palm trees through special control gates. At low tide the river levels drop and water accumulated in the field furrows and channels starts to flow back into the rivers but some is retained by control bunds. By this means the date palm orchards can be irrigated as required. Sea water intrusion is one of the main problems with this method when the river levels are low.

Although this method was used for centuries, it was abandoned during the Iraq-Iran war and date palm plantations were seriously damaged and control structures were destroyed by bombing. Without water control the plantations rapidly became saline and the land became a marsh. The extent of the damage was so severe that during the years after the war, despite all efforts to rehabilitate the area there has not been much success.

4.3 Water requirements

For purpose of this study date palm water requirements were calculated using two methods and sources, cropwat4.3, which is widely used throughout the world, and a national water document which is based on Netwat (Table 19). Netwat comes from the National Water Document (NWD), which was prepared by joint activities of some of the top national university and research professors, is a modified integration of all the methods used for calculating crop water requirement and was adjusted to natural and climatic environments in Iran. The actual figure of date palm water requirement differs between two methods. Calculation using NWD results in lower figures. Although cropwat4.3 is internationally accepted for estimating crop water requirements the NWD is well accepted in Iran.

* Table 19 Date palm net water requirements (m^3/ha/yr) – comparing calculation methods

Station name	Province name	Cropwat	Netwat	Difference
Boushehr	Boushehr	16,393	12,940	3,453
Abadan	Khouzestan	20,980	19,720	1260
Ahwaz	Khouzestan	18,440	16,840	1,600
Bam	Kerman	19,883	13,230	6,653
Jiroft	Kerman	13,249	13,400	-151
Kahnouj	Kerman	20,240	16,860	3,380
Bandar abbas	Hormozgan	16,393	14,680	1,713
Minab	Hormozgan	14,712	15,030	-318
Lar	Fars	16,774	14,680	2,094
Iranshahr	Sistan & Balouchestan	18,484	16,120	2,364
Chabahar	Sistan & Balouchestan	15,134	12,270	2,864
Saravan	Sistan & Balouchestan	20,470	16,120	4350
Average	country	17,596	15,152	2,444

Estimates of actual water use by dates suggest that an average of 13,000m^3/ha/yr are applied. This is in comparison with the calculated amounts in the above table of 13,240–20,980 m^3/ha for Cropwat and 12,270–19,720m^3/ha for the NWD method. This implies that most date palms in Iran are under water stress, except in a few plantations in Khouzestan and Boushehr provinces where the amount applied is more than the crop needs.

4.4 Irrigation agronomy

4.4.1 Saplings

Irrigation of saplings is most necessary after planting. For surface irrigation the best method is ponding or basin method.

However, research has shown that the best method for date palm saplings is trickle irrigation. This method produces a more uniform moisture distribution and is preferred to surface irrigation methods. In Bam region (Kerman province) drip irrigation of young date palm trees using an 80% coefficient relative to Class A evaporation pan. The water requirement is estimated to be 5,000m^3/ha with an irrigation interval of two days.

Saplings must be irrigated immediately after planting and irrigation should continue for 4-6 months so that the soil around the sapling is kept permanently moist.

4.4.2 Salinity and inundation

Compared with other fruit crops date palms have the greatest resistance to salinity and it is relatively resistant to water shortages. Date palm trees can tolerate salinity levels of 6,000-7,000 ppm but this salinity range has a negative effect on quality and the quantity of dates produced. Date palm plantations can be irrigated with water with EC of 3.5 dc/cm without any reduction in crop performance. Date palm trees can tolerate flooding and water logging conditions because they have air voids in their rooting system. However, long durations of inundation can have negative effects.

Productivity

Table 20 shows the plantation areas in the different provinces together with date production and total water use. From this the water productivity is determined. The average productivity is 0.37kg/m^3.

* Table 20 Date palm water productivity

Province	Plantation area (ha)	Production (tons)	Water used (Mm^3)	Water productivity (kg/m^3)
Boushehr	28,769	140,181	403	0.35
Sistan & Balouchestan	32,883	132,075	427	0.31
Fars	27,138	121,165	353	0.34
Kerman	43,865	279,799	570	0.50
Hormozgan	35,304	132,520	459	0.29
Khouzestan	27,444	145,071	357	0.41
Other areas	3,669	9,662	47	0.20
Total	199,072	960,473	2,616	0.37

4.5 Irrigation methods

Although date plantations have been increasing over the past 30 years the method and efficiency of irrigating them has not improved. Modern irrigation systems like trickle irrigation (which has been recognized as most suitable for date palm trees) were introduced in the country about 40 years ago, but the area covered by these method before the 1979 revolution was negligible. After the revolution, especially after the end of the eight year imposed war, considerable attention was paid to the development of modern irrigation systems for all annual and perennial crops. During the last 15 years some progress has been made in this respect but the area of date palm plantation converted to modern irrigation is still very low.

One constraint is that most plantations are old and are irrigated with surface methods. There are concerns that switching to trickle irrigation may cause problems as the root system may not be able to respond to the new and localized method of applying water. This is a strong belief amongst the date growers which has affected the development of modern irrigation methods. Also some plantations are either already unproductive or the date palm variety is so inferior that it does not have good economic value. So investing in expensive modern irrigation is not a viable option.

In many cases, soil and water quality does not allow farmers to use modern irrigation systems especially in some parts of Hormozgan, Sistan and Balouchestan, and Boushehr provinces. The financial status of date palm farmers together with low knowledge and information about irrigation is another reason for poor take up of modern methods.

An estimate of the areas of date palms using trickle irrigation is shown in Table 14. According to the government data there is approximately 81,000ha of trickle irrigation on perennial crops in six provinces of which 10,700ha are date palm plantations. Only 3% of the plantation area is equipped with trickle irrigation, the majority is irrigated using flood methods.

* Table 21 Estimate of date palm areas using trickle irrigation

Province	Perennial crops (ha)	Date palm plantation area (ha)	Trickle irrigation date palm (ha)	Trickle irrigation perennial crops (ha)
Boushehr	39,331	34,785	1,200	5,200
Sistan, Balouchestan	57,450	37,819	4,640	7,796
Fars	325,525	29,361	1,697	27,574
Kerman	485,242	54,437	867	13,902
Hormozgan	82,745	39,118	2,100	22,000
Khouzestan	57,785	37,741	200	5,000
Other areas	154,7939	5,602	---	---
Total	2,596,017	238,862	10,704	81,471

4.6 Institutions

Because date palm is one of the main fruit crops in the country and is important both for the domestic and international markets it receives a great deal of attention.

At the ministry level there is a "Deputy of orchards affairs". This especially deals with policy-making, managing and implementing all activities to do with fruit crops. Under this deputy there is the "Bureau of date palm and tropical crops". There is also an "Institution date palm and tropical trees research" under the deputy minister for research and training of the Ministry of Jahad– Agriculture (moja).

In terms of irrigation there is a bureau for "Improvement and development of irrigation methods" working under the Deputy Minister for Industry and Infrastructural Affairs. This bureau has the duty to plan, study, and recommend suitable irrigation methods for field crops and orchard crops. In southern parts of country especially in orchard plantations, the main emphasis is on improvements to date palm irrigation. In each province there is a provincial Jahad - agricultural organization, under which two directorates deal with date palm affairs and more specifically their irrigation affairs.

All these organisations are government run and rely on long and complicated procedures. None are solely engaged in date palm work. The private sector is only engaged in implementing and to some extent training and education. Nearly all the government financial projects are implemented by private contractors through tenders.

At provincial and township level Soil and Water Units coordinate and monitor date palm irrigation projects. During the past two decade (after ending the war with Iraq) a significant effort has been made to recreate and empower private irrigation contracting and consulting companies. Altogether 500 of these companies have been established throughout the country with an expert ability of more 1,200 experts. All those involved in irrigation, private and government, try to provide good support and services to farmers but the main government extension agency is not fulfilling its obligations in an effective way. The framework and set up for government activities and support services are in place but a lack of proper economic productivity of old plantations, negative effects of soil and water quality, a lack of financial ability among farmers, and a lack of good training and practical information on good irrigation management of date palm plantations has meant that services are ineffective.

Although there are many Water User Associations in irrigation areas none have formed in date palm growing areas to improve water allocations. These social and non-governmental organisations play an important role but since the date palm farmers are relatively poor and illiterate and date palm is normally intercropped with some annual and perennial crops, the formation of a separate organisation specifically for date palms is unlikely.

4.6.1 Advisory and extension services

Although there is good coverage of government services in date palm growing regions, the staff are not well educated and trained in the different issues and aspects of modern irrigation methods. This is one of the reasons why it has been difficult to change farmer views and behaviour. Indeed one of the reasons for low efficiency of irrigation is the unsatisfactory performance at different levels within this organisation.

References

Ministry of Jahad-agriculture statistical yearbook of 2004-2005, statistic and information technology office.

Deputy of horticultural affairs, ministry of jahad-agriculture (2001) Date palm guideline; planting, husbandry and harvesting.

5 Libya country paper

5.1 Background

Libya has 610,000ha under irrigation and 1,992,000ha under rainfed agriculture mainly as range land especially in the coastal region where there is enough annual rainfall – 50-300mm annually. Early statistics from 1850 estimated the number of date palm trees to be around 11 million but due to many adverse conditions the number now is only about 3.5 million trees and only one half of them are under production which produce about 150,000 tons. These data are taken from reports prepared by the national authority for information and documentation from an agricultural census in 1987 and 2001. But in contrast to these figures the Ministry of Agriculture suggests there are about 7 million palm trees.

Date palm culture in Libya is many centuries old – they are grown where ever soil and water are available. There are 400-550 different date cultivars, a few are excellent fruit quality but the rest are of fair and poor fruit quality.

Climatic factors influence the cultural practices of date palm in each region. Trees in the north are widely spaced, not more than 50palms/ha, while in the oases and the south spacing is 100-150palms/ha. Date palm trees in the north are usually intercropped with legumes in winter time and forage crops in summer. In such cases date palm trees get most of their water and fertilizer requirements by sharing it with the inter-crop. Newly planted orchards in the oasis and the south are also inter-cropped but only in the first few years of growth. After that the close spacing produces too much shade.

Date palm fruits were the main staple for the Libyan population before the discovery of oil. People used to take good care of the date palm trees because of their very nutritious fruits and they used all parts of the date palm – its fruits for human consumption, its leaves, leaflets, and seeds for animal feed. They use the tree for all types of agricultural equipment, home furniture, building houses and barns. In general date palm trees were an important crop in every orchard and agriculture was the backbone of the Libyan economy. Some 80% of the population worked in agriculture. In the late 1950s and early 1960s oil was discovered and this changed the lives of the people and the economy of the country. Agricultural workers left their farms for easier jobs, most date palm farms were deserted. Before the oil you would never find a neglected date palm tree and you would also not see a tall palm. It would be cut down as soon as it reached a good height and used for some useful purpose and replaced immediately with a new offshoot.

During this period date palm plantations in the oases suffered from water shortage and most of them were lost to drought and desertification. In more recent times the government has taken steps to bring date palms back as part of the agricultural landscape and planted more than one million offshoots in a short period of time. All the new date palm plantations were put under drip irrigation.

5.2 Date palm areas

Date palms are grown in the three main agro-climatic regions of Libya:

- The coastal region characterized by high humidity, rain and low heat unit accumulation for fruit ripening.
- The central region comprising the entire oasis north of 28° north; it is the most suitable region climatically for excellent date fruit production.
- The southern region contains all the oases in the south. Most of the dates produced here are hard, dry fruits.

The Coastal Region is the agricultural region along the Mediterranean Sea which is about 1900km long. Date palm trees grow in many cities, towns, and oases. The total number of trees is around 1.3 million covering an area of about 10,000ha. The climate in this region is the Mediterranean type and generally considered not the best place for excellent date production, but it is good for some varieties. The early rain in the fall spoils the fruits which must be harvested, packed and stored for winter consumption.

The Central Region is the most important for date palm production. It includes Ghadames, Jofra (oases of Hun, Sukna and Weddan). The relative humidity is 40-55% which is very suitable for the production of excellent fruits, especially as there is no rainfall in the autumn, when the fruits are ripening. There are about 800,000 date palm trees grown in oases covering an area of 6,000ha which produces 32,000 tons of good quality dates.

The Southern Region is characterized by desert climate with low humidity. About 1.5 million date palm trees grow here in an area of 15,000ha and produce 50,000 tons of dry dates. This region is good for the production of hard date fruits, high temperatures injure fruits in many years making them tough. Many varieties are only good for animal feed.

5.3 Date production

Irrigation of date palm trees along with other cultural practices increases yield and improves quality of fruits. There are about 14,000ha of date palms in the south that produce about 80,000 tons of dates and consume 280Mm^3 of water annually. Most of these are poor quality dates and it is estimated that pre and post harvest losses are as high as 30-40%.

5.4 Water resources

Libya relies extensively on underground water but over-abstraction is depleting the resources. The Jafara aquifer, for example, can yield 280Mm^3 annually but consumption is estimated to be 1,750Mm^3. As a result many wells are drying up and there is increased sea water intrusion along the coast.

Salinity in fresh water aquifers is increasing year after year and in places it has reached 8-12g/l. This high salinity destroyed all the citrus orchards, pomes trees and other stone fruit tree in the region. Even though date palm trees are highly tolerant of saline water they suffer also. One reason behind all these problems was the conversion of thousands of hectares of range land and rain fed agriculture into irrigated farms to grow crops requiring a lot of water such as peanuts, watermelons, tomatoes, and citrus. In the early 1990s the Secretary for Agriculture established some 100ha of bananas grown under glass which consumed large quantities of water.

There are huge underground water resources in Kufra, Sarir and Morzoq but the main problem is that they are located in the middle of the desert and the soils are pure sand with no organic matter and very poor water holding capacity.

The Great Man-Made River was built to transport water from these distant underground supplies to the coastal region for domestic, industrial, and agricultural purposes. One of the main objectives of this was to stop further deterioration of the Jafara aquifer, and to increase the agricultural production in the north close to the skilled farmers, fertile soils, and markets. The other objective was to reclaim land for agriculture and to grow date palms using drip irrigation systems to conserve the water.

5.5 Water requirements

Table 22 shows the calculated monthly and annual water requirements for date palms planted at 100 trees/ha. It ranges from 8,800m^3/ha at Tripoli near the coast to 20,900m^3/ha in the desert region at Kufra.

These data were calculated using FAO's Cropwat7.

* Table 22 Water requirements for date palms in selected locations (m^3/ha)

Location	1	2	3	4	5	6	7	8	9	10	11	12	Total
Tripoli	135	414	729	1,103	1,326	1497	1,556	1,002	686	337	21	32	8,840
Kufra	934	1,526	2,072	2,5501	2,913	3,075	3,003	1,852	920	920	5,200	600	20,900

5.6 Irrigation agronomy

Water is the most important factor for date palm cultivation. It influences vegetative growth as well as quantity and quality of the yield. If the root zone is kept dry for a long time it will affect tree vegetative growth, it will restrict the growth of the tree, and the number of leaves.

Yield is influenced by drought even though date palm trees are very well known for their ability to tolerate drought. This is true for date palm trees planted under rainfed conditions in the coastal region of north Libya, especially in years of low rainfall. The production decreases drastically and trees are forced to alternate bearing habits. Shortage of irrigation water affects the quality of fruits, resulting in smaller size, but early ripening.

Date palm trees have an extensive root system that can spread to more than 8m from the trunk of the tree. However, most roots (40% of them) are found in a circle around the trunk of 2m diameter. They can also penetrate deep – up to about 10m. Significant differences in root distribution were not found when comparing palms growing in frequently irrigated plots and dry plots.

Vegetative growth is appreciably reduced by water shortage but this may not significantly reduce yield. But water deficits that nearly or entirely prevent growth result in reduced yields and other harmful effects.

In one study with holding water for four months in summer reduced leaf growth but not the yield of dates. In another study irrigation was supplied at 2, 4, 8 and 16-week intervals to 18-year-old Khadrawy date palms on a stratified alluvial soil for two seasons. Root sampling studies showed that feeder roots were concentrated in the top 1.5-2.0m in the silty soil and were scarce below this depth. In the 2, 4 and 8-week treatments the water capacity in the high root-feeding zone fluctuated between field capacity the wilting percentage. In the late summer and early autumn in the 16-week treatment the moisture content of most of the soil in the top layer remained above the wilting range for several weeks in both years. So long as the moisture content of the soil remained above the wilting range, neither yields nor leaf-growth rates were significantly reduced by water shortage. When the soil was allowed to remain in the wilting range for several weeks, there were significant reductions in leaf growth rate and in fresh weight per fruit, and inflorescence emergence in the following spring was delayed. But there was no significant reduction in yield because the shortage occurred when the fruit was mature or ripening.

In a 2-year irrigation experiment, 3 treatments were imposed, viz. moderate summer drought (June-July); moderate autumn drought (August-September); and adequate water throughout. Those palms subjected to summer drought had markedly less leaf growth and lower yields because of increased hard end, khalal shrivel, and immature shatter. The autumn drought did not cause significant increases in these fruit disorders. The severity of drought injury appears to depend on temperature and on the development stage of the fruit.

Another experiment was conducted on Khadraway variety to assess the effects of water shortage during the fruit-ripening period and of nitrogen fertilization. Although the moisture content of the soil was reduced to one quarter of the available moisture in the top 1.5-2.0m of the root zone, leaf growth rate was reduced only slightly during the period of drought, and total growth for the year was as great in the dry treatment as in the wet treatment. Between treatments in both the irrigation and the fertilization experiment the differences in annual trunk growth and in yields of fruit were small and statistically not significant. In certain picks the dry treatment had some effect on the quality of the fruit harvested, but this effect was not consistent and the differences in the grade of fruit from the two irrigation treatments were not significant in any one year or in the 5-year period over which the experiment took place. The results of the irrigation experiment indicated that on soil of medium texture the practice of withholding water during harvest will have little influence on yield or grade of fruit and may be practiced for convenience in performing harvesting operations with little fear of harmful effects.

The traditional method of irrigating newly planted off-shoots is to irrigate them daily for 60 days during the summer. Young seedlings need a lot of water in the summer, because the rate of evaporation and transpiration is high and the seedlings do not have an effective root system to enable them to absorb their water needs. Shortage of water during this stage could lead to retarded growth and in many cases death of the seedling. Farmers who are not familiar with date palm culture loose a lot of seedlings for not taking care during this stage.

5.6.1 Inter-cropping

The traditional practice in the northern region is to plant crops between date palm trees. Forage crops, winter and summer season vegetables provide a good source of income. In the oases and in the south it is recommended that date palms are planted together with citrus trees. This is a good combination since date palm trees provide very good protection from the heat and reduced sun scaled injuries to the fruits and young twigs of citrus tree. But careful attention is needed to provide the water requirements of both date palm and citrus trees. Olive trees and date palms also make another good combination.

5.6.2 Salinity tolerance

A 5-year salinity and leaching trial was conducted with water containing 1 ton of salt/ha.cm. Water was applied at 1.8, 3.0 or 4.2m/yr for irrigation and leaching and N was applied at 0.36 or 6kg/tree/yr. Conductivities of the saturation extracts were 3 millimohs/cm for the 4.2m application and 4-7 millimohs/cm for the 1.8, and the 3m being intermediate. Salt accumulated more in the lower half of the root zone but was similar in the 0-2.5 m and 2.5-5 m. soil zones. With the application of 3m of water/yr salt removal was adequate, but with 1.2m it was not. Heavy N improved leaf growth and yield but reduced quality. In the first three years yield and quality were unaffected by differences in water supply, but in the last two years yields were lower in the 1.8m irrigation treatment. Fruit grades, however, were not affected.

Increasing the electrical conductivity of the soil by the addition of calcium and sodium chlorides had no effect on the growth rate and Cl content of the leaves, nor on the yield, size or quality of the fruit.

In another experiment seedling of the varieties Deglet Noor and Medjool were grown in peat moss plus vermiculite and watered with Hoagland's solution. At the 2-leaf stage salt was added to 1/3-strength Hoagland's solution at 6,000, 12,000, 18,000 and 24,000ppm. The growth rate of selected leaves was measured and later the extent of the dying back of the leaf tips was also measured. After 8 weeks the plants were analyzed for salt content. Plants receiving the highest salt concentration accumulated the most Na and Cl, but the Cl content in the roots and tops of plants from the 24,000ppm treatments were less than double, and the N content in the tops only about double those in plants from the 6,000ppm treatment. The roots accumulated 2-3 times as much Cl and 5-10 times as much N as the tops. As the salt content of the substrate increased, leaf growth decreased and more Na accumulated in the tops rather than the roots. Growth depression was more closely related to the osmotic pressure of the saline irrigation water than to salt accumulation in the plants.

An experiment was conducted on young date palms of the Deglet Noor and Medjool varieties. The plants were irrigated for one year with water containing 253 (control), 6,000, 12,000, 18,000 and 24,000ppm of salt. Leaf growth rate was halved by the 6,000ppm treatment and decreased considerably further at higher concentrations. Very small increases (up to 0.5%) in the Cl content of dry pinna tissue of palms receiving the salt treatment were not closely related to soil salinity; small Na increases were also not closely related to salinity. The Medjool variety was slightly more salt tolerant than Degelt Noor.

In another experiment the objective was to determine whether it was possible to grow mature date palms using drip irrigation. After two years, an advantage was found in the trickle-irrigated trees with regard to vegetative growth and yields. The latter was pronounced in the second year and could be explained by the higher weight of individual fruits in these treatments.

A long-term irrigation experiment, comparing sprinkler and drip methods was conducted for five years on mature, bearing Deglet Noor date palms. Under drip irrigation, two sets of drippers were compared (12 or 24 drippers/tree, dripper discharge rate 10l/hr). Drip was superior to sprinkler irrigation, as expressed in greater annual leaf and bunch production, fruit size and total yield. The advantage was explained by higher water availability.

Date palms could be grown and made to yield when only a small part of the area between trees was wetted. The advantage of using drip irrigation under marginal conditions of saline water, high water table and atmospheric dryness (the conditions under which the experiment was carried out) is discussed in the research.

Beginning in 1974, a small planting of abandoned 36-year-old Zahidi date palms was successfully renovated by means of good maintenance, fertilization and irrigation with a drip system. In 1978-79, the yield averaged 100kg/tree.

5.7 Irrigation methods

Surface irrigation is still widely practised in the coastal region, especially close to Tripoli, around Tajoura , Mosrata , and Tawergha. Large basins around several trees are flooded with water both for irrigation and leaching the salts that accumulate in the soil, since irrigation water contains about 4000mg/l of TDS. The soil is also saline.

* Figure 2 Basin irrigation of offshoots

Sprinkler irrigation, introduced in the country in the early 1950s, is also still practiced on date palms. It is widely used almost everywhere in date growing regions and several types of equipment are used.

* Figure 3 Sprinkler irrigation of mature trees and young offshoots

Drip irrigation is considered to be the most desirable method for date palms but it is not yet widely used in Libya. The equipment and its installation is still very expensive and converting the old traditional date palm orchards to drip irrigation has produced some negative results because of misunderstandings about the system and its operation. Growers still do not believe that the drippers will provide the required water for their crops. A great deal of extension work is needed, such as pilot orchards, training courses for extension agents and growers, workshops and appointment of qualified personnel from the colleges of agriculture graduates in order to convince growers.

* Figure 4 Drip irrigation of young off-shoots

5.8 Institutions

There are several institutions that are directly or indirectly involved in the irrigation:

- Six colleges of agriculture, the most important one being the College of Agriculture University of Alfateh at Tripoli.
- The General Water Authority
- The Agricultural Research Center – established in 1971 with staff members conducting research in the field of horticulture and date palms research and development.
- The Great Man-Made River – in charge of planning and managing investment in infrastructure for conveying water to agricultural projects in the north.
- The Agriculture Extension Service – this is rather a poor service. It requires much more support from the Ministry of Agriculture.

References

ABOU-K HALED A, CHAUDHRI SA and ABDUL—SALAM S (1981) Preliminary results of a date palm irrigation experiment in Central Iraq. Date Palm Journal, 1:199—232.

AL-BEKR AJ (1972) The Date Palm: A review of its past, present status and the recent advances in its culture industry and trade. Iraq (Arabic); 1085pp.

ARMSTRONG WW and FURR JR (1959) Root distribution of Khadrawy date palms in relation to frequency of irrigation. Rep. 36th Ann. Date Growers Institute. 13-15.

DOWSON VHW (1961) Report to the Government of Libya on date production. FAO; Rome.

FURR JR (1975) Water and Salinity problems of Abadan Island date gardens. Report of Annual Date Growers' Institute, 52:11.

Furr JR and Armstrong WW (1955) Growth and yield of Khadrawy date palms irrigated at different intervals for two years. Report of the Annual Date Growers' Institute, 32: 3-7.

Furr JR and Armstrong WW (1956) The seasonal use of water by Khadrawy date palms. Report of the Annual Date Growers' Institute, 33: 5-7.

Furr JR and Armstrong WW (1958) The influence of heavy irrigation and fertilization on growth, yield and quality of Deglet Noor dates. Annual Report of the Date Growers' Institute 35: 22-24.

Furr JR and Armstrong WW (1959) The relation of growth, yield and fruit quality of Deglet Noor dates to variations in water and nitrogen supply to salt accumulation in the soil. Annual Report of the Date Growers' Institute 36: 16-18.

Furr JR and Armstrong WW (1960) Influence of summer or fall drought on hard end and immature shatter of Halawy dates. Annual Report of the Date Growers' Institute, 37: 7-10.

Furr, JR and Armstrong WW (1962) A test of mature Halawy and Medjool date palms for salt tolerance. Annual Report of the Date Growers' Institute, 39: 11-13.

Furr JR, Currlin EG and Armstrong WW (1952) Effects of water shortage during ripening and of nitrogen fertilization on yield and quality of Khadrawy dates. Report of Annual Date Growers' Institute, 29: 10-12.

Furr JR, Currlin EC, Hilgeman R.H and Reuther W (1951) An irrigation and fertilization experiment with Deglet Noor dates. Report of Annual Date Growers' Institute, 28: 17-20.

Furr JR and Ream CL (1967) Growth and salt uptake of date seedlings in relation to salinity of the irrigation water. Annual Report of the Date Growers' Institute, 44: 2-4.

Furr JR and Ream CL (1968) Salinity effects on growth and salt uptake of seedlings of the date (*phoenix daotylifera* L.) Proc. Amer. Soc.Hort. Sci., 92: 268-73.

HUSSEIN F and HUSSEIN MA (1982) Effect of irrigation on growth, yield and fruit quality of dry dates grown at Asswan. First Symposium of the Date Palm, 23-25 March, , KFU, Al-Hassa, Saudi Arabia, p. 168-173.

REUVENI O (1974) Drip versus sprinkler irrigation of date palms. Report of the Annual Date Growers' Institute. 51:3-5.

ROBERTSON E Jr (1979) Drip irrigation of mature date palms. Report of the Annual Date Growers' Institute, 54:1 2.

SHARPLES GC and HILGEMAN RH (1951) The influence of irrigation and bunch management upon shrivel of the Maktoom date. Report of Annual Date Growers' Institute, 28: 9-11.

6 Morocco country paper

6.1 Background

In the 18th century, Morocco was famous for exporting good qualities of dates to Europe. London used to be the principal importer of Mejhoul and Boufeggous dates which acquired world fame. But today the bayoud disease, which destroyed more than 65% of the palms in the country, has meant that export is no longer possible. In addition the long droughts, water scarcity, and the oases becoming covered with wind-blown sand have all constrained production.

Date palms have been cultivated in Morocco for many centuries in the Tafilalet and Ouarzazate regions. Both surface and groundwater are exploited using 'khettaras' (drainage galleries) and well established ancestral rules for water sharing developed by the local population that has served them well in the harsh desert climate.

6.2 Date production

Date palms are cultivated mainly along Ziz (Tafilalet) and Draa (Ouarzazate) valleys. They contribute 60% of agricultural incomes for one million people. In addition to fruit, they provide various materials for the craft industry, building, and for energy production. Moreover, the date production constitutes a significant commercial activity between South and North of country and helps to generate employment and stabilize communities in the pre-Saharan zones with fragile agro-ecological equilibrium.

Morocco has approximately 4.8 million palm trees producing 100,000 tons in a normal year and an average of 75,000 tons (over last 10 years) as a result of water shortages recorded in recent years. This average is clearly below that recorded during the period 1987-1994, which is approximately 88,000 tons. Date consumption is 2kg/person on a national average but 15kg/person in the areas of production.

* Table 23 Distribution of date palm trees in Morocco

Region	Ouarzazate	Errachidia	Tiznit	Tata	Figuig	Guelmim	Agadir	Marrakech	Total
No of trees	1,900,000	1,383,000	112,150	929,000	204,500	147,000	6300	100,000	4,782,150
Prod. trees	735,725	747,100	67,160	360,000	120,000	100,000	3,000	30,000	2,162,985
Yield (kg/tree)	40.8	32.4	8.0	13.3	13.0	22.0	33.3	16.7	29.6
Product. (tons)	30,000	24,200	535	4,860	1,560	2,200	100	500	63,955

In 2006, in spite of a satisfactory fructification in the main production areas, the national production was only 64,000 tons because of weak production in Zagora oases (area of Ouarzazate).

6.2.1 Agricultural practices

Cultivation techniques in Moroccan oases remain traditional in spite of new methods developed by research organisations. The realized yields at the experimental stations exceed 50 kg/tree, which is three times the average yield realized by farmers. Indeed, the average national yield of 18 kg/tree, remains weak in comparison with the average yields attained in North-African countries. The settlement of palm trees is not very dense and badly disposed. The average density is 50 trees/ha.

The lack of control of planting density of palm and other trees leads to a strong shadow for low crops which fade. This blocks photosynthesis process and consequently affects the crops productivity. The insufficiency of applied irrigation water generates great competition between plants and crops in the same plot for water and nutrients.

6.2.2 Intercropping

In the two principal zones of date palm, Tafilalet and Ouarzazate, palm trees are rarely planted alone.

The tradition in Morocco is to integrate date palms with other crops. The practiced cropping system is on three levels – palm trees, fruit trees below the palms such as olives or apples, and an annual crop below the trees such as cereals, legumes, forages and vegetables.

6.3 Irrigation

More than 70% of palms are grown in Tafilalet and Ouarzazate which represents about 90% of the production. The cultivated zones and the principal irrigation infrastructure in these regions are managed by Regional Agencies for Irrigation and Agricultural Development of Tafilalet and of Ouarzazate, respectively ORMVATF and ORMVAO.

6.3.1 Historical perspective

Irrigation in Tafilalet and Ouarzazate is secular. Some historical writings affirm that Khettaras, the old and clever system of collecting and mobilizing groundwater, is a pure creation of the North-African population. Malika Hached confirms this hypothesis thanks to rupestral engravings existing today in the Algerian Sahara (Malika Hached, “Les premiers Berbères” -The first Berbers, Edisud/ENA, 2000).

According to Briggs, the Khettaras system is more developed on the Western side of the central Sahara. Some one estimated that Jews and Jewish Berbers of Libya would have introduced Khettaras into these zones, approximately two thousand years ago (“Les déserts” - The deserts, Théodor Monod, Jean Marc Durou, AJEP, 1997)

Although the introduction of the date palm is attributed to Arabs during their conquest of Morocco at the beginning of the 8th century, the rules and customs of irrigation water sharing confirm that irrigation practices are much older.

6.3.2 In Tafilalet

Tafilalet is located in the South-East of Morocco, in the pre-Saharan zone south of the Atlas Mountains. It extends nearly 77,250km², or 11% of the national territory. It covers all the Province of Errachidia and the administrative Circle of Beni-Tadjit concerning the Province of Figuig, a total of 53 rural districts.

It is subdivided in three agro-ecological zones: the mountains zone (in North), the intermediate zone and the plains zone (in South). It also includes four watersheds: Ziz, Gheris, Guir and Maider. The three rivers, Ziz, Gheris and Guir run in plains, starting from the High-Atlas Mountains.

The climate is semi-arid with strong continental influences. Annual average precipitation is low at 265mm in north and 50mm in south with only 25 days of rain each year.

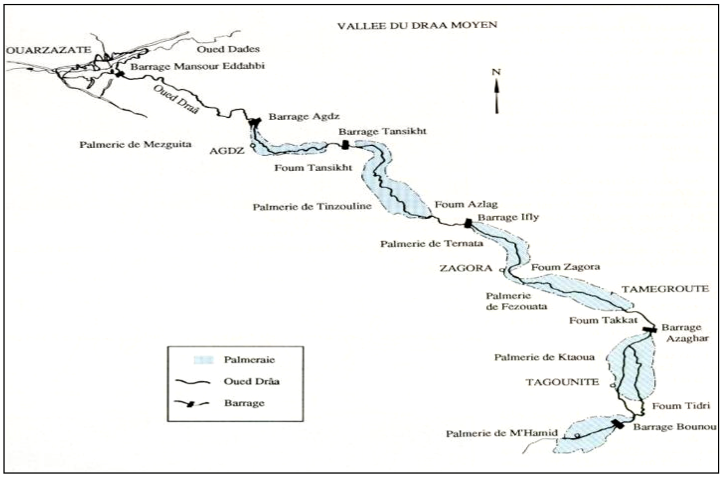
Temperatures are very variable from north to south with an annual average of 18°C. Potential evapotranspiration (PET) reaches 2,500mm/yr. But under the palm trees, there is a favourable microclimate with PET averaging only 1,200mm.

6.3.3 In Ouarzazate

The Ouarzazate region covers all the territory of the province of Ouarzazate, the administrative Circle of Foum-Zguid in the province of Tata and the administrative Circle of Taliouine in the province of Taroudant. The total surface drainage basin area of the ORMVAO is of approximately 10,000km².

This covers an area of about 5.5Mha. Less than 1.4% is agricultural land, that is to say 78,000ha including 9,000ha of rainfed agriculture.

The valley of Drâa consists of a chain of six palm plantations along the river, individualized and separated from each other by natural contractions called "Foum".



* Figure 5 Ouarzazate region of Morocco (Source: ORMVAO)

The climate of this region is arid. Rainfall decreases from north to south and from the west towards the east – from 481mm/yr in Askaouen to 50mm/yr in M'hamid. The city of Ouarzazate receives on average 119mm/yr. The snow falls in the Atlas Mountains, starting from 1,800m and occurs between November and May.

The annual average of temperatures varies between a minimum of 14°C in Ighrem Ougdal and a maximum of 23°C in Tazarine. Annual average evaporation varies from 2,980 to 3,000mm in Zagora and 2,950mm in Tagounit. Winds are violent, hot and dry and accentuate the process of salt concentration by increasing the evapotranspiration.

The area is characterized by a prevalence of small property. Some 85% of farms are less than 2ha and only 5% of farms are greater than 5ha.

The main problem in the irrigated area of Ouarzazate is the scarcity and the irregularity of the surface water resources due to the frequency of droughts.

6.4 Water requirements

The life in the oases is organized around water which is scarce. The date palm is most the adapted crop to grow in a dry atmosphere, provided adequate water is available. Prolonged water stress results in the reduction of size of palm trees and the growth of more spines. A palm tree whose palms are desiccated does not inevitably die. The heart of the palm tree can survive for a long time (several months) and its growth can start again when the water conditions become favorable again. The reaction of the date palm to lack of water for long periods does result in a significant reduction of growth and yield, and sometimes the production stops.

Water requirements for mature date palm are not yet well understood by the ORMVAs nor by the farmers. In the literature, there are very different data on water requirements. Toutain in 1977, recommended a water supply from 12,600m^3/ha to 23,900m^3/ha (for a density of 100 trees/ha). FAO, since 1993, recommended theoretical water supply varying from 9,000m^3/ha to 13,300m^3/ha (for a density of 100 trees/ha). In Tafilalet, it is recommended that amounts should vary from 8,000m^3/ha to 14,000m^3/ha (for a density of 100 trees/ha).

In the traditional palm plantation, the rural populations of Tafilalet irrigate the intercrops associated with the palm trees and do not take account of the water requirements of date palm.

In Draa, water requirements for date palms vary between 8,700 to 9,300m^3/ha.

The oases system is often based on crops and livestock. Their interdependence is one of the principal characteristics of this system. The relationship between these two is alfalfa. It allows the farmer to fatten his cattle in order to sell them at a high price. Livestock is very often the capital on the farm and alfalfa is the means to make it profitable.

6.5 Irrigation

6.5.1 Systems

In Tafilalet and Ouarzazate regions, irrigation systems were not set up by considering the adequacy of the water resources and water requirements of the cropping pattern. Indeed, the oases are spaces of traditional agriculture practised for centuries and based on groundwater mobilization by Khettaras and flood diversion along rivers which traverse these two areas thanks to the Seguia networks (traditional earth channels) built by the local population. Water management is based on common water laws.

In both regions water is conveyed using two complementary networks:

- The modern network – concrete lined canals to transport water from dams.
- The traditional network – mainly earth channels (Seguias) originally built to transport flood water.

The area served by a hydraulic structure is called perimeter. In the perimeter, water is conveyed to plots using a main channel, lateral channels, tertiary channels and sometimes quaternary channels.

The two networks of main and secondary channels are completely independent but they merge at the level of tertiary and quaternary channels.

In the two regions (Tafilalet and Ouarzazate), an estimate of water requirements for irrigation remains difficult to evaluate, because of:

- Variability in time of the practiced cropping patterns and cultivated lands
- Heterogeneity of the density of plantations from one palm plantation to another and even inside the same palm plantation
- Cereal sowing dates
- Climatic risks conditioning the inflows and water availability in dams at the beginning of each agricultural campaign, which helps farmers to decide what crops to grow.

Studies of the irrigation systems' operation in the two regions showed that the available water resources are less than the total needs of date palm and associated crops.

In the area of Ouarzazate, the deficit can vary from 22% during an average year to 31% in a wet year. In a dry year, there is almost a balance between supply and demand thanks to maximum groundwater pumping and the reduction in the cultivated areas of cereals and lucerne.

A similar study carried out in Tafilalet showed that the deficit varies between 6% in wet year and 22% in normal year. In dry years, balance is reached only thanks to the reduction of cereals to 6,500 ha and pumping about 32 Mm^3 of groundwater.

6.5.2 Methods

Since their arrival in the oases the rural populations have developed irrigation strategies which have sustained their livelihoods as they are today.

The inhabitants of the area have mobilized floods and groundwater for centuries. This water is generally distributed to the plants by surface irrigation. Various techniques of surface irrigation: basin irrigation, border irrigation, furrow irrigation, and pond irrigation are used. These irrigation techniques depend on the origin of water (fresh water, salt water), the water availability and the intercropping.

But recently, some farms have started to use drip irrigation. For two years, the ORMVAs have been encouraging the farmers to migrate towards this water saving method. The Moroccan government set up a system of incentives which provides subsidies of 60% of the cost of drip systems.

SURFACE IRRIGATION

Basin irrigation is based on water coming from floods or from dams. Very large flows are used. Excess water is used to recharge aquifers. The basins are relatively small (20m x 30m to 50m) and surrounded by bunds some 1.0m high. The slope of the basin is less than 1.5%. The flows are higher than the permeability of soils. Water accumulates and infiltrates slowly. This technique has the advantage of allowing leaching of excess salts but it has the disadvantage of requiring large flows and it also compacts the soil.

Border irrigation can be short or long. They are surrounded by bunds (up to 50 cm in height) which retain water. The farmer opens a levee at the top of the border to allow water to enter. When the necessary water volume has been applied the levee is closed again and the next board is irrigated.

Furrows have a length varying from 8 to 20 m. They are irrigated from a Seguia which is located at the edge of the field. In the Saharan region small farms use this method to grow many crops.

Pond-irrigation: This irrigation method is used mainly in recently created modern farms. The ponds are built immediately after set up of the young palm trees. They are circular and approximately 1 m radius when the trees are young. They get progressively larger as the tree grows.

This technique is also used in the traditional palm plantations where water is scarce and palm trees are strongly attacked by the bayoud disease.

The ponds are often placed along the course of the Seguias. They are also used to supply young replacement palm trees in existing plantations. Generally, this technique is not practiced where there is intercropping.

DRIP IRRIGATION

This technique is not widely used in the oases – only about 1,176ha in Tafilalet and 419ha in Ouarzazate. The possibilities of its development in the future remain very limited in spite of government incentives. Indeed, in these two regions, and more particularly in the palm plantations, the cost of the conversion from surface to drip irrigation would be very high.

In Tafilalet conversion cost is estimated to be around US$18,000/ha, whereas the subsidies provided by government are less than US$4,000/ha.

Drip irrigation can be very efficient compared to the other irrigation techniques provided it is managed properly. But date palms irrigated by this technique develop limited root systems and consequently require protection against the violent winds which are frequent in desert. The costs of installation of wind breaks must be taken into account in such situations.

6.5.3 Efficiency

ORMVAs do not control the water distribution inside the sectors, they do not charge for water and they do not control the pumped volumes and those coming from floods. Consequently, they cannot provide reliable information concerning the water use at the farm level. So it is difficult to appreciate the water duties actually applied and to estimate the efficiency of the on-farm irrigation.

6.6 Constraints

The main constraints that limit the oases are:

- The scarcity and the randomness of rainfall and then frequent droughts
- The Bayoud disease which affects the date palm production more and more
- The sand invasion and the natural resources degradation which result from the human actions and the severe climatic conditions
- The parceling out of farms (smallness) and the water rights which often handicaps agricultural development
- Weak economy characterized by traditional agriculture and the predominance of small farms
- Poor value of dates as a fruit and raw material for various purposes
- Harvest and post-harvest practices are still very traditional and crop quality can be poor as a result
- Poor market as a result of poor post-harvest handling of dates
- Badly organized chains of distribution.

The management of large scale irrigation systems in Morocco is governed by the Agricultural Investments Code (AIC), promulgated in 1969 and which entrusts to the Regional Agency for Irrigation and Agricultural Development (ORMVA) this mission within a contractual framework with farmers. This framework stipulates that the ORMVAs ensure the operation and maintenance of irrigation systems using a water payment by users who are held to cultivate their farms according to standards set by the State. This however, is not the reality on the farms.

For the palm plantations water remains the determinant factor for their preservation and for the diversification and improvement of production. The analysis of irrigation practices shows that climatic, technical, socio-economic, and institutional constraints persist and make the efforts made by the ORMVAs insufficient to satisfy requirements of an optimal irrigation management system. The date palm, centre piece of oases agriculture, is most affected by this situation.

There is a lack of information needed for irrigation scheduling and water distribution.

The weakness of the water resources management systems, emanating from the irregularity of the inflows in dams, make it difficult to determine the essential parameters that management needs (degree of guarantee of future inflows; minimum reserve at the end of each year; the volumes of water of derived floods; the pumped volumes; the groundwater quality). Consequently, formalized procedures for dam management are non-existent.

The irrigation networks are under-equipped to measure flows to determine the water quantities actually taken at the level of each water intake. The networks for monitoring aquifers and water quality are poor.

There is no control by users of crops water requirements. In general, the farmers have more concern for irrigating the intercrops. In fact, the date palm is not irrigated; it must to take its water requirements from water table and from excess of water intended for the associated crops.

There is not enough support for farmers on irrigation matters. There are not sufficient incentives to save and use water wisely.

References

ANAFID (1990) Gestion des grands périmètres irrigués au Maroc, volume 1.

ANAFID, Revue Homme Terre et Eau (2004) n°129, Irrigation du palmier dattier, juin.

Keller A & Keller J (?) un concept d'efficience d'utilisation des ressources en eau douce.

DDGI, AGR, MADRPM (2004) Rapport des performances des ORMVA.

DPV, MADRPM (2006) Note sur le palmier dattier au Maroc.

RENEVOT Guénaëlle (2006) Analyse comparative des pratiques d'irrigation dans différents systèmes oasiens dans le Tafilalet, CNEARC.

Haddouch (1995) Situation actuelle et perspective de développement du palmier dattier au Maroc.

VIDAL-MBARGA H & MBARGA S (2005) Ajustement entre des systèmes irrigués et des systèmes de cultures dans le Tafilalet, thèse.

INRA-ICRA (2004) Agro biodiversité et durabilité des systèmes de production oasien dans le Tafilalet.

JICA (2005) Rapport final, étude de réhabilitions des Khettaras.

JP Liebenberg et A Zaid (?) Date production support systems. FAO.

Malika Hached (2000) Les premiers Berbères, Edisud/ena.

MATEE (2006) Débat national sur l'eau : plate forme, Décembre.

Monod T, Durou JM (1997) Déserts, AJEP.

ORMVAO (1995) Etude d'amélioration de l'exploitation des systèmes d'irrigation d'Ouarzazate-, rapport de diagnostic.

ORMVAO (1999) Plan d'action de la gestion participative.

ORMVATF (1995) Etudes d'amélioration de l'exploitation des systèmes d'irrigation de Tafilalet, Rapport de diagnostic.

Ruf T, Ahmed B (?) La gestion de l'eau et les systèmes de culture dans les oasis entre la tradition et la modernité.

Terre et Vie N (?) 36 et 37: La phoeniciculture au Maroc.

Toutain G (1979) Eléments d'agronomie saharienne, de la recherche au Développement.

VLIEGEN N (2005) Institut Supérieur industriel Huy Gembloux: Optimisation des systèmes goutte à goutte dans les palmeraies de Tafilalet (Maroc).

Yao N'Dri JN (2006) Problèmes de pollution des eaux liée à l'irrigation dans les grands périmètres du Maroc.

7 Oman country paper

7.1 Background

The total cropped area in the Sultanate of Oman is 58,850ha distributed among 132,860 farms with an average farm size of 0.44ha. Palm tree oases constitute an integrated agricultural and environmental system in Oman. The area cropped with palm trees is estimated to be 31,350ha with some 7.44 million trees. Some 95% of farm holdings in the country have palm tree plantations. Palm trees thus represent 51% of the total cropped area constituting by far the major and most important agricultural activity.

7.2 Date production

During the decade 1994-2004 the total volume of dates produced in Oman ranged between 193,000 tons and 298,000 tons/yr with an average of 244,000 tons/yr. The variations in production are attributed to the availability of water resources and insect attacks. Only 60-65% of all the dates produced are suitable for human consumption. Over the past ten years the average annual yield was 37.5kg/tree.

* Table 24 Average date palm production 1994-2002

	Average production/tree/yr (kg)							
	1994	1998	1999	2000	2001	2002	2003	2004
Average	29.2	38.5	44.6	43.2	37.9	36.8	33.88	35.62

Most Omani dates are sold in the local market. But about 6,000 tons/yr are exported mainly to India with some going to the UAE, Malaysia, Japan, and Bahrain. Omani exporters compete with exporters from Iran, UAE, and Pakistan. Date producing countries are finding it difficult to open new markets. They are competing in the same traditional markets. Better processing, exploration of markets and new types of packaging are needed to enter the more quality driven European and Asian markets.

Small quantities of dates are imported into Oman. However with the opening of the GCC market more and more dates are imported from Saudi Arabia and UAE which are competing in the local market with the best Omani varieties. Saudi and Emirates producers benefit from subsidies at different levels of production.

7.3 Water resources

The only source of available water in Oman is groundwater. Approximately 93% of the water is used for agriculture. The remaining part is used for urban uses (3%) and for environmental uses and landscaping (4%).

Groundwater is exploited in two ways. The first and most ancient way of exploitation is by aflaj which is used to irrigate about 21,600ha. These are underground channels dug in the ground to convey water by gravity from one place to another. They are considered as one of the most important and ancient systems adopted to convey and distribute waters to the villages by gravity. Many of the aflaj in Oman have existed for over 1,500 years and some of them date back over 2,500 years. The most recently constructed systems are 150 years old and are in the Ibra-Mudharib region. The excellent organization of the aflaj institution based on farmers participation and involvement has ensured the maintenance of the systems over the centuries and made their survival possible.

All aflaj farmers have clearly established water rights. Both water rights and aflaj are privately managed by farmers independently of government intervention. The water rights are allocated on a time-share basis. The most used time-share method is Athar and this is based on 30 minutes per water turn or cycle. The water turns differ from one falaj to another according to the soil characteristics and falaj flow.

According to the National Falaj inventory there are 4,112 Falaj. Only 3,017 falaj are still active while the others dried up and stopped flowing. Aflaj systems are used to irrigate 33% of the cropped area. The total flow is about 552Mm^3/year representing 44% of total groundwater available in Oman. The water loss from aflaj is estimated to 128Mm^3/year, or approximately 23%.

Water quality is usually very good with average electric conductivity is about 600µS/cm for most of the aflaj. However, in a few cases the salinity goes up to 1500µS/cm.

The second way of extraction is through the dug wells and tube wells – some 140,000 wells exist within farms and provide about 56% of irrigation water. Wells are in most cases owned privately by farmers.

7.4 Water requirements

Farmers believe that the more water applied the healthier is the palm tree and the higher is the harvest. In addition, basin irrigation allows growing fodder crops under the palm trees to feed the sheep or goats. The area watered between the palm trees depends on the soil type, availability of the water and the total area of the holding. It has been observed that the smallholders usually have a large number of date varieties to provide for their animals with complementary feed.

All these factors add to the complexity of determining the water requirements of date palms.

7.4.1 Experiments with aflaj

Experiments to determine water requirements have been conducted on the use of surface irrigation in two aflaj.

On one farm the annual water supplied was 3,235mm while the ETc was estimated to be 3,620mm. So there was an under-irrigation of 385mm which occurred mainly in the summer months, even though there was excess flow during the winter months. This was mainly due to the fact that farmers cannot control the water flow in the aflaj.

On a second farm the total supplied water was 6,767mm while the ETc was much less than this at 3,620mm. This produced a low Demand/Supply (D/S) ratio of 0.53 indicating an over irrigation problem and a low water use efficiency. The monthly D/S ratios indicated a huge waste of water during winter as the D/S ratio reached the low value of 0.25 in December, while the summer D/S ratios varied from 0.6 to 1.0. Again, the final judgment about water use efficiency in aflaj depends on the farmers' capacity to adjust to the volume of water supplied. Since farming is becoming more of a part-time job it is expected that water use efficiency will diminish in the future.

In 1997-1999 experiments were conducted on 8-year old palms to assess date production in relation to water applied. Annual ETo was estimated to be 2,597mm using climate data. The EC of water ranged between 0.7 and 0.8 g/l. Three irrigation treatments were tested:

Treatment 1: irrigation after depletion of 51-70% of available water.

Treatment 2: irrigated after depletion of 71-90% of available water.

Treatment 3: field practices (irrigated normally twice a week).

The results are shown in Table 25 and Table 26. Water use (ETc) of date palm for the high irrigation level (Treatment 1) was 2,802mm while for treatment 2 it was only 1,673mm. So treatment 2 used 40 % less water than treatment 1. This was a result of the limitation in soil moisture of treatment 2 that reduced water availability to the palm trees and therefore water loss. Both irrigation levels indicated an increase in water use from February to June which is associated with increased ETo and fertilization and the early fruit development phase. The ETc reached its maximum values in June and July, and that was also related to full date fruit growing and ETo increase. After harvest in mid August there was a marked decrease in water use which continued till February. During this period the date palm was apparently "inactive". In summer, for treatment 1, irrigation took place every two or three days. While for treatment 2, irrigation took place every 8 to 10 days. In winter however, irrigation was undertaken every 8 to 10 days for treatment 1, while for treatment 2 it was undertaken every 18 to 21 days.

Peak water demand reached 12.2mm/day in June and July and the minimum demand was 3.5mm/day in February. The table below shows the ETc and Kc factor for treatment 1 and treatment 2. Assuming an application efficiency of 60% for surface irrigation the annual crop water requirement per hectare for treatment 1 was 39,228m^3 and 23,422m^3 for treatment 2. The crop water requirement for the existing field practice was 39,389m^3.

* Table 25 Average monthly water use for dates (mm) (1997-1999)

Month	ETo	Treatment 1 (50-70% depletion)		Treatment 2 (71-90% depletion)		Existing field practice	
		ETc	Kc	ETc	Kc	ETc	Kc
Jan	135	129	0.96	73	0.54	193	1.43
Feb	164	98	0.60	65	0.40	147	0.90
Mar	205	192	0.95	117	0.57	288	1.40
Apr	250	194	0.75	143	0.56	194	0.78
May	331	306	0.92	183	0.55	306	0.92
Jun	293	366	1.25	200	0.68	366	1.25
Aug	247	342	1.38	175	0.69	342	1.38
Sep	229	284	1.23	159	0.68	284	1.24
Oct	193	192	1.24	149	0.77	192	0.99
Nov	142	203	1.40	126	0.87	304	2.14
Dec	132	131	1.05	81	0.65	196	1.49
Total	2,597	2,802		1,673		2,813	

The water use efficiency was estimated for the same period 1997-1999. The yield was 28% lower for treatment 2 compared to treatment 1. However, the WUE was 0.74kg/m^3 for treatment 1 in comparison to 0.9kg/m^3 for treatment 2. Such a result is quite interesting in an environment characterized by an excess supply of dates an water shortages. In fact reducing water application will reduce yield by 28% and will result in 40% water saving which will help considerably to reduce the excess of groundwater pumping and the consequent seawater intrusion in the coastal areas. However, those farmers who rely on aflaj and water turns would not be able to adopt a water conservation programme as they depend strictly on the established water turn from the aflaj.

* Table 26 Productivity of water for dates (1997-1999)

Treatment	Yield (kg/tree)	Water (m^3/tree)	WUE (kg/m^3)
Treatment 1 (50-70% depletion)	58.7	79.3	0.74
Treatment 2 (71-90% depletion)	41.9	46.6	0.9
Treatment 3: field practice	57.6	80.4	0.72

7.4.2 Experiments with bubbler irrigation

Experiments were conducted on intermediate mature date palms planted in basins with 8m×8m spacing to compare the water use efficiency of flood and bubbler irrigation. Two bubblers were installed per palm tree. For the flood irrigation the water cycle was 14 days. The irrigation water was of very good quality with salinity around 0.5g/l. The soil was a clay-loam.

For the flood irrigation system the Kc values ranged between 0.95 in May and 1.6 in January. The high values can be attributed to the fact that the Khalas variety starts its new leaves in late November early December, thereby increasing their demand for water. Despite the low ETc in January the maximum value of Kc was reached in January which can be explained by the presence of full mature leaves leading to an increase in leaf area. After harvesting, the Kc declined steeply indicating a low demand for water during that stage. Actually, farmers in the region reduced the application of water during maturing stage. They also reduced water after harvest and started thinning the leaves to allow the trees to rehabilitate for the next season. It was observed that farmers reduce water application during the pollination stage in order to maintain the maximum number of fruits in the tree. For Khalas, the pollination starts during the first week of February. The current water management observations showed that farmers adjusted to the production stage of the palm trees indicating that the traditional local knowledge is very valuable and should be reconsidered and documented for a better use of water in date palm trees.

The total annual ETc was 2,522mm, while total applied irrigation was 2,932mm. That is an excess of 410mm. On a palm tree basis the annual volume of water applied was 124m^3 and a daily average of 0.34m^3/palm.

For the bubbler irrigation system, the Kc values ranged from 0.9 in May to 1.5 in January. Even though the predicted Kc values were lower before and during the maturity stages, the soil water regime curve showed that during the fruiting stage the palm tree was suffering from water shortages. The maturity stage is July-August and this was characterized by a high ETo. The total ETc was 2,272mm. Total applied irrigation was 2,195mm or 21,950m^3/ha. On a palm tree basis the annual volume of water applied was 81m^3/tree and a daily average of 0.22m^3/tree. This is compared with the flood irrigation system the volume of irrigation was 29,320m^3/ha.

Comparing the bubbler irrigation system to the flood irrigation system the difference in the volume of irrigation applied is estimated to 737mm (7,370m^3/ha) or 43m^3/tree or 0.12m^3/tree/day. Even though the difference is high, the figures should be compared in financial terms, in order to analyze whether it is profitable or not to introduce bubbler irrigation.

* Table 27 Performance comparison between bubbler and surface irrigation

	Kc in Jan	Kc in May	ETc (mm)	Irrigation (mm)	Water use (m3/tree/yr)	Yield (kg/tree)	Productivity (kg/m3)
Bubbler	1.5	0.9	2272	2195	81	60.5	0.75
Flood	1.6	0.95	2522	2932	124	80.9	0.65

Given that the experiment was conducted during one year only, the yield difference between the bubbler and flood irrigation system is high. In fact, the yield per tree was only 60.5kg/tree under the bubbler irrigation system while it reached 80.9kg/tree under the flood irrigation. However, the water productivity is higher for the bubbler system reaching 0.75kg/m^3 while for the flood system it is only 0.65kg/m^3. The overall quality of the dates harvested under the bubbler system was considered to be better than the dates obtained under the flood system. The sugar content of the dates was similar in both systems.

Given the prevailing water scarcity problem in Oman coupled with an over supply of dates the increased use of the bubbler system can help reduce water pumping by as much as 25%. It can also help to reduce the production of dates by 25% as well. The advantage of this is thought to be higher prices for farmers and hence a higher return from water application. This may lead to a true market in dates and Government subsidies may be no longer necessary.

7.5 Irrigation agronomy

Omani farmers usually reduce the volume of irrigation water after pollination and before harvesting. This is done in order to maintain the maximum number of fruits in the tree and to increase the sugar content of the dates. Peak water requirements for each palm tree variety vary according to the pollination and harvesting periods. For instance peak water requirements for three intermediate and early-maturing varieties varied between $103m^3$/day/ha during May and $109m^3$/day/ha in August.

7.6 Irrigation methods

7.6.1 Flood irrigation

The 2004-05 agricultural census shows that 96% of palm trees are irrigated using the flood irrigation system. Large basin irrigation can be found in Aflaj areas. Cemented channels for the main channel and earthed channel for sub main are in use. Each basin can hold up to 5 trees and can have mixed crops in between. The small basins are found in areas irrigated using wells. In this type of basin only one palm tree is irrigated and normally without mixed crops.

It was observed in many instances that the farm employees do not control the water flow from one basin to another and do not guide or check the earthed channels in order to achieve better distribution and save water. In some cases when farm owners do not have employees the water pump is functioning on a 24 hour basis. These management practices are responsible of the low water use efficiency and cause a considerable waste of water and quality degradation because of seawater intrusion. The efficiency of the surface systems is low and it is estimated to be less than 50%. Occasionally it may rise to 60% when the soil is of heavy texture coupled with a good management.

7.6.2 Modern irrigation systems (MIS)

MIS refers mainly to the use of bubbler irrigation systems that are well suited to date palms and are promoted by the Ministry of Agriculture. The system is characterized by a high flow compared to the drip system.

Only 4% of the palm tree plantations use Modern Irrigation Systems (MIS). Overall the palm tree plantations irrigated with MIS cover an area of 1,235ha more than 61% of which are located in the Batinah region where the most recent farms were established. MIS in used on 12,129ha or 19.2% of the total cropped area. The two major types of crops that most benefit from MIS are the vegetables (52% of cropped area) and perennial forage crops 42% of cropped area).

Socially, the bubbler system is accepted for date palm irrigation as farmers can see the water they are delivering, unlike the drip system. The existing recommendation is to use two bubblers per tree for already existing old palm trees and one bubbler for small newly planted palm trees. The cost of installation of the bubbler system is high due to the over sizing of the laterals and the additional bubblers used.

However uptake is low for date palms and this could be explained by the fact that most of the plantations are old. When farmers plant new palm trees, they usually replace dead or unproductive palm trees. They seldom replace an entire existing plantation with a new plantation. This means that the existing flood irrigation system remains in place. In fact, many farmers believe that the MIS are not suitable for old trees. Farmers believe that the roots of old palms are widely spread as a result of long term flood irrigation. They believe that bubblers do not provide sufficient lateral spread of water. To correct for this wrong perception several demonstrations were carried by the Ministry of Agriculture to demonstrate to farmers that palm tree productivity is not affected by the change of the irrigation system from flood to bubbler.

* Table 28 Areas of flood and modern irrigation (MIS)

Palm tree area under plantation				Modern irrigation systems (%)			
Flood irrigation	Modern systems	Total area	Modern systems	All tree crops	Vegetables	Field crops	Forage crops
30,117ha	1,235ha	31,352ha	4%	6.1%	52.0%	8.9%	42.4%

One major reason for the slow introduction of MIS is the very limited funds allocated for subsidies. When farmers do get a subsidy for MIS though they tend to use the system for vegetables and/or perennial forage crops as these are more profitable than dates. More targeting is needed if the objective is to modernize the palm tree plantations.

7.6.3 Institutions

The two institutions responsible for water are the Ministry of Regional Municipality Environment and Water Resources (MRMEWR) and the Ministry of Agriculture and Fisheries (MAF). The MRMEWR is in charge of monitoring the hydrological parameters, evaluation, and development of water resources. The MRMEWR has the responsibility and authority to issue tube well and open well permits as well as permits for deepening wells. They also issue permits for well maintenance and pump replacement. In addition, the MRMEWR contributes to the maintenance and repair of some the aflaj systems when the cost exceeds the capacity of the falaj community to undertake the reparation. MRMEWR has completed the regulations for the protection of the water resources. However laws are not strictly implemented.

MAF is responsible for administering support to the agricultural industry. Historically it had responsibility for water, but this was transferred to the Ministry of Water Resources (MWR), and currently to MRMEWR. Recently MAF's responsibility consists in helping farmers to improve the management of irrigation water and to increase the productivity from each cubic meter of water. MAF is the only institution with responsibilities for the management of irrigation water. The tasks assigned to MAF are the support to farmers through irrigation extension, irrigation research, and irrigation technical and financial support.

There are currently no water user associations or organizations to manage the groundwater pumped from wells. The absence of farmers' organizations and the absence of water quotas leads to over-pumping and mainly seawater intrusion in the coastal areas which drastically affected palm tree production and causes environmental degradation.

However, water drawn naturally from aquifers through aflaj is extremely well managed. In every falaj farmers are organized in an institution responsible for the allocation and distribution of water. There are currently more than 3,000 aflaj in Oman. The Falaj Wakil or manager supervises all operating and maintenance operations. The falaj institution usually owns a 24-hour water share which is leased on a weekly basis. Returns from the water lease or auction are the source of finance for operating and maintaining the falaj. If the funds collected from the water auctions are not sufficient, farmers contribute to cover the deficit according to the water rights they hold. These aflaj institutions are an excellent example of local governance and farmers self dependency on water management.

A new system of computerized control was introduced by MAF in 2005 in a falaj in the region of Nizwa. This increased the water use efficiency and the area irrigated was doubled. However, the cost of the operation was considerable, around US$650,000, paid by MAF for only 40ha of irrigation. Farmers have not been trained on how to manage the highly sophisticated system and they rely on a technician still being paid by the company who installed the system. Steps are needed to make sure that at least one of the farmers is trained for the task to ensure its sustainability. However, this sustainability is in doubt.

7.6.4 Subsidies for MIS

Support to farmers to introduce MIS started in 1990. At that time the MAF was responsible for the design of the MIS and a contracting company was responsible for the execution of the plan on the farmer's farm. The role of the farmer was limited to paying the corresponding monetary share to the company. Everything was done either by the ministry or the irrigation company. Now farmers are more involved in the process and it is their responsibility to select the company and the material to be installed. A list of companies and providers of approved equipment and materials is given to the farmer. The role of the ministry is still to help the farmer in the design of the system and quantification of the required items to be purchased. Once the farmer has selected the providing company, the ministry supervises the installation of the equipment and make sure that the installed material is in conformity with the required standards and that the installation is appropriately done. The subsidy is released by MAF only after installation is completed and tested. Currently several irrigation companies are operating. These companies have been trained by MAF in order to ensure the required quality for equipment installation. Farmer participation in the process is very important because he is now responsible for selecting the company providing the service, which is now accountable to the farmer not to MAF. By selecting the company the farmer selects both the material and the quality of service. The farmer also learns about the installation and maintenance which results in a better care for the equipment. MAF also benefited from this process as the cost of the MIS was reduced by almost 35% compared to the earlier approach.

Currently the Government bears 75% of the MIS's cost if the area is less than 4.2 feddans. If the area to be irrigated by the MIS is greater than this but less than 21 feddans the subsidy is 50%. Finally, if the area is greater than 21 feddans the subsidy is reduced to 25% of the total cost of the MIS.

References

Al-Ghafri A (2006) Aflaj's Irrigation Water Demand/Supply Ratio: Two Case Studies. Agricultural and Marine Sciences, 11 (SI), pp 85-92.

Al Khatri AMH (2006) Rationalization of Groundwater Monitoring Network in South Al Batinah Region, Oman. Master thesis. Sultan Qaboos University. Sultanate of Oman.

Al-Lawati EAM (2000) Date Palm Water Requirement in the Interior Region of the Sultanate of Oman. Master thesis. College of Agricultural and Marine Sciences. Sultan Qaboos University. February 2000.

Al-Lawati EAM, Wahby H (1997) Date palm Irrigation in the Sultanate of Oman. Third Gulf Water Conference. Water Sciences and Technology Association. Sultanate of Oman.

Al-Mamary S (2007) Integrated Water Resources Management and Modern Irrigation Systems. National Workshop on : The Agricultural Sector's Sustainable Development & The Organization of the Labor Market. 10-12 February 2007. Samail. Sultanate of Oman. 39 Pages (Arabic).

MAF (various years). Dates production. Department of Statistics and Information. Ministry of Agriculture and Fisheries. Sultanate of Oman.

El-Nadi AH (2003) Index guide for crop water requirements in the Sultanate of Oman. Ministry of Agriculture and Fisheries Wealth, Oman.

El-Nadi AM, Al-Wahaibi H, Al-Amri M, Al Gharibi E (2006) Effect of Soil Moisture Depletion on Water Requirements and Yield of Date Palm. Sultan Qaboos University. Muscat, Sultanate of Oman.

Norman WR, Shayya WH, Al-Ghafry AS (1998) Irrigation Water Costs and Management Practices Among Farms in Northern Oman. Agricultural Sciences, 3; 1-8.

Zekri S, Kotagama H, Boughanmi H (2006) Temporary Water Markets in Oman. Agricultural and Marine Sciences, 11 (S.I). 77-84.

Zekri S (2007) Water Use Licensing versus Electricity policy Reform to Stop Seawater Intrusion. Paper presented at the International conference on Sustainable water Management. Tunis. Tunisia. 21-24 March 2007.

8 Saudi Arabia country paper

8.1 Background

Date palm is one of the oldest fruit trees in the world and is mentioned in the Qur'an and Bible. The number of the date palms is about 100 million worldwide, of which 62 million palms can be found in the Arab world. The place of origin of the date palm is uncertain. Some claim that the date palm first originated in Babel, Iraq, while others believe that it originated in Dareen or Hofuf, Saudi Arabia or Harqan, an island on the Arabian Gulf in Bahrain. In later times, Arabs spread dates around northern Africa and into Spain, and dates were introduced into California by the Spaniards in 1765, around Mission San Ignacio. The date palm is a perennial, the females of which normally begin to bear dates within an average five of years from the time of planting of the offshoot. The date palm can reach an age of about 150 years.

In the oases of Saudi Arabia, the date palm trees stand tall with their branches outstretched towards heaven and their roots anchored deep into the earth. These dense green groves have been a treasured part of the Saudi landscape for generations, both for their beauty and their utility. Since ancient times, the date palm has been a source of food for the inhabitants of the Arabian Peninsula, and its branches have granted him shade from the strong desert sun.

The palm fronds are used to thatch roofs and provide the baskets for gathering fruit. During Ramadan, the annual month of fasting for Muslims, the daily fast is broken with a few dates and then a few sips of water. The end of Ramadan is celebrated with a four-day long feast, called Eid Al-Fitr, during which a popular treat is small cookies with a date filling called mamoul. Saudi women have long chosen to eat dates when they are pregnant or nursing in order to make sure they are receiving adequate vitamins and to boost their energy. In the *Qur'an*, in sura (chapter) 19, verses 23-25, during the birth of Jesus, Mary is guided to the palm tree to eat the dates to lessen the pains of childbirth: "But (a voice) cried to her from beneath the (palm-tree): Grieve not! For thy Lord hath provided a rivulet beneath thee; and shake towards thyself the trunk of the palm-tree: it will let fall fresh ripe dates upon thee." It comes as no surprise then that dates continue to be an integral part of Saudi culture. When a Saudi host offers a guest coffee, a plate of dates is always on hand to sweeten it. Low in fat, cholesterol free, high in carbohydrates, fibre, potassium, and vitamins, dates stay fresh for several weeks when properly stored. They are a nutritious staple of the Saudi diet and an excellent source of energy for the health conscious.

Before oil became Saudi Arabia's primary industry, date farming was an integral part of the national economy. However, during the early 1970s, date cultivation became stagnant due to a lack of labor, poor technology and disappointing harvests. With the encouragement and assistance of the government, the date industry was back on track by the early 1980s. Today, the Kingdom is the world's second largest producer of dates, supplying 17.6% of the world market. After wheat, dates are the second biggest sector of the nation's agricultural economy, with an annual production in 1994 of 568,000 tons. While a significant portion of the dates are consumed within the Kingdom, many are exported to outside markets. Through the United Nation's World Food Program, Saudi Arabia also donates a notable amount of its harvest to areas of the world suffering from food shortages.

8.2 Date production

The Government of Saudi Arabia has exerted incessant efforts to develop the agricultural sector. Continuous support and care was allocated to date palm production because of the cultural and food security issues that surround this crop. Several farmers, with government support, started cultivation of high quality date cultivars. Numerous modern projects for date palm plantation and production were established in many parts of the Kingdom. Table 29 shows estimated number of date palms in the Kingdom of Saudi Arabia for the years 1999 to 2005, while Table 30 shows the mean areas and production over a 5-year period.

* Table 29 Estimated numbers of date palms 1999 to 2005

	1999	2002	2003	2004	2005
Total	19,305,188	20,849,602	21,324,111	22,287,857	22,625,983

* Table 30 Average area and production of dates 2001-2005

Mean area (ha)	Mean production (tons)	Production (t/ha)
144,008	888,659	6.17

Saudi Arabia is considered as one of the pioneer countries in date palm cultivation and date production and has reached self-sufficiency. Production in 2005 reached an 970,000 tons – an increase of about 45% during the last 20 years. The cultivated areas of date palm also increased and reached about 140,000ha in 2004 – an increase of 57% during the same period. The number of date palms in the Kingdom is estimated at 21 million trees and there are over 400 different date varieties spread all over the different agricultural areas of the Kingdom. Each area is characterized by certain date palm varieties.

Despite the increase in the date palm cultivated areas, the production per hectare has deteriorated in recent years. This is attributed to the fact that many of the recently cultivated date palm orchards have not yet reached the production phase. It is expected that production will increase significantly and exceed 1Mtons/yr as the newer date palm farms reach the production phase, particularly as they have adopted modern production technologies for pollination, pruning, and irrigation. In recent years the adoption of organic farming had spread in the Kingdom so that the product can be marketed at higher prices on international markets.

The worldwide annual production of dried date is 3.11 Mtons. Saudi Arabia is considered the first producer and contributes 19% of the total world production. It is second only to Iraq as an exporter. The drop in the exporting quantities is attributed to the high consumption of local production and the storage of large quantities in the harvest season for food security purposes.

8.3 Irrigation

Water is a limited resource in the Kingdom and in an arid climate it is one of the most important factors affecting agriculture. The important sources are underground water, rainwater, and treated wastewater. The Ministry of Agriculture being aware of the importance of water conservation and the rationalization of water consumption in date palm plantation in trying match the supply and demand for water while taking account of food security. The Ministry encourages farmers to meet the irrigation crop water requirements and to adopt irrigation practices that increase irrigation water production – more crop per less drop – i.e. more crop production by using lower quantities of water instead of the concept of ‘more crop per drop’ i.e. increased production using the same quantity of water. In this context the Ministry is striving to introduce modern irrigation systems such as drip irrigation and avoid the traditional methods such as flood irrigation through associating agricultural licences with the precondition that modern irrigation systems will be used.

8.3.1 A historical perspective

In early times the majority of the old date palm orchards were irrigated from wells using surface irrigation systems, especially basin irrigation. Water was supplied from hand-dug wells 5-15m below the soil surface and using rocks and clay around the edges of each well to prevent soil erosion. In that time the ground water level is very close to the soil surface.

The most common way to lift water was the swani method. This consisted of 1-4 camels or cows, circular buckets made from animal skin, ropes made from date palm trees and circular wheels. Water was lifted from the well by the buckets using the wheels and the ropes which connected to the animal and the buckets. The capacity of the buckets was usually low and so it took some time to get water from source to field. Ditches were used to convey the water known as saqias. The farm was often irrigated once a week in the summer and every three weeks during the winter season. But, in some regions where there was not enough water available, palms were likely to be watered once or twice a week, or perhaps once or twice a month. Such factors as size of head, character of the soil, length of the ditch, and length of time the water is allowed to run determines the amount of water put on at any given irrigation.

During the late 1970s and early 1980s, the government undertook a multifaceted program to modernize and commercialize agriculture sector. Perceiving the values of dates nationwide the government implemented a number of promotional programs to advance investments in producing and processing dates. Such programs include offering free agricultural lands, free-interest loans and farming and investment subsidies. Consequently, area allotted to date palm farming and date production doubled throughout the last three decades (1972-2005).

But, despite all these encouragements, most traditional date palm plantations are still irrigated by flooding or furrow systems. In modern plantations, drip systems are becoming the systems of choice due to high irrigation/fertigation efficiency; easy to operate, suitable for use with automation; easy to irrigate the trees only, preventing weeds and lower system costs. Drip irrigation systems can apply irrigation water by different types of emitters such as, orifice emitter method, bubbler method, valves method and spray method.

8.4 Water resources

The cultivated area in the Kingdom has increased from less than 0.4Mha in 1971 to slightly over 4Mha in 1999. Practically all this area is equipped with irrigation – 55% under modern irrigation systems (pivot, drip and sprinkler) and the remaining area under traditional systems.

Total consumption of irrigation water has increased from about 1,850Mm^3 in 1980 to 29,826Mm^3 1992. Non-renewable groundwater from shallow and deep aquifers supplied about 28,576Mm^3 in 1992 for irrigation use. This represented about 94% of the total irrigation water use and 90% of the total national water use in Saudi Arabia.

In several agricultural regions, rapid economic development has resulted in a substantial imbalance between the available water resources and demand. Ambitious agricultural programs and the absence of conservation measures have lead to significant overdraft of the existing water resources. One source estimates that about 35% of non-renewable ground water was already depleted by 1995. A clear sign of unsustainable development of groundwater was shown by the continuous decline of water table levels, which in critical areas dropped 200m during the last two decades. Many springs in shallow aquifers dried up.

Consequently, improvement of groundwater management and reduction in irrigation water consumption, especially for wheat cultivation, became essential for maintaining the long-term productivity and quality of the aquifers. Ultimately, an awareness of the water shortage should serve to put concerns about water in perspective, deciding whether to plant water-conserving vegetation. The wiser choice is likely to be made if guided by awareness that water is a very scarce and valuable natural resource. The water scarcity condition of the kingdom justifies a substantial shift in policy, from "food security" to "water security", where the sustainability of the Kingdom's water resources dictates its proper level of development. The challenge today is to substitute technology and better management for water.

Irrigation application efficiency is highly controversial. There are large uncertainties on how much water is applied to each crop and the overall water consumption at the farm level. In the modern farms specializing in date palms intercropped with citrus trees Al-Hassa, the irrigation efficiency remains low. This is in spite of the fact that modern irrigation equipment is used to apply water to a very high standard – 40,000m^3/ha/yr corresponding to over 300 l/tree/day. It seems that there is an urgent need for an in-depth assessment of the current levels of irrigation water use, the irrigation performance and the way irrigation water is managed by farmers.

There are many ways to solve the problems and concerns in irrigation. The most important solution is to improve water conservation. The two best water management approaches are to decrease demand and increase supply. Demand management objectives include reducing water delivery (non-beneficial ET) and reducing water requirements (beneficial ET). Demand can also be reduced by better irrigation scheduling, increased irrigation efficiency, reduced evaporation, and reduced water use by non economical crops. Technologies available for reducing crop water requirements include limited irrigation, cropland acreages, crop/variety selection and decision-making models and technical assistance.

8.4.1 Water requirements

Most date plantations are located either in oases or along beaches where the water table is high, or in the vicinity of lakes. In such regions sufficient water is available year round rendering irrigation management unnecessary, although they are still consuming a valuable resource.

In areas where more formal irrigation is required there is a lack of data on crop water requirements. The pertinent literature on the subject is very limited and scattered in different regions. However, date palms are known to withstand water stress and high salinity levels, but nevertheless it is reported to be sensitive to irrigation and drainage management. Data that are available are calculated values based on climatic data and crop coefficients produced by the FAO Irrigation and Drainage Bulletin No 56 (Table 31, Table 32, Table 33). Although coefficients have been suggested for arid and semi-arid climates, they have not been tested under the severe hot and arid climate of Saudi Arabia.

* Table 31 Crop coefficients from FAO I&D Bulletin No 26

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crop coefficient	0.80	0.85	0.90	0.95	1.00	1.00	1.00	1.00	0.90	0.85	0.85	0.80

* Table 32 Calculated crop evapotranspiration (ETcrop) for date palms

Region	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Riyadh	3.73	3.81	4.54	5.83	6.4	7.31	6.89	5.21	3.71	2.86	2.03	2.30
Aseer	3.47	2.88	4.16	4.8	5.23	5.53	5.69	5.56	5.76	4.37	3.39	2.49
Madinah	3.78	4.45	6.29	7.56	9.1	8.82	8.28	8.97	7.1	4.95	4.18	2.63
Oassrn	3.87	4.09	5.45	7.07	8.27	8.06	7.68	7.93	6.35	4.52	3.51	1.64
Al-Hassa	3.52	3.9	5.34	6.49	8.71	9.39	9.87	9.12	6.85	5.16	3.49	2.64

* Table 33 Monthly irrigation requirement for date palms using surface irrigation in five selected regions (m^3/ha)

Month	Region				
	Riyadh	Madinah	Al-Hassa	Qassim	Aseer
Jan	2,163	2,558	1,984	2,180	1,953
Feb	1,766	2,265	1,980	2,084	1,466
Mar	2,560	3,546	3,008	3,071	2,347
Apr	3,177	4,122	3,538	3,858	2,622
May	3,632	5,127	4,910	4,661	2,946
Jun	3,987	4,812	5,121	4,398	3,218
Jul	3,882	4,668	5,562	4,331	3,205
Aug	3,932	5,053	5,140	4,472	3,177
Sep	2,838	3,873	3,723	3,463	3,141
Oct	2,091	2,787	2,909	2,549	2,460
Nov	1,555	2,276	1,904	1,914	1,847
Dec	1,148	1,482	1,489	925	1,402

A field experiment on 17-year old trees to test the response of dates to different water regimes (50, 100, and 100% of pan evaporation rate) using three irrigation methods (basin, bubbler and trickle irrigation systems) was conducted over four successive years (1991-1994). The results demonstrated a general trend of yield increase as irrigation increased (Table 34). Although the yield increased as the amount of water used increased the productivity of water was highest at the lower water applications.

* Table 34 Date palm yields for 1991-94 for different levels of water application and different irrigation methods

Irrigation method	Irrigation level	Yield (kg/tree)	Water applied (m^3/tree)	Productivity (kg/m^3)
Bubbler	50% E	133.7	120	1.14
	100% E	154.5	220	0.70
	150% E	182.5	325	0.56
Basin	50% E	162.0	120	1.35
	100% E	178.0	220	0.81
	150% E	165.5	325	0.51
Trickle	50% E	203.7	120	1.70
	100% E	191.7	220	0.87
	150% E	188.3	325	0.58

The estimated consumption of water for date palms varies depending on irrigation method, region and age of the tree.

* Table 35 Annual consumptive use of water in some regions (m^3/ha)

Regions	Irrigation System		
	surface	bubbler	drip
Riyadh	34,343	25,046	20,602
Makkah	34,451	25,095	20,667
Madenah	43,305	31,545	25,978
Qaseem	35,204	25,647	21,121
Eastern	34,782	26,120	20,865
Aseer	25,107	18,289	15,061
Tabuk	32,157	23,424	19,290
Hail	35,254	25,680	21,148
Northern	34,976	25,647	21,121
Najran	28,868	21,028	17,317
ABaha	25,107	18,289	15,061
Jouf	35,204	25,647	21,121

Estimates of water consumption and productivity for mature 17-year old palms in the Qaseem region are shown in Table 36.

* Table 36 Water consumption, yield and productivity for 17-year old palms

Season	2000	2001	2002	Average
Total yield (kg)	7,873	12,537	17,003	12,471
Average yield (kg)	75.5	120.25	163.1	119
Average water Consumption (m^3/tree/yr)	86.4	86.0	102.5	91.6
Water productivity (kg/rn^3)	0.87	1 .43	1.59	0.82

8.5 Irrigation agronomy

Like any other fruit tree, date palms need sufficient water of acceptable quality to reach their potential yield. Taking into consideration that there are differences in summer (July, August and September) and winter requirements (December, January and February), summer requirements are almost double the winter especially in arid areas. Also, differences in water requirements between different regions of the same country are common as illustrated in the tables.

The shape of the leaves also influences the evapotranspiration rate. The date palm does not close its stomata under extreme climate conditions, as long as the hydraulic conductivity of the water in the soil is high. In certain regions it is common to irrigate twice a day and many cover the fruit bunches with paper bags to protect the fruit from the elements (rain, dust) and from rodents.

The critical stage for newly planted date scions is during the first six weeks after planting. For mature trees, the critical stage is during fruit development – from the end of fruit set until the fruit attains its full size.

Mature date palms root down to about 5m with a 3m radius around the trunk. So about 40 % of all water is extracted from the first 50cm, 70% is from the first 100cm, 90% is from the top 150cm and only 10 % is from the last layer or 150 to 200cm and deeper. For young date plantlets this depth can vary from 25 to 50cm and the radius from 10 to 30cm 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 in such a way that it does not reach the deeper soil levels in order to ensure proper root development of the date palms. Localized irrigation (e.g. drip and micro) will therefore be more efficient than non- localized methods such as flood irrigation.

After planting small tissue culture-derived date palms the volume of soil from which it can extract water is very small. If care is not taken sufficient water may be applied but not enough will be available to get 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.

8.5.1 Date palm spacing

Irrigation water requirements when expressed in terms of cubic metres per hectare depend on the number of palms planted per hectare. The spacing between date palms differs worldwide. The recommended spacing in Saudi Arabia is 10m×10m i.e. 100 offshoot/ha. This spacing allows sufficient sunlight when the plants grow tall in 7-10 years, and allows sufficient working space within the field. In some regions, the planting is 7m×7m – about 204 trees/ha. In some older oases, such as Al-Hasa, it is common to grow some other crop with the date palms – intercropping. Vegetables crops are grown while the date palms are still young and after the palms become taller, fruit trees such as citrus are planted between them. In other areas such as on the edges of irrigation basins, the date palms are grown with alfalfa and citrus, figs, and pomegranate as associated crops. Some private farmers also use 8×8m spacing but it is not advisable to use spacing less than this.

8.5.2 Salinity

Date palm production is influenced by both soil and water salinity. Although the majority of fruit trees are salt sensitive date palms are the most tolerant fruit tree.

Most of the soils in the Kingdom are suitable for date palms since these soils have values of ECe less than 4 with very good aeration. However, date palms can grown in saline soil where ECe reaches up to 16-20dS/m in some area of the central region, between 2-8dS/m in Al-Hasa oasis, and more than 20dS/m in coastal soils of Al-Hasa.

The irrigation water quality of the main aquifers in Saudi Arabia measured in electrical conductivity EC ranged from 2-5dS/m.

Table 37 sets out the water quality limits for salinity for date palm cropping and Table 38 the limits of soil and water salinity on yield potential as set out in FAO I&D Bulletin No 29.

* Table 37 Salinity requirements for irrigation water

Salinity(affects crop water availability)	Units	Degree of restriction on use		
		None	Slight to moderate	Severe
EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
(or)				
TDS	mg/l	< 450	450 – 2000	> 2000

Although the date palm is a fruit plant it is one of the most tolerant plants to salinity where soil salinity ECe can be 4dS/m without losing any yield (Table 38). The table shows that if irrigation water salinity (ECw) of a given value is used continuously to achieve a LF of 15-20% it would result in a corresponding fall in yield potential. The ECw value at 100% yield potential is 2.7 dS/m which represent the poorest water quality that, if used continuously, will produce and ECe level of 4.0 dS/m, which is equal to the salinity threshold value.

If the average value of ECe at the root zone throughout the season was 10.9 dS/m, or ECw with leaching fraction of 15-20% is 7.3 dS/m, then the yield potential of date palm is reduced to 75%.

* Table 38 Soil salinity (EC_e) and irrigation water salinity (EC_w) for date palms

	Yield Potential				
	100%	90%	75%	50%	Maximum EC_e
EC_e (dSm^{-1})	4	6.8	10.9	17.9	32
EC_w (dSm^{-1})	2.7	4.5	7.3	12.0	

8.5.3 Irrigation scheduling

Research in Saudi Arabia, where most water is pumped from wells, shows that effective irrigation scheduling can save on average 20-30% of the water and energy used for irrigation. An experiment carried out in the Hail region to evaluate an automatic irrigation scheduling technique for conservation of water on a wheat crop for three seasons showed an overall saving of 24%.

In Saudi Arabia the use of instruments to measure and monitor soil water and their use in irrigation scheduling is limited to research centers, educational institutions, and some of the large agricultural companies. Farmers typical farmers can not use these techniques. Either they cannot afford them or there is no extension service available to encourage their use.

8.6 Irrigation methods

Different irrigation techniques are available to irrigate crops, but not all of them are suitable for date palm irrigation.

Traditional irrigation systems prevail throughout the Kingdom with the exception of some farms that have introduced drip systems and bubbler systems. The drip and bubbler systems adopted have actually been modified, taking away the emitters in order to prevent clogging. But this practice results in high discharge rates and this can lead to water distribution problems along laterals. Some water savings are acknowledged by farmers in comparison with conventional surface methods. The common practice by farmers is still to fill basins around trees to a depth of 15-20cm. But the amounts applied are still lower than those reached through the traditional practice. The latter includes three types of systems: flooding the entire planted area, borders with non irrigated strips of land with the palm trees in the middle, and large basins around trees 3-5m in diameter. With these systems, the flooded area represents 70-100% of the total and the depth applied is between 8 and 15cm of water.

The use of micro-irrigation is recommended were soils are sandy. Care is needed however to make sure that water is not sprayed into the crown of the small palm. To this effect, micros with a 300° to 320° spray pattern should be used. Furthermore, to optimize the efficient use of water it was decided to change the type of micros during the initial growing period of the date palm to ensure 100% coverage of the rooting area. A more frequent irrigation schedule is recommended during the early years because of the shallow rooting of newly planted palms:

- From planting to year 4 the area covered is about $12m^2$ and the flow rate 96l/h/palm
- From year 5 to 10 the area covered is 18m
- and the flow rate 104 l/h/palm
- From year 10 onwards the area covered is $28m^2$ and the flow rate 156 l/h/palm.

This larger area covered in the initial years will lead to some waste of water. But on the other hand it will serve to leach the soil and this will benefit the palm as a whole. Due to shallower rooting in the first years of development a more frequent irrigation schedule is required in those years.

8.7 Institutions

The current assignment of responsibilities for managing irrigation constitutes a grey area between the Ministry of Water and Electricity and the Ministry of Agriculture (including several regional water related agencies). While the overlapping of responsibilities is harmful in any organization, the lack of a responsible attitude for certain areas of management is the most damaging. As an example in the irrigation sector, note that there is no institution at any level of government in charge of water allocation to the farmers and water use data collection – two basic obligations of government.

Experience from other countries indicates that it is not the issue whether irrigation management should fall entirely under one organization or the other to make the irrigation sector perform properly, but rather the appropriate coordination and close collaboration should be there between the ministries. Often this has been achieved by setting up a high level council where all ministries and decentralized organizations are involved in the administration and operation of water resources with active representation. It is convenient to have the management of water as a natural resource-its allocation and monitoring should be under the authority of MQWE. As soon as water trespasses the farm gate and becomes a production factor - irrigation activities - it should be controlled by the agricultural authority and given the necessary coordination with other production factors.

The Ministry of Agriculture and Water was in charge of irrigation water development and management until the creation of the new Ministry of Water and Electricity in 2003. The latter is structuring and strengthening its capacity in headquarters while seeking advice on the sharing of responsibilities and creation of cooperation mechanisms with what has become the Ministry of Agriculture.

The institutions under the Ministry of Agriculture concerned with irrigation at the field level are of two categories: Agriculture Directorates in all Governorates and autonomous authorities such as Al-Hassa Irrigation and Drainage Authority (HDA) and the National Irrigation Authority. Agriculture Directorates which are by far the largest in terms of number and manpower have irrigation services, but their irrigation related activities are limited to granting permits for digging wells, assisting farmers to get subsidies and loans and providing some minute extension services. In general, they have low institutional and legal links with farmers.

The Al-Hassa Irrigation and Drainage Authority (HIDA) is relatively closer to farmers and provides better services, in comparison with the Agriculture Directorates in view of the limited area covered, its financial and administrative autonomy and a larger ratio of staff to the number of farmers covered. However, according to many interlocutors, the law on well licensing is not well enforced, performance is still well below the needs, there is a lack of an adapted legal framework, an inadequate institutional structure, and low technical manpower capacity.

8.7.1 Technical Support

Irrigation technical support services are essentially non-existent, with the exception of extremely limited extension services by HIDA in Al-Hassa oasis and by some of the Agriculture Directorates. The current situation of irrigation management reflects the existing legal and institutional setups. More specifically, the level of technical assistance and provision of extension, training and advisory services to farmers are generally low. Linkages between governmental institutions in charge of irrigation and farmers are rather weak and the capacity of these institutions is limited in terms of manpower and technical know-how.

The legal framework for water allocation, monitoring and control and the limitations thereof seem to be in part the reason for the current situation. The much needed assessment of irrigation water use would address these aspects as well, with a view to their improvement. Setting up such links in the future and making them operational should be the priority of the Ministry of Agriculture as a means of improving the current situation of irrigation water management.

The social aspect of irrigation and on-farm water management seem to have a direct impact on their current status and level of their performance. All irrigation managers and field operators are foreign. Occasional labourers have very limited knowledge of irrigation practices and on-farm water management. Integration of this aspect in the assessment will also be necessary for future improvements.

References

Abderrahman WA (2001) Water demand management in Saudi Arabia**.** International Development Research Centre (*IDRC)* Bulletin No.12.

Abderrahman WA and Al- Nabulsi Y (2001) Irrigation water use of date palm . Fourth date palm symposium, Alhassa, Saudi Arabia.

Abo-Ghobar HM and FS Mohammad (1995) Actual evapotranspiration Measurements by lysimeters in a desert climate. Arab Gulf Journal of Scientific Research. 13 (1). p.109-122.

Abou-Khalid A, Chaudhry SA and Abdelsalam S (1982) preliminary results od date palm irrigation experiment in central Iraq. Dtae palm journal 1(2):199-232.

AL-Amoud AI (2006) Date Palm Response to Subsurface Drip Irrigation. The Canadian society for Bioengineering. Paper No. 06-204.

Al-Amoud AI, Bacha MA and Al-Darby AM (2000) Seasonal Water Use of Date Palms in Central Region of Saudi Arabia. Agricultural Engineering Journal 9(2): 51-62.

Al-Ghobari HM (2000) Estimation of reference evapotranspiration for the south region of Saudi Arabia. Journa of Irrigation Science, vol. 19:8186.

Al-Ghobari HM (2002) Gross irrigation requirements for major crops in Najran region. Journal of the Saudi Society of agricultural sciences, vol. 1 (2):84-106.

Al-Khatib AA, and AM Al-Jabor (2006) Date palm in Saudi Arabia. Ministry of Agriculture, National research center for date palm in Al-Hassa. In Arabic.

Al-Wasel AS (2005) A survey study on: Somalonal variations in vitro-drived date palm tree. Proceedings of the international workshop on True-to-typeness of date palm tissue culture-derived plants, Morocco, 23-15, May, 2005.

El-Dairi N, AS Al-Ghamdi, M Jahjah and G Hussain (1986) Effect of drip irrigation on the development of root system of date palm (phoenix dactylifera L.) offshoots. Proceedings of the second symposium on the date palm in Saudi Arabia March3-6,1986.king faisal university, Al-Hassa.

Erskine W, AT Moustafa, AE Osman, Z Lashine, A Nejatian, T Badawi, and SM Ragy (2005) Date palm in GCC countries of the Arabian Peninsula. Internet Documents.

FAO (1995) Report of the Expert Consultation on Date Palm - Pest Problems and their control in the Near East. (22-26 April, 1995); Al-Ain, United Arab Emirates.

FAO (2003 & 2004) Agro-Statistics Database.

Heakal MS and MH AlAwajy (1989) Long-Term effects of irrigation and date palm production on Torripsamments, Saudi Arabia. Geoderma, 44:261-273.

Ministry of Agriculture and Water (2004, 2006) Agricultural Statistical Year Book, vol.17 and 19, Department of Economic Studies and Statistics, Riyadh.

Nixon RW & JB Carpentar (1978) Growing Dates in the United States. U.S. Dept. of Agriculture, Agric. Information Bulletin No. 207: USDA. Technical Document 63 pp.

Saeed AB, HA Etewy, OA Duheash and OS Aly-Hassan (1986) Assessment of date palm water requirements under Al-Hassa conditions. Proceedings of the second symposium on the date palm in Saudi Arabia March3-6 1986. King Faisal University, Al-Hassa.

Van ZYL HJ (1983) Date Cultivation in South Africa. Information Bulletin No. 504; Compiled by the Fruit and Fruit Technology Research Institute, Department of Agriculture, Stellenbosch, RSA. 26pp.

Walid AA (2000) Water demand management and Islamic water management principles: A case study. International J. water resources development. 15(4):465-473.

9 Syria country paper

9.1 Introduction

Date palm trees originated in Tadmor in ancient times. The word Tadmor is a distortion of the word (Tad Moor) i.e. the country of date palm in the old Tadmorian language, Palmyrian, or Palmyra in English.

Date palm trees are now planted in Palmyra, Derelzor, Al Boukamal and Raqa. From 1986 to 2006 the number of trees planted increased from 50,000 to 206,000 (60-355ha) and production increased from 500 to 3,258 tons.

Homs and Deralzor provinces are considered to be the pioneers in date palm plantations followed by Alraqa and Alhasska provinces. In Tadmor's badieh, there are around 104,000 date palms – 60,000 are from old local seed groups with an important hereditary diversity.

Syria has a wet climate in the western coastal areas but is dry in the eastern Badieh area. It is the drier areas that provide the most favourable conditions for date palm production. The fruits ripen from May to October when the temperatures are high and the relative humidity is low (30-40%). Soils in the area are well suited with pH values of 7-8.

In Syria, there is a convenient environmental belt for planting date palm trees. It is divided into five different classified regions by their ability to produce date palm trees according to their agro-climatic conditions:

- From Al Raqqa to Al Boukamal following the Euphrates River.
- From Al Raqqa to Al Hassakeh and Iraqi borders (East) and around Al Kabour River.
- Between 34-35° Latitude N and between 39.2–4.30° longitude E to the Euphrates River.
- Between 37-40.3° Longitude N from Jordan–Iraqi border to Tadmor region.
- From Al Raqqa (North) to south nearby East of Tadmor to Al Hyjana.

9.2 Date production

The government of Syria has established special centres for date palm cultivation and propagation at Tadmor, Sebghet Mouh, Al Bokamal, Al Raqa and Al Hasaka. Their main contributions and objectives are:

- Collecting the best Syrian varieties and clones and propagating and distributing them to farmers.
- Introducing imported varieties from UAE, Iran, Libya, KSA, and Egypt.
- Improving quality and quantity of date palm production by offering technical and scientific supports to farmers.
- Providing specific training courses, field school days and brochures to improve technical skills of practitioners and farmers.
- Cooperating with international associations and institutions in the field of scientific research and technology of date palm trees.

9.2.1 Economic value

An economic study in Al Boukamal region showed that the net average income is around S£30,116/Donum/yr with a typical cropping system shown in Table 39.

* Table 39 Farm cropping system in Al Boukamal

Cropping system	%
Fruit trees including date palm	88% (dates about 92%)
Vegetables and crops under/intercropping	11%
Breeding farms	1%
Total	100%

In Tadmor the net average of annual income is around S£12,275/Donum/yr based on a typical farm cropping system (Table 40).

* Table 40 Farm cropping system in Tadmor

Cropping system	The percentage
Fruit trees including date palm	90% (dates about 42%)
Vegetables and crops under/intercropping	6%
Breeding farms	4%
Total	100%

The results show that dates produce the greatest income in the environmental belt region compared to other regions.

Date palms are associated with vegetables, forage crops, and olive trees as in Tadmor. Therefore, they can be associated with cash crops (beet, cotton) and stone fruit trees (peach, apricot, almond) as in DerelZor and Al Bokamal.

In Al Bokamal, dates in new plantations are planted on a 10m × 10m grid.

9.2.2 Development and production

Over the past 20 years number of date palm trees and the production of dates has increased (Table 41).

* Table 41 Date production from 1986-2006

Year	Area (ha)	No of date palms (000s)		Production (tons)
		Total	Fructuous	
1986	60	50	40	500
1996	90	100	62	2,500
2000	1008	187	76	3,051
2004	353	186	60	4,145
2006	355	206	70	3,258

9.3 Water requirements

The most critical factors for rowing and producing date palms are temperature and water. There is an Arab proverb Said: "Date Palm tree, its roots in water and its head in fire". This common proverb is right scientifically.

A study of irrigation water requirements for date palm trees was carried out at the Centre for Date Propagation at Al Bokamal over a period of six years from 1995 to 2000.

A local variety (Zahedi) was used on a clay soil with an average age of offshoots of three years. The irrigation frequency was twice weekly in the hot season and once weekly in winter. This experiment produced the results shown below in Table 42.

* Table 42 Irrigation water requirements for date palm trees in Al Bokamal

Year	1995	1996	1997	1998	1999	2000
Water req (m^3/yr)	25.6	31	38	48.3	50.8	62.3

Similar irrigation experiments were undertaken at the Dates Propagation Centre of Tadmor using 9-year old fructuous date palm trees. The soils were of moderate structure and texture and irrigation was practised by tankers. This experiment indicated the optimal irrigation water requirement was 152m^3/tree/yr. High economic production and good repetitive growth were obtained during the experimentation period.

9.3.1 Irrigation agronomy

In Syria it is recommended to irrigate weekly or fortnightly in sandy soils in summer and once in 20 or 30 days in winter. But for medium and heavy soils, irrigation frequency will be higher. Young plantations should be irrigated daily during the first 45 days in sandy soils and every 2-3 days in heavy soils.

Irrigation methods used vary according to soil characteristics, water resources, age of trees and economic factors – basin, furrow, dripper and bubbler).

Most private date palm gardens are irrigated by traditional surface irrigation techniques, but government centres use bubbler and drip irrigation systems.

9.3.2 Irrigation methods used at Date Propagation Centres

The different characteristics related to irrigation methods practised at the various Date Propagation Centres are shown in Table 43.

* Table 43 Irrigation methods used at different Date Propagation Centres

Item	Site	Water source	Salinity (EC)	Irrigation method	Flow
Tadmor	Tadmor	Artisan well	1.4 g/l	Drip irrigation	40 m^3/hr
		Shallow well	5 - 7.5 g/l		150m^3/hr
Al Boukamal	Derelzour	Euphrates River	0.6 - 1g/l	Surface irrigation	450m^3/s
Sebghetmach	Tadmor	Artesian well	1.03 g/l	Bubbler system	280 m^3 /hr
Al Raqqa	Al Raqqa	Euphrates River	1.06 g/l	Flood (basin)	450m^3/s
Khabour	Al Hasaka	Shallow well	2.7 - 5 g/l	Drip irrigation	50m^3/hr
Al Jazira	Al Hasaka	Shallow well	3.7 g/l	Drip irrigation	34m^3/hr
Sa'alo	Derelzour	Euphrates River	0.6 -1 g/l	Flood (Furrow irrigation)	450m^3/s

References

Al Bakur, Abd Ajabar (1982) Date Palm tree, second edition.

Botanic resource (1983) Department-Date Palm tree in UAE.

Huseen Ahmad Kahtani M, and Wanly J (1979) Date Palm tree in Arabian and Islamic world.

Hamed Huseen and Hediri Heder (1983) Offshoots and the problem of extension of date palm plantation. King Faisal University.

Al Jabori Hemed (1993) Date Palm tree UAE University, College of Science, UAE.

Albaba Monzer (2000) Date Palm tree. Agriculture Ministry, Syria.

ACSAD (1994) Date Palm Research and Development Network (DRDN) Analysis Agro Systems in Date Palm tree regions in Syria.

Barabandi Abd, Osman Awad and Kurdi Salah (2000) Date Palm (Technical and horizons).

FAO (1996) Prospects of date palm by–products and residues utilization in the Near East Region.

FAO (1995) Report of the expert consolation or Date Palm. Al Ain.

Faraj Karem (2005) Date Palm between research and application.

Al Ghamdi Abdullah, Al Maree Khalil (1998) Date Palm: Tissue culture propagation.

Dowson VHW (1982) Date production and protection FAO. Plant production and protection.

FAO (1993) Date Palm improvement project.

10 Tunisia country paper

10.1 Background

In Tunisia dates are principally grown in oases of the Governorates of Gafsa, Gabes, Tozeur and Kebili – some 32,980ha of which 15,350ha are traditional oases. In 2005-06 it was estimated that 4.5 million palm trees were growing and producing about 133,320 tons of dates – an average yield of 29.6kg/tree.

* Table 44 Date palm distribution (ha)

Location	Traditional	Modern	Total
Tozeur	3,370	4,850	8,220
Kebili	4,220	11,780	16,000
Gafsa	820	1,000	1,820
Gabès	6,940	-	6,940
Total	15,350	17,630	32,980
	46%	54%	

* Table 45 Distribution of date palms Tunisia

Location	Palms	%
Tozeur	1,609,000	35.4
Kebili	2,282,000	50.3
Gafsa	178,000	3.9
Gabès	470,000	10.4
Total	4,539,000	100

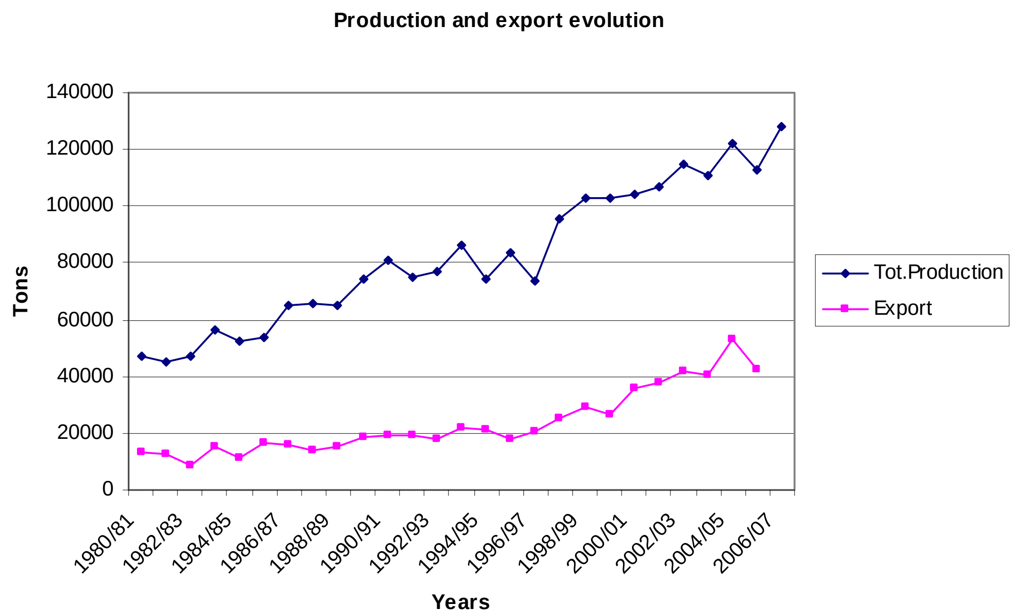
10.2 Water resources

Water resources are scarce in Tunisia. In 2004 the consumption of water per capita was only 417m^3/person/yr. Dates are grown for both local consumption and for export. Table 46 shows the amount of dates exported from 1984 together with the water used to grow the dates, which is also effectively exported.

* Table 46 Dates exported from Tunisia

Year	Dates (tons)	Water use (Mm^3)	Year	Dates (tons)	Water use (Mm^3)
1984	16206	16.2	1998	27299	27.3
1985	15214	15.2	1999	23099	23.1
1986	14267	14.3	2000	22411	22.4
1987	15764	15.8	2001	47043	47.1
1988	15766	15.8	2002	41890	41.9
1989	16611	16.6	2003	42010	42.1
1990	18031	18.0	2004	40200	40.2
1991	19453	19.4	2005	53217	53.2
1992	17119	17.1	2006	42770	42.7
1993	18510	18.5			
1994	20782	20.8			
1995	20872	20.9			
1996	18216	18.2/			
1997	21310	21.3			

On the basis of yearly average water needs of 12,000m^3/ha for date palm and an average yield of 12 tons/ha this means that it takes 1,000m^3 of water to grow 1.0 ton of dates.



* Figure 6 Date production and exports since 1980

Economically, dates represent the main financial resource for many people in cities and village around the oases. Indeed, the sector contributes 4.34% of agricultural production in 2001 and 15.7% of the value of agricultural product export. This sector occupies third place in the agricultural export scale after oil and sea products.

The main importing European Union countries are France, Italy, Spain and Germany.

10.3 Oases

Oases provide the main source of water for date palms. Water appropriation and sharing systems are governed by customary management rules and a social code related to the organization of the local society. Date palms develop well in the microclimate created in and around the oases.

Coastal oases are characterized by mild winters where only the common varieties of date palm are cultivated. Palm trees are of secondary importance in comparison to other crops such as Henné, salad crops grown under glass for export, and pomegranates.

Continental oases are essentially located in Jerid (Tozeur, Nefta, Degache), Nefzaoua (Kebili, Douz), and Rjim Maatoug. Date palms, particularly the Deglet Ennour variety are the main crops in these oases. They contain 85% of the total palm trees in the country and contribute 90% of the national date production.

The oases environment conceals a rich genetic diversity that has adapted to particular arid and salty soil conditions. Crops associated with date palms are numerous – arboriculture, vegetables, fodder crops, and crops with high economic value such as Henné. Animals are also an important part of the farming system and a major contributor to the economic and ecological balance of the oases.

The oases agricultural system and the population that live there react to the technological contributions and to the market economy. An example of this is the growth in handicrafts, tourism, and other oases products.

10.4 Inter-cropping

Date palms are the main crop in the oases but other crops are also grown as an inter-crop. Below the date palms are the pomegranate and fig trees. At ground level are the fodder crops and vegetables.

10.5 Irrigation practices

Until the advent of modern irrigation practices oases were the most elaborate model of the collective management of water resources. Water sources were the focal point of the oases and the sharing of the water allocation, relative to a water right was an important power for an owner or a family to have.

Surface irrigation is practised in all oases. When it is not used properly it can be a source of significant water losses.

References

Ministère de l'agriculture et des ressources hydrauliques (2006) Statistiques sur les oasis.

Institut des hautes études de Tunis (1957) Les cahiers de Tunisie.

Ministère de l'Agriculture et des ressources hydrauliques (2005) Amélioration de l'irrigation dans les oasis du sud de la Tunisie.

Ciheam (2000) L'amélioration de l'efficacité de l'irrigation pour une économie d'eau : cas d'un périmètre irrigué en Tunisie - Plan Bleu. Oct.

Chaibi N (2002) Potentialités androgénétiques du palmier dattier. Biotechnol.Agron.Soc.Environ.

Michel F (1990) Concurrence et complémentarité des espèces végétales dans les oasis: Ciheam- Options Méditerranéennes.

Agence de Promotion de l'Industrie (2000) Etude du positionnement de la branche dattes: Tunisie.

Groupement Interprofessionnel des Fruits (2006) Traçabilité de la filière dattes: Tunisie.

Abidi B (2001) Analyse de la situation actuelle Rapport. La nappe du continental intercalaire du Sud-est tunisien.

Riou C (1990) Options Méditerranéennes. Bioclimatologie des oasis.

Noureddine N et Mares H (2006) Dynamique des législations du foncier et de l'eau pour un accès équitable et une gestion durable des ressources en eau.

Mamou A (Dec 1993) La salinisation des sols, incidence de l'exploitation des nappes du sud tunisien dans les oasis sur la qualité chimique de leurs eaux.

11 UAE country paper

11.1 Background

The United Arab Emirates (UAE) is a federation of seven Emirates: Abu Dhabi, Dubai, Sharjah, Ras Al khaymah, Fujairah, Umm al Quain and Ajman. It is regarded as an arid and semi-arid region with high temperatures (annual average of 26°-28°C). The highest recorded was about 48°C during June and the lowest about 4°C during January. Relative humidity is higher than 50%. The average annual rainfall varies from 40mm in the southern deserts to about 60mm in the north–eastern mountains.

The UAE government has formulated laws and regulations to safe-guard the cultivation and production of dates. Different strategies in this regard are being executed by the different governmental organizations and institutions, private date palm growers, and local societies. The Ministry of Environment and Water (MOEW) in UAE is one of the governmental organizations that is directly involved in the achievement of the governmental policies and the short-term and long term goals. This is made possible through its research stations in the different Emirates as well as co-operation with the national, regional and international organizations dealing with date palm cultivation and dates production. Constructive discussion and dialogues led to a marked improvement and expansion in date palm production.

Dates are grown in the different regions of the UAE. They are cultivated along the western coast of the Arabian Gulf in areas such as Jumaira in Dubai Emirate and Al-Hayra in Sharjah Emirate. Likewise, along the eastern coasts, date palm cultivation stretches from Kalba in the south to Diba in the north. The dates are soft type and mainly consumed at "Rutub" Stage or dried at "Tamr" Stage.

Date palm oases are spreading from the plains and mountains that stretch from Ras-al Khaimah (RAK) in the north to Al-Ain city in the south. These oases differ in their size and date palm plantation depending on the availability of water. The system of watering of date palm trees uses natural springs (as is the case for Masafi and Khatt) or "Aflaj"(as is the case in Al-Ain, Dhaid and Falj-al-Moualla) or using tube wells (as is seen in Adhn). The amount and frequency of rain in this area are the major factors for date plantation.

The most important oases are Al-Ain and Liwa. Al-Ain oases are irrigated with a network of "Aflaj", while Liwa oases depend on dug wells as the water table is at 5-10m depth. Date palm irrigation is practiced at its early age, but as it develops, it relies on the shallow water table for its water need.

11.2 Date production

Date production in the UAE has increased dramatically over the past 30 years from 8,000tons in 1970 to over 50,000tons in 2003.

* Table 47 Date production in UAE (tons)

Region	1999	2000	2001	2002	2003
Central	2,126	2,204	3,004	3,284	4,059
Northern	3,700	4,473	5,550	5,908	6,144
Eastern	1,706	2,499	3,402	3,804	3,451
Abu-Dhabi	10,348	17,228	18,416	27,868	36,854
Total	17,880	26,404	30,372	40,864	50,508

11.2.1 Climate

The climate of UAE is characterized by very high summer temperatures (ranging from 40-45°C). Maximum relative humidity reaches 79% while the daily evaporation reaches 8.2mm. Mean annual rainfall is about 120mm, fluctuating from about 335mm during rainy seasons to less than 15mm during dry periods. Rainy seasons usually last from October to May. Floods flow from mountains towards the plains at times of heavy rainfall. Soils generally range from sandy to sandy loam with high permeability and low organic matter content, while in the mountainous areas it ranges from stony to gravelly. Soil salinity due to secondary salinization increases in non-sandy areas as a result of the use of saline irrigation water. Coastal areas are affected due to higher sea water intrusion. Water resources for agriculture are basically surface water and groundwater. Falajes and springs are also used for irrigating crops. Tertiary sewage water is used for irrigating landscapes, while desalinated water is used for domestic and industrial purposes. In some cases it is blended with irrigation water at the farm level to be used for agricultural production. The UAE government, through the Ministry of Environment and Water (MOEW) and other related authorities, is seeking to grow environmentally safe and economically feasible species using saline groundwater for irrigation. Recently MOEW, in collaboration with the International Center for Biosaline Agriculture (ICBA) and through a joint project with the International Atomic Energy Agency (IAEA), is assessing the potential use of saline water resources for agricultural production including date palm.

The two main water resources utilized for irrigation are surface water and groundwater. They are characterized by fluctuations in quality and quantity as a result of the unstable nature of rainfall and the unpredictability of floods. The development of agricultural lands during the last 10 years has resulted in the lowering of groundwater levels and an increase in irrigation water salinity in most of the agricultural regions of UAE.

Groundwater plays an important role in the socio-economic development of the country. Agricultural development, especially in desert regions of UAE, also depends largely on this source. The agricultural expansion that started at the beginning of the 1970s continued and ground water abstraction resulted in a marked fall in water levels. The general trend shows an annual decline in groundwater level in the different agricultural areas ranging from 0.8-2.0m/yr. Some recovery of groundwater takes place during the flooding seasons.

The annual recharge for groundwater is estimated between 120Mm^3 and 150Mm^3 while the current annual extraction far exceeds the annual average recharge. Groundwater abstraction for 2005 reached about 4,000Mm^3.

Rainfall in the UAE is very low and fluctuates from one year to the next and, as such, floods differ in their magnitude in time and space. There are about 25 main wadis located in the Northern, Eastern and Southern (Al-Ain) regions of the UAE.

In order to utilize the runoff water during the floods seasons more than 100 retention dams were built on the main wadis. These also aid groundwater recharge. The total capacity of these dams is about 115Mm^3.

Falajes water is also exploited for agricultural use. This is renewable and although it is limited it does contribute annually about 9 Mm^3 to the total water use in the country. Due to the limitations of groundwater in terms of both its quality and quantity, the UAE government has resorted to using unconventional water resources such as desalinated water and treated sewage.

* Table 48 Water resources exploited in 2005

Source	Mm^3
Groundwater	4,052
Desalination	950
Treated wastewater	319

11.3 Water requirements

The date palm, like any other fruit tree, requires enough water to compensate for the losses due to soil surface evaporation and the transpiration from the leaves as well as the amount that is needed during its growth stage and fruiting. It is a fact that date palms grow under desert climatic conditions and are drought resistant and salt tolerant as compared to other crops. However, it is equally important to irrigate the tree with sufficient water of good quality in order to produce acceptable yield and better fruit quality. Other factors to be considered when estimating date palm water requirement are those related to the environmental condition of the location where date palm trees are cultivated. This includes the different meteorological parameters (temperature, relative humidity, wind speed and direction, sunshine hours, solar radiation etc.), soil physical and chemical characteristics (texture, infiltration rate, soil salinity…etc.) and also the crop (date palm) characteristics (age, variety, spacing, root depth, etc.). All these factors and the quantity and quality of the irrigation water are considered for estimating the date palm water requirement. The objective is always to achieve the optimal utilization of water. In this regard the system of irrigation used and the frequency and time of irrigation scheduling become important aspects of date palm irrigation.

Empirical formulae are used to estimate water requirements for the different periods of the year taking into consideration the effect of a number of meteorological parameters such as temperature, humidity, evaporation, wind speed and direction, sunshine hours, radiation as well as the available soil water and the tree canopy (based on the age of the tree). The data required for the calculation of the crop water requirements are made available by the Ministry of Environment and Water in UAE through the meteorological section of the Department of Water and Soil (Table 9).

* Table 49 Estimated reference evapotranspiration (ETo)

Hargreaves & Saimani (mm/day)	Class A Pan (mm/day)	Penman (mm/day)	Month
2.8	2.8	2.3	Jan
3.6	3.58	3.0	Feb
4.4	4.82	4.2	Mar
6.5	6.37	6.8	Apr
8.1	7.74	8.2	May
8.2	7.37	8.6	Jun
8.6	7.40	8.7	July
7.0	6.85	8.3	Aug
6.5	6.50	6.9	Sep
5.5	5.40	5.0	Oct
3.9	3.91	3.3	Nov
3.3	2.98	2.3	Dec
68.4	65.72	67.6	Yearly Total (mm)

11.3.1 Crop coefficients

Various crop coefficients are used for date palms in the UAE (Table 50).

* Table 50 Crop coefficients used in UAE for date palms

	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Matured Trees	0.7	0.73	0.8	0.9	0.9	0.9	0.9	0.9	0.85	0.75	0.73	0.7
Trees (50%) GC	0.65	0.65	0.6	0.55	0.5	0.5	0.55	0.55	0.55	0.55	0.6	0.6
Trees (20%) GC	0.55	0.55	0.5	0.5	0.5	0.45	0.45	0.45	0.45	0.45	0.5	0.5

11.3.2 Gross irrigation requirements

The gross irrigation water requirements are calculated using the Penman method for mature 7-year old date palms.

* Table 51 Gross irrigation requirements for mature date palms based on Penman

Month	ETo		Kc	ETc (mm/month)	Gross application (mm/month)		
	mm/day	mm/month			Basin irrigation	Bubbler irrigation	Drip irrigation
					Eff = 65%	Eff = 0.8%	Eff = 0.9%
Jan	2.3	70.9	0.70	38	59.1	48.0	42.7
Feb	3.0	82.8	0.73	47	72.8	59.2	52.6
May	4.2	129.5	0.80	80	124	00.8	89.6
Apr	6.8	203.1	0.90	141	217.5	176.8	157.1
May	8.2	253.3	0.90	176	271.8	220.90	196.3
Jun	8.6	257.4	0.90	178	275.1	223.5	198.7
Jul	8.7	269.5	0.90	186	287.5	233.4	207.7
Aug	8.3	255.9	0.90	178	274.3	222.9	198.1
Sep	6.9	207.7	0.85	135	208.6	169.5	150.7
Oct	5.0	153.4	0.75	89	137.8	112.0	99.6
Nov	3.3	97.5	0.73	55	85.4	69.4	61.7
Dec	2.3	69.8	0.70	38	59.1	48.0	42.7
Total					2,074	1,685	1,500

11.3.3 Recommendations to farmers

Based on the above calculations recommendations are made to farmers depending on their planting conditions. A sample calculation based a sandy loam soil, palms planted on a 7m×7m spacing of trees and the use of a bubbler system for water application is shown in (Table 52).

* Table 40 Recommended farmer's date palm irrigation requirements

Age of tree	Period				
	Dec-Feb	Mar-May	Jun-Sept	Oct-Nov	Total
1st Year					
m³/tree/period	2.70	4.05	7.20	2.88	16.83
l/tree/day	30	45	60	48	
2nd Year					
m³/tree/period	4.05	5.22	8.40	3.12	20.79
l/tree/day	45	58	70	52	
3rd Year					
m³/tree/period	5.40	7.65	13.2	4.5	30.75
l/tree/day	60	85	110	75	
4th Year					
m³/tree/period	8.10	11.25	18.00	6.90	44.25
l/tree/day	90	125	150	115	
5th Year					
m³/tree/period	10.8	16.20	26.40	9.30	62.7
l/tree/day	120	180	220	155	
6th Year					
m³/tree/period	12.60	18.90	31.2	10.8	73.8
l/tree/day	140	210	260	180	
7th Year					
m³/tree/period	13.95	22.50	37.20	12.00	85.65
l/tree/day	155	250	310	200	

11.4 Irrigation methods

The UAE has adopted a modern approach to agriculture using modern irrigation techniques. Field studies carried out at the Humraniyah Agricultural Research Station (HARS) showed that the use of the modern irrigation systems (drip, bubbler and sprinkler) can save about 80% of irrigation water at the field level when compared to open earth channels and of about 45% water saving on improved lined channels. Labour saving of 70-80% could be expected with the improved irrigation methods.

Date palm irrigation methods differ according to the source of water, its availability and quality, the type of soil and its topography, climatic conditions, the labour force and the age of the date palm under cultivation. The system of irrigation has developed considerably from what was used under the old date palm cultivation to that which is now used under modern date palm plantation.

11.4.1 Traditional Methods

The traditional method of irrigating date palms comprises individual basins for each palm. These basins are of different shapes (circular, rectangular or square). Earthen bunds or barriers are made around the basin in order to hold the applied irrigation water. The areas of the basin could be as large as $4m^2$. Usually a cemented water storage tank supplies the irrigation water through earthen or lined canals. Several sub-main canals are branched and with the help of individual earthen canals supply the required amount to the individual date palm trees. The topography of the farm comes in to consideration when practicing this system of irrigation.

This method is mostly used in old farms growing matured date palm trees. The irrigation efficiency is very low ranging from 50-60%.

11.4.2 Modern irrigation systems

The first modern irrigation systems were introduced during the FAO/Ministry of Agriculture project (1975-1984). Bubbler, drip and sprinkler systems of irrigation were first introduced at the research level. The MAF then, through its regional departments adopted these modern systems based on the results of applied research work conducted at the different research stations of the UAE. Results in some cases showed an increase of 30–40% in crop yield as compared to the traditional system of irrigation. Accordingly in 1982, a specialized company was given the task of executing the installation of drip and bubbler systems in different parts of the region totaling about 400ha. The MAF also subsidized 50% of the total cost of the complete installation of the systems. The out come of this project was so beneficial that the farmers started themselves installing the irrigation systems and sometimes at their own expenses.

Bubbler irrigation is largely used to irrigate fruit trees including date palms. It is available with adjustable flow but farmers mostly use bubblers with a discharge of 360l/hr (Figure 7).

* Figure 7 Bubbler irrigation

This system is used for date palm trees 3–4 years old (off shoots) and is continued even after maturity. There are some disadvantages that are associated with bubbler system. Farmers usually depend on unskilled labour to irrigate their date palm fields. This usually leads to losses during irrigation as care is required in applying the recommended amount of water. Labourers tend to over-irrigate as they prefer to irrigate more in a short time. The efficiency of bubbler irrigation is about 80%

Drip irrigation is regarded as an advance in modern irrigation techniques as it is localized and releases water slowly and precisely. This is done through drippers that vary in their discharges from 4l/hr to 8l/hr to 24l/hr. (Figure 8). There are online and also inline drip systems that were introduced recently in UAE for irrigating forage crops and to some extent fruit trees. Most recently research was conducted at Al–Humraniyah Agricultural Research Station (HARS), in the Northern Agricultural Region of Ras -Al-Khaimah Emirate of UAE, to evaluate the effect of modern irrigation systems on date palm yield, vegetative and fruit characteristics.

* Figure 8 Drip irrigation

These modern systems are provided to farms at 50% cost. Data in Table 53 shows the cropped areas under the different irrigation systems.

* Table 53 Cropped areas under different irrigation systems

Location	No. of farms	Cropped Areas (ha) Irrigation system				Total Area
		Drip	Bubbler	Sprinkler	Other	
CAR (2001)	1,836	1,363	2,153	1,411	741	5,669
EAR (2001)	286	178	639	163	0	980
NAR (2002)	767	1,509	908	1,723	766	4,906
Northern Region (2001)	2,413	3,879	838	408	197	5,323
Al-Ain Region (2001)	844	1,225	198	176	1,035	2,634
Western Region (2001)	6,717	13,716	634	276	933	15,560

Most of the cultivated areas are under bubbler irrigation followed by sprinkle and drip systems of irrigation. In NAR, however, most of the cropped areas are under sprinkler irrigation (35%) followed by drip irrigation system (31%). Areas like Digdaga and Khatt in NAR mostly use bubbler irrigation system for about 71% of the cropped areas for fruit trees including date palms. About 80% of the total cropped area in the Western Region uses drip irrigation system. This is mostly due to the large scale vegetable production under protected agriculture.

11.5 Institutions

The Ministry of Energy deals with Petroleum and Electricity and also water. However, the Ministry of Electricity and Water is the institution that deals generally with the non-conventional water resources in the

UAE (desalination, treated sewage water). The Ministry is regarded as the central source of information coming from the different electricity and water authorities functioning in the different Emirates of the UAE.

The Ministry of Environment and Water based in Dubai, has two main departments dealing with water, namely the Department of Water Resources and Dams, and the Department of Irrigation and Soils.

In spite of all the research on water and irrigation systems there is no clear government policy on the allocation of water for irrigation purposes at farm level. Pumped ground water is subject to the farmer's need of water to irrigate the crop. Underground water is a national wealth and most farmers use this source of water to grow their crops. No metering system and water pricing is enforced at the farm level by the government as yet, although, given the present water scarcity in agriculture, such a policy, along with the application of crop water requirements, would help in reducing the ground water abstraction for crop production.

11.6 Extension services

Agriculture development starts at the research stations and achieves its primary goal when their findings reach the farmers. Agricultural research stations conduct trials and studies related to the farmer's field problems. The results and findings of the applied research studies require a system to transfer these findings to the farmers. Such a service is provided by the extension centers that form a link between the institutions dealing with research and the end users (the farmers). The different methods used for the transfer of results to the farmers have been largely developed by the UAE government. It can be through audio visual aids, technical bulletins, in-service training, lectures, news papers and field visits to pilot farms. The transfer of knowledge and on-farm technologies help to provide feed back from the farmers through the agricultural extension agents to the researchers. It becomes, therefore, of vital importance to formulate research policies that will help in developing and solving field-related problems and, at the same time, strengthen the co-operation between the research institutions, the extension agents and the end users.

The Ministry of Environment and Water, which is the most important contributor to the development of agriculture in the UAE, established a number of extension centers all over the UAE region. These extension centers come under the supervision of the Departments of the Agriculture in the different regions. Field related issues like water management advice, soil and water analysis, pest and diseases identification and their proposed control measures, field survey and irrigation net work layout, are all executed through the extension centers.

There are no standards yet which specify the qualifications of an extension agent. However, a field survey of the academic qualifications of the extension agents working at the different Departments of Agriculture that are affiliated to MOEW showed that about 50% of the extension agents are graduates.

11.7 Comments

The pressure on water resources, in particular groundwater resources, has been intense and somewhat alarming. Agricultural activities consume 70-80% of the ground water resource. Groundwater aquifer are exploited at a rate greater than their sustainable yields. At the farm level, over pumping has resulted in both the reduction in the available water and the deterioration of groundwater quality. The concept of "When", "how much" and "how" to irrigate is not properly applied at the farm level.

Date palm cultivation and dates production using groundwater irrigation has become a priority in the agriculture sector although there is limited research work on date palm irrigation. Date palm orchard management practices have been widely covered by researchers at MOEW. But farmers continue to use less efficient systems of irrigation such as basin flood methods.

On the newly established date farms, bubblers, and open polyethylene hoses are used. However, in most cases, due to poor supervision and insufficient knowledge on the water requirements and irrigation scheduling, excess water is applied which results in water and nutrients losses. Date palm gross irrigation requirements under basin, bubbler and drip systems of irrigation were 20,740, 16,850 and 15,000 m^3/ha respectively. Daily water requirement for a matured date palm is between 260-300 l/day during the peak periods in summer (June – September), 180-200 l/day during (October – November) and between 140-155 l/day during the winter period (December-February). Date palm irrigation scheduling is found to be 9-12 days interval during the winter period and between 5-6 days interval during the summer period.

Drip irrigation systems are the preferred modern method of irrigation for date palm trees, but because of its concept of wetting only the top soil layer, farmers sometimes show their unwillingness for its use on their farms. Farmers' awareness programmes and active extension work by the agricultural extension agents would greatly help in this regard.

Estimated date palm water requirements at different ages of the tree and at different soil conditions as well as irrigation methods, as referred to in this study, would help as a guideline for date palm irrigation.

References

Al-Assam MS and Sattar HM (2005) Irrigation Water Management in the United Arab Emirates (Policy and Development).International Conference on Water, Land & Food Security in the Arid Semi-arid Regions 6-11 September,2005,Mediterranean Agronomic Institute, Bari, Italy.

Aboodi AH & Al-Shakir SH (2004) Date Production, Marketing and Date Palm Residual Uses in United Arab Emirates. Date Palm and Dates Residual Uses Conference, 6-8 June, Al-Madina, Saudi Arabia.

Agriculture Statistics Handbook (2003) MAF, Dubai, UAE.

AOAD (1995) Date palms in the United Arab Emirate. Date Palm Development Project (AOAD/MAF), 131p.

Blatter E (1926) The palms of British India and Ceylon. Milford, London (In FAO Plant Production and Protection Paper 156, Rev.1, Rome, Italy, 2002).

ICARDA (2004) Date palm development in the Gulf Co-operation Council Countries of the Arabian Peninsula. Summary Proceedings of a Regional Workshop, 29-31 May, 2004, Abu-Dhabi, UAE.

Sattar HM (2003) Feasibility studies on the Use of Saline Water for Agricultural Production in the Northern Agric. Region. MAF/ICBA Project, UAE.

12 Yemen country paper

12.1 Background

Yemen has been popular for the cultivation of palm trees and the production of dates since medieval times. Date palms are widely cultivated in Hadhramout Coast and Wadi, Suqutra Island, Tehama Plains and Al-Mahara. The palm trees now cover and area of some 13,740ha producing 28,576 tons of dates (in 2004) – equivalent to 2 tons/ha. Some 321 varieties of palm trees are grown including 42 varieties with excellent quality, 165 varieties of good quality, 67 varieties of satisfactory quality, and 42 varieties of poor quality.

It is known that palm tree cultivation was spread in Yemen thousands of years ago and this had significant economic revenues that had positive impacts on the life of the society and individuals. With the modern state in the 1970s and the economic, social and political development, which focused on major urban cities, many of the rural population, in areas where palm trees are cultivated, immigrated into the cities for work, particularly in building and construction. Thus agriculture, including palm trees cultivation, was abandoned.

Furthermore, the Yemeni markets were opened to foreign agricultural products, including dates, which came from neighbouring countries such as Iraq. The high quality, good packing and cheap price of the imported dates provided stiff competition for home grown Yemeni products and this led to further neglect of date palms. Other crops, such as mango, oranges, lemon and other fruits, took precedent. This situation was made worse by the lack of attention paid to the agricultural sector by the government with regard to extension services and farmer support.

In recent years the Yemeni government has returned to a focus on the rural sector. The political leadership represented in the Ministry of Agriculture and Irrigation (MAI), AREA and the Northern Regions Development Authority (Sana'a, Sa'ada, Hajjah and A'amran) gave considerable attention to encouraging and developing the cultivation of palm trees by assisting farmers and motivating them to introduce new imported varieties from abroad and providing them with efficient cadres to demonstrate the cultivation process.

It improved the agricultural research and extension services and introduced new varieties that can be multiplied through tissue culture and through the use of seedlings that are well known internationally for their quality and productivity. It started in Hadhramout and Tihamah regions, in collaboration with FAO. Demonstration farms were set up. But the high cost of seedlings prevented many farmers from purchasing them and so the government had to layout short term and long term plans for development of palm trees plantation, bearing in mind the importance attached to this crop from a nutritional and economic view point. They developed a suitability map for the location of palm tree cultivation, and provided infrastructure, including varieties that could compete in the local and international markets. They provided irrigation and expanded research and extension activities, and trained cadres that would be capable of developing factories and plants to process dates for packing and wrapping.

12.2 Water resources

Yemen is an arid country with very limited water resources. It has no rivers or lakes and the economy depends mainly on agriculture – some 46% of the GDP and more than 76% of the population.

The annual renewable water resources are estimated at 2.1Bm^3. The population of Yemen is 24 million and so the per capita share of water is only 87.5m^3. This can be compared with the world average of 7,500m^3 per capita. The water used in 1994 was estimated to be 2.8Bm^3 which means that the country is overdrawing its water resources by 0.7Bm^3. This is taken mainly from underground supplies. In the Sana'a basin for example, 224Mm^3 was used when the recharge was only 42Mm^3 resulting in an estimated annual depletion of 182 Mm^3. Alternative supplies to Sana’a are under consideration but all cost more than US$1 per cubic meter. Desalination and conveyance from the sea for example will cost more than US$6.6/m^3.

Uncontrolled use of water has resulted in the drying up of many basins. More than 65,000 wells were drilled to try and overcome such shortages and the irrigated area from wells increased from 8% in the 1970s to 34% today.

The benefits of rainwater harvesting have been neglected. In the past Yemenis benefited from rainwater harvesting by constructing terraces, dams, barriers, pools, pits and breakers. Water was stored for agriculture and for domestic use. The average annual rainfall is estimated at 67 Bm^3 but most of this is lost in evaporation and runoff into wadis and to the sea. The urgent need is to develop agricultural projects to benefit from rainwater harvesting and improve surface irrigation efficiency, which represents more than 90% of the irrigated lands.

12.3 Date palm areas

Yemen comprises five main areas of agricultural production.

The Coastal Strip (Tehama) is considered the richest agricultural part of Yemen. It extends some 450km and is 35km wide. Annual rainfall varies between 150-300 mm/yr, most of which falls in August and September. Rainfed crops include sorghum, corn and maize covering an area of 158,797ha and forage covering an area of 41,306ha. Fruit, vegetables, legumes and cash crops are cultivated depending on the availability of groundwater and spate irrigation. The strip is considered to have considerable potential for further development of irrigated agriculture particularly using modern methods to improve the efficiency of water use.

Western Highlands has an estimated cultivated area of 350,000ha and has an annual rainfall between 450-750 mm. This falls intensively and so tends to run off into wadis and supports groundwater recharge. In some years the rapid runoff causes damage to lands, livestock and trees and most of the water flows into the sea. This area is in great need of rainwater harvesting technologies to conserve water.

Southern Highlands has an estimated potential cultivated area of 500,000ha but at present only 256,00ha are used. About 186,000ha depend on rainfall and the rest is irrigated from wells and springs. The rain is moderate in April and May and reaches its peak in August and September. Rainfall in this region varies considerably between 800–1500 mm/yr. Cereals represent one of the main crops in this region.

Central Highlands has a potential cultivated area of 400,000ha much of it depending on rainfed irrigation. Annual rainfall is between 250–450mm.

Eastern Plateau is a region distinguished by gentle slopes and ends at the Empty Quarter desert. Rainfall is limited within the range of 300mm in the west and 100mm in the east. It is less in the far east of the region. The potential for underground water development is moderate from the underlying sediments of the wadis and in the volcanic rock and the sand stones. Cereals, sesame, forage, vegetables and fruits are cultivated in the area. Palm trees are cultivated in this area – 409ha in Maáreb producing 851 tons, 329ha in Al-Jowf producing 684 tons, 536ha in Shabwa producing 1,115 tons, 5,363ha in Hadhramout producing 11,155 tons, and 956ha in Al-Mahara producing 1,988 tons.

The quantity of rain that falls on the mountainous regions that lack plant coverage allow floods to flow towards the wadis. Agricultural systems, including palm tree cultivation, depend on these wadi floods and primitive barriers are used to change the course of the water flow.

The general policy on water use is still very basic and falls well short of modern methods used in other countries. Water use efficiency could be improved using modern irrigation methods but their introduction is not an easy matter. It requires high technical experience in planning, design, installation, operation, maintenance, effective maintenance and investment costs. But the critical nature of the water resource means there is no option but begin to use these methods and gradually introduce them by offering incentives for farmers to use them.

12.4 Water resources

The topographical conditions of Yemen largely determine much of agricultural methods used. More than half the country is mountainous and agriculture is spread in the mountain chains and highlands in the form of terraces. Cultivation of such terraces depends mainly on manpower and animals for plugging.
Throughout its long history, Yemen has depended on rainwater for agriculture and farmers have harvested the rain and the floods it produces. Yemeni farmers used to maintain sand barriers and channels for the purpose of saving water. However, in the 1970s certain political, economic and social changes occurred that reduced the way in which farmers cooperated and contributed towards construction and maintenance of their own irrigation utilities. The government took over all these responsibilities as it aimed to radically expand irrigation by the construction of projects and infrastructures to achieve food security. The government encouraged drilling of wells by providing subsidies and providing material assistance, aid and loans to cover drilling of new wells. Massive investments were made in the construction of barriers and canals and the distribution of pumps and engines. All this had an impact on economic efficiency and water use efficiency but there was little consideration for the long term sustainability of water resources and agricultural productivity.
More modern agricultural practices are being introduced such as the use of new crop varieties, fertilizers, pesticides and irrigation. However, such development is still limited to a few people who have the potential to take advantage these new technologies. Modern irrigation technologies are being introduced but they are not well planned and so they can cause over abstraction of groundwater and saline intrusion into the aquifers.

* Table 54 Areas cropped according to irrigation water sources in 2004

Cultivable area (ha)	Cultivated area (ha)	Rainfed (ha)	Wells (ha)	Floods (ha)	Springs (ha)	Dams (ha)	Tank on cars (ha)	Others (ha)
4,152,437	1,188,888	637,416	407,869	89,363	33,924	4,215	12,517	3,584

12.4.1 Date production

Date palm cultivation is widely spread in the western part of Tihama, and particularly from A'abs region in the north to the Maza'a region in the south and in the south eastern part in Hadhramout, Al-Mahara, Shabwah, Al-Jowf and Ma'areb. Table 55 shows date production for the whole country in 2004. It is estimated that 12.8kg/palm tree are produced on modern farms using 8×8m tree spacing. Old farms based on 5×5m spacing only produced around 4kg/palm tree.

* Table 55 Date production in Yemen in 2004

Crop	Dates
Area (ha)	13,739
Production (tons)	28,576
Production (tons/ha)	2.1

12.5 Water requirements

Date palms in Yemen use 2000-2600mm of water annually.

* Table 56 Average evaporation rates and crop factors used for date palm irrigation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporation (mm/day)	5	5.4	6.6	7.6	7.8	8.2	8.2	7.2	6.9	6.0	5.7	5.3
Crops factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85

* Table 57 Typical irrigation requirements for dates in Al-Jarr Region (l/tree/day)

Age of tree (yrs)	1	2	3	4	5	6
Jan	24	47	142	236	300	350
Feb	25.5	51	153	255	324	378
Mar	31	62	187	312	396	362
Apr	36	72	215	359	456	532
May	37	74	227	368	468	546
Jun	39	77	232	387	492	574
Jul	39	77	232	387	492	574
Aug	34	68	204	340	432	504
Sep	32	64	195	326	414	483
Oct	28	56	170	283	360	420
Nov	27	54	161	269	342	399
Dec	25	51	150	250	318	371

12.6 Irrigation agronomy

The following irrigation practices are recommended for growing palm trees in Yemen.

Palm trees seedlings should be irrigated on a daily basis for a period of 45 days from the day of planting.
In the regions where temperatures are high irrigation should be conducted in the early morning or at night, particularly during the summer season.
After root formation the seedlings should be irrigated from 2 to 3 times a week according to the climate.

There are times when priority should be given to irrigation of palm trees:

- Prior to inoculation season to promote growth for an early inoculation process.
- Immediately after appearance of fruits, palm trees require a large quantity of water to assist in the growth of the fruits.
- At the bending process.
- After harvest to motivate formation of the new growth in the coming year.

There are times when irrigation should be reduced:

- When the water table is high.
- When the greatest part of the crop becomes ripe in order to preserve the quality of the fruits, since irrigation in this period delays the process of ripening.
- When temperature decreases in winter.

Recommendations for irrigation scheduling include:

Period	Irrigation frequency
For years 1 to 3	
January, February and December	6 days
March, September, October & November	4 days
April, May, June, July and August	3 days
For mature trees	
January, February and December	10 days
March, September, October and November	8 days
April, May, June, July and August	6 days

12.7 Irrigation methods

Traditional flood irrigation methods dominate irrigation farming in Yemen and these are most commonly used for palm tree irrigation. However, there is a move to increase the area under modern systems in order to improve water use efficiency.

Basin irrigation is common and widely used for irrigating all fruit trees and mainly palm trees, whereby the land that is to be irrigated is divided to leveled basins surrounded by fences of sand and abutment on the four sides. Water is directed through an opening in the basin. When the basin is full, excess water is discharged through an opening into the adjacent basin. The area and dimensions of the basin are specified according to the type of soil, experience of the farmer and the shape of the farm. Water penetration is an important factor, whereby soils of high penetration are divided into small basins and soils of low penetration are divided into larger basins. The basins are constituted with less than 2% slope.

In the last twenty years, the use of plastic pipes started through the Land and Water Conservation Project, which was funded by the World Bank. Plastic pipes were distributed to the farmers at cost price and consequently the efficiency was upgraded from 20% to 60%. The open sand canals, that were subject to decantation from the bottom and sides and evaporation of the open water surface were substituted with plastic pipes. However dissemination of this method was very limited as many farmers were unable to purchase the plastic pipes.

Modern systems such as drip and bubbler systems are being increasingingly used in Al-Jarr region, north of Tihama and in Wadi Surdoud, Wadi Siham, Wadi Rima'a, Wadi Zabid, and in Wadi Hadhramout, but its use is limited to large investment farms. In 1999 the Tihama Development Authority conducted a study in Wadi Al-Jarr region, in which it described the numerous irrigation systems that depend on groundwater (Table 58). The region depends completely on the underground water as a main source for irrigation.

* Table 418 Irrigation systems used for date palms in Wadi Al-Jarr region

System	Usage
Dripping (Bubblers)	52%
Flood Irrigation	27%
Drip + flood Irrigation	3%
Lands under Reform	18%

Sprinkling/bubblers irrigation system installed on large farms to cultivate palm trees in both Tihama and Hadhramout are designed properly and were meant to result in reduced water losses. However, the absence of an adequate technical cadre to handle such systems has meant that water use has been excessive.

Annex I – Regional Project Profile

<u>Title</u>: Sustaining water resources and date palm production systems in the Near-East

1. Priority Issues of Date Palm Irrigation in the Near East Region

   - The sustainability of production of date palm and associated crops is at stake.
   - Farmers income from date palm production is generally low and not cost-effective.
   - The prevailing practices of date palm irrigation do not safeguard the environment.
   - There is a lack of information/technology exchange and dissemination regarding date palm irrigation.
   - The capacity of farmers and technicians to manage date palm irrigation is low.

2. Goal and Objectives of the Regional Project

   2.1. Goal/ Development Objective

The overall development goal of the project is to improve the knowledge base on date palm irrigation as well as technical and managerial capacities to increase water productivity for date palm irrigation with a view of sustaining the crop and water resources in participating countries.

   2.2. Long-term Objectives
   - Optimizing water use for the production of date palm and associated crops
   - Improving water-related cultural practices of date palm and associated crops
   - Assessing crop productivity of date palms under non-conventional water resources
   - Assessing the performance of newly developed varieties for drought and salinity tolerance.
   - Sustaining water resources in the areas where date palms are grown
   - Enhancing and improving livelihoods among date palm growers

   2.3. Immediate Objectives
   - Improving water use efficiency and date palm productivity
   - Developing and implementing a training program to date palm growers and irrigation advisory service providers
   - Elaborating a manual on date palm irrigation.

3. Outputs of the Regional Project

   3.1 Savings of irrigation water and yield improvement for date palm and associated crops are achieved

   Activities:
   - Compile information on suitable irrigation methods
   - Develop irrigation scheduling methods and test them in the field
   - Compile information on best cultural practices for date palm production
   - Conduct country assessments of date palm irrigation with marginal waters
   - Assess the performance of date palm genotypes that are resistant to water-deficit.

   3.2 A training program on the irrigation of date palms and associated crops is developed and implemented and the capacity of pilot farmers and Irrigation advisory Services extension agents is improved

   Activities:
   - Elaborate a training program based on the results obtained under Section 3.1 above and international experience
   - Conduct training of trainers at regional level
   - Implement awareness campaign at national level
   - Conduct training of farmers at national level (farmers field schools)

- Implement study tours and field visits

3.3 Guidelines on irrigation of date palms are developed and practitioners from participating countries are trained on its dissemination and use

Activities:

- Develop draft guidelines
- Hold national and regional workshops to discuss the guidelines
- Test the guidelines in the field
- Finalize the guidelines
- Conduct training of trainers on dissemination and use.

4. National Institutions Concerned

- Ministries (agriculture, water, irrigation, environment…)
- Universities and research institutions
- Environmental authorities and municipalities
- NGO's
- Farmers, consultants and associations

5. Inputs Needed

- Equipment
- Financial support
- Training: engineers, extension agents and farmers
- Human resources and areas of expertise: legal specialist, irrigation and drainage, soil and water, agronomy (plant protection and production), water-policy specialist and socio-economist
- Project management: project manager, steering committee, technical committee and FAO as implementing agency.

6. Risks and Assumptions

- Very low risk
- Commitment of involved institutions

7. Cost of the project: US$ 7 million

8. Project Duration: 5 Years

Annex II - Opening speech

Message from Dr. Mohamad Albraithen, FAO Assistant Director General and Regional Representative for the Near East:

Dr. Mohamed Bazza, Senior Irrigation and Water Resources Officer, FAO Regional Office for the Near East, delivered the following message on behalf of FAO Assistant Director General and Regional Representative for the Near East:

Your Excellency The President of Damascus University

Representatives of Sister Regional and International Organizations

Country Representatives and Participants

Experts and Colleagues;

I would like first to express to you the best greetings and highest consideration, on behalf of Dr. Mohamed Albraithen, Assistant Director-General and Regional Representative for the Food and Agriculture Organization of the United Nations, Regional Office for the Near East, along with my best personal wishes for a successful meeting.

It also gives me great honor and pleasure to welcome you all on this very Special Day in the Arab Republic of Syria and to address our thanks and appreciation to the kind Government of the Arab Republic of Syria, represented by H.E. The President of Damascus University, for partnering with FAO and hosting this important event, as well as for the warmth with which we were received and the efforts made by the Preparatory Committee, headed by the Dean of the Faculty of Agriculture and professionally managed by the Head of the Rural Engineering Department.

We all are happy today to hold this Workshop on the Irrigation of Date Palms and Associated Crops, the organization of which was possible thanks to the close collaboration between the Rural Engineering Department of Damascus University and the Food and Agriculture Organization of the United Nations Regional Office for the Near East, on one hand and to the interest and contributions of all of you International and Regional Organizations, Country Representatives, Researchers and Experts, on the other.

Ladies and Gentlemen,

The preparation and holding of this workshop came in response to several appeals by FAO Member Countries of the Near East Region and as a result of FAO’s experience and convictions that the irrigation of date palm is lagging behind in terms of technological and managerial developments that other crops have benefited from over the past 2-3 decades. In preparation for this event, FAO supported and commissioned a study in a number of pilot countries of the Neat Region, aimed at making a thorough assessment of date palm irrigation and identifying the issues facing its advancement.

The workshop provides an opportunity for taking stock of this assessment, sharing experience between countries, discussing priorities and technological innovations and making recommendations for follow-up activities and cooperation with a view of assisting Member Countries to address the common issues identified.

Ladies and Gentlemen,

Date palm has been deeply rooted in the Near East Region’s economy, history and culture since ancestral times. It is the oldest tree known and cultivated by man and well adapted to the dry and semi-dry regions of the world.

Date palm offers a good source of food of high nutritional value. Especially for countries with harsh climatic conditions and remote arid areas, it provides the people with the main source of food as well as working opportunities for the laborers in the rural areas.

The date palm tree tolerates 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 an important role in stopping desertification and giving life to desert areas. Its fruit generates good income for the farmers and foreign exchange earnings for the countries.

Presently, about 80% of the total area planted by date palms in the world (1 million ha) is found in the Near East region. World production of date palm reaches some 6.7 million tons with the Near East contributing more than 90% of this total production. However, yields and quality in the region are characterized by extreme variability from country to country, from year to year and from variety to variety. They oscillate between 18 and 120 kg/palm in comparison with yields as high a 250 kg/tree recorded in California and Arizona.

While date palm tolerates the arid climates prevailing in the most of the Near East countries, the fact remains that date palm is a major water consumer when compared to other fruit trees. Reported figures on its water use range from less that 12,000 to more than 35,000 m^3/ha/year for many countries in the region.

As we all know, water scarcity is the main characteristic in most of the Near East countries where date palm is grown. But the paradox is that, with the exception of a minor, negligible fraction, the area under date palms continues to be irrigated today as it was several centuries ago. Date palms have not benefited from the important advances irrigation technology has known over the past century.

The region is characterized by a lack of practical guidance and advice related to date palm irrigation management. Water requirements are not well known and even in the case where they are, the amounts of water actually applied are often very large. The fact that irrigation management is not well optimized affects both the quantity and quality of the dates produced and results in the wastage of important amounts of water.

Research on Date palm has received ample attention over the past 2-3 decades and has made important advances, especially with regard to genetic engineering; however, research on irrigation has received only limited attention and where it took place the link between research, extension and development has been lacking and, consequently, the results have not been implemented by farmers and practitioner. Hence the justification for focusing this workshop solely on the aspect of irrigation water management.

Ladies and Gentlemen,

I am sure you agree with me that the strength of this workshop hinges primarily on all of us here today, for creating the necessary awareness and momentum as well as providing guidance on future policies and actions to the address the issues you have identified in the studies that some of you have conducted in your respective countries. And I take this opportunity to thank you specifically for your efforts and time to collect a wealth of information that we will be sharing and discussing during these four days.

I hope that your esteemed meeting will reach practical and specific recommendations, with clear orientations and objectives, for addressing the common problems and for the maximum benefit of all.

Finally, I would like to express to all of you once again, my thanks and appreciation for your attendance and participation. Thanks are also due, to all the organizing parties, for the facilities and services they provided, in order to make this meeting run smoothly. Specifically I would mention the Ministry of Agriculture for the excellent collaboration with Damascus University, and the Management and staff of the Faculty of Agriculture who worked behind the scene for making this event pleasant.

I wish you a fruitful and successful meeting.

Thank you.

Annex III –Workshop Agenda

Saturday, 26 May
Arrival to Damascus, installation in hotel and pre-registration
Sunday, 27 May
08:00 - 09:00 Registration 09:00 - 09:30 Courtesy welcome by the Head of Damascus University 09:30 - 10:00 Official Opening Ceremony Presentation of Workshop Scope and Arrangements 10:00 - 10:30 Break 10:30 - 11:00 Keynote Paper: Irrigation of Date Palm and Associated Crops – A Synthesis Report of National Studies M. Bazza and M. Kay, FAO 11:00 - 11:20 Date Palm Water Productivity: Index for Irrigation Performance. T. Oweis, ICARDA 11:20 - 11:40 Evaluating Evapotranspiration in Palmyra Oasis I. Jnad*, J-P. Brunel and A. Droubi, ACSAD 11:40 - 12:30 Discussion 12:30 - 13:00 Country Paper Algeria B. Merabet and D. Souissi 13:00 - 13:30 Country Paper Egypt A. El-Bana 13:30 - 14:00 Country Paper Iran (Islamic Republic of Iran) M. Keykha 14:00 - 15:00 Discussion
Monday, 28 May
08:30 - 09:00 Country Paper Libya M. Benismail 09:00 - 09:30 Country Paper Oman S. Zekri 09:30 - 10:00 Country Paper Morocco H. Keddal 10:00 - 10:30 Country Paper Saudi Arabia H. Al-Ghobary and A. Alomran 10:30 - 11:30 Discussion 11:30 – 12:00 Break 12:00 - 12:30 Country Paper Tunisia F. Lebdi 12:30 - 13:00 Country Paper United Arab Emirates A. Abdulsattar and M. Al Alawi 13:00 - 14:00 Discussion 14:00 - 15:00 Recommendations for follow-up
Tuesday, 29 May
08:00 - 15:00 Discussion of a draft Regional Project
Wednesday, 30 May
07:00 - 10:30 Travel to Palmyra 10:30 - 15:30 Field Visit in Palmyra 15:30 - 19:00 Return to Damascus
Thursday, 31 May
Return home

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