ICARDA

Science for resilient livelihoods in dry areas

Development of sustainable date palm production systems in the GCC

Public-private-producer partnerships for a vibrant date palm industry and market

Ministry of Works, Municipalities Affairs and Urban Planning

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Ministry of Agriculture, Fisheries and Water Resource

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Executive summary

The Sustainable Development of Date Palm (DP) Production Systems in the GCC Countries project focuses on producing knowledge and practices to improve date palm production. Beginning in 2006, the project started its 3rd phase in 2018 and successfully built upon the achievements and improved technologies developed in partner countries over the past 15 years. The project is focused on preservation and utilization of effective dryland resources to generate water saving cropping techniques, integrated pest management and mechanization to bring about cost-effectiveness in the DP production, industry and marketing systems.

Through the project the national project partners explored, tested and documented diverse technologies and systems truly revolutionizing for water productivity, DP pollination and quality date production in the region and beyond. These included: new subsurface irrigation systems, soil fertility enhancement using mycorrhiza, liquid pollination, bunch ventilation techniques, polycarbonate drying chambers, biotech guided biodiversity conservation, Trichogramma production and use in biological control, and mass inventory of DP pests and natural enemies. Each of these technologies has standalone impact when applied individually and cumulative impacts as a package. Development of relevant and revolutionizing technologies under extreme water scarcity, poor soil and climate change triggered abiotic and biotic stresses is important and is a part of what makes this project special. What makes this project unique is its innovative cross-institutional and national boundary R&D integration, the inbuilt national partner ownership fostering effective agriculture innovation, cross learning and instant up-and-out scaling of technologies. The public-private-producer-partnership (PPPP) model adopted proved to be a solid foundation to develop a vibrant date palm industry and market in the region. The development and popularization of date drying chambers in Oman and UAE is an excellent example of PPPP. The national and international R4D institutions, manufacturing companies, and producers actively participated in the designing, testing, demonstration, documentation of the project, ensuring policymaker buy-in and producer adoption (with and without government subsidy).

This project successfully promoted technology for subsurface irrigation reducing water use by 40% in Oman, 37% in Saudi Arabia and 35% in Qatar. The Al-Foah Organic Farming Company in UAE adopted subsurface irrigation for 7000 date palms, with 41% water saving. The use of fertigation by hydraulic injectors in UAE showed 42% and 75% of fruit weight increase in Medjhool and Sukary cultivars, respectively. The benefits of integrated pest management with Abamectin, Sulphur and Matrine biopesticides on Dust Mite and Lesser Date Moth as well as use of *Trichogramma* with a capacity to feed on over 200 insects, have also been demonstrated. Sixty DP cultivars in the GCC countries have been fingerprinted, 947 technical staff and farmers benefited from capacity building programs and 119 publications produced.

Building on these successes, Phase 3 (2020-2022) focuses on: (i) consolidating and scaling the proven technologies within and beyond the region; (ii) advancing research on soil fertility through composting and recycling of DP waste; and (iii) advancing digital augmentation of advisory services for a sustainable and resilient DP industry in the region.

The calculated ROI ranges from 5.03 to 15.38 times initial investment.

Introduction

Date palm (DP) has been deeply rooted in the Arabian Peninsula (AP) region's economy, history and culture since antiquity. In 2018, the AP region produced 2.8 million tonnes of dates on 353 thousand hectares, representing over 33% of the global production area of DP.

Research on DP was ranked as a priority by the GCC countries during a study conducted by ICARDA (International Center for Agricultural Research in the Dry Areas) to set up Agricultural Research Priorities for the Central and West Asia and North Africa Region (CWANA). In March 2003, as a follow-up ICARDA organized the "Regional Workshop on Date Palm Development in the Arabian Peninsula". This was a response to a request from representatives of the six GCC countries (Bahrain, Emirates, Kuwait, Oman, Qatar and Saudi Arabia), as well as international date palm scientists, to provide a forum for discussion on the status and gaps of date palm R&D in the AP countries, and to develop a research program to address these gaps. The meeting called for an integrated regional research program to address problems associated with date palm production systems and to establish closer collaboration among the participating countries.

ICARDA in collaboration with the NARS (National Agriculture Research Systems) of the AP countries designed a joint proposal, and in 2006 started implementing a project with the overall goal to develop date palm production systems in the GCC countries, utilizing available modern technology. The project comprises three key interrelated components: problem-solving research; technology transfer; and capacity building. Funded by GCC countries, the project has taken a regional approach with the major objective to improve date palm production in terms of quantity and quality, and has been implemented in three phases: Phase 1 (2006-2011), Phase 2 (2012-2018), and Phase 3 (2020-2022).

The regional approach and coordination among the different project countries helps avoid duplication of effort while optimizing the utilization of allocated resources. Moreover, the formation of a specialized team from all GCC countries, directly from project inception allows for active and ongoing information exchange between the NARS in the six GCC countries.

This report presents the key achievements under the three components highlighted above during each Phase of implementation, and presents ongoing activities and an outlook to the future of date palm production in the Arabian Peninsula.

1. Phase 1: 2006-2011

Introduction

The objective of the Phase 1 of the project was to generate adaptive research outputs to improve date palm productivity in terms of quantity, quality, nutrition and food security and income generation. In the area of yield increase, the impact of irrigation using tertiary sewage water, liquid pollination, selection of male pollinator on yield have been investigated and results documented and promoted. Up to 40% yield increase has been achieved through bubbler irrigation using sewage water. For quality improvement, the focus was on improving ventilation to reduce disease incidence, improve fruit size and minimize skin separation. It was demonstrated that up to 50% increase in fruit size and 30% of reduction in skin separation were achievable through application of proper bunch ventilation procedures developed by the project. Use of improved extraction and drying methods increased yield and germination of pollen grains of date palm by 20% and 12%, respectively with increased longevity.

Through a faunal survey for the date palm insect pests and natural enemies in the GCC countries, 305 species have been collected and identified. The effectiveness of two biopesticides on dust mite infestation, namely Baicao No.1 and 0.36% Matrine has been demonstrated in UAE.

In the area of post-harvest handling, the development of cost-effective date drying systems using locally developed technologies has been supported and promoted. One of such systems has been developed and widely distributed on a 50% subsidized price in UAE and Oman.

Facilities for genomic analyses and DNA extraction were established in all countries. In collaboration with Cornell University, ICARDA developed a set of 1000 SSR markers for date palm diversity studies. Out of the abovementioned SSR markers, 30 were tested for their efficiency on local date palm cultivars and found to be polymorphic as well as co-dominant, which can be used for genetic diversity analysis of date palm

All the outputs from the applied research have been documented and shared with the target communities and individuals through joint implementation, training and workshop sessions. A bulletin on harvesting and post-harvest handling of dates was prepared in Arabic and English and distributed. A total of 10 training courses benefiting, 153 trainees have been organized. A total of 35 publications of which 5 were in English, 28 in Arabic including 5 poster presentations and two Videos on various subject of Date Palm R&D were prepared and distributed.

1.1 Applied research

During the period between 2006 and 2011 the project conducted 45 applied research activities as presented in the following table. The summary of the achievements of these activities are developed below.

Table 1. Summary of applied research activities during phase one (2006-2011)

Research Area	Bahrain	KSA	Kuwait	Qatar	UAE	Oman	Total
Crop management	2	2	6	2	2	7	21
Integrated pest management	1	3	1	0	1	2	8
Post-harvest techniques	0	1	1	1	3	1	7
Biodiversity conservation	1	1	1	3	1	2	9
Sub Total	4	7	9	6	7	12	45

1.1.1 Crop management

A total of 21 research activities were carried out under the project in the area of date palm crop management in the six GCC countries. The most important results are as listed below:

1. Through an experiment carried out in the Kingdom of Bahrain on *Khinaizi* cultivar we showed that fruit thinning and irrigation with tertiary sewage water through bubblers gave 40% more yield with better fruit quality compared to ordinary water. No increase in levels of heavy metals in soil and plants was observed.
2. The effect of irrigation reduction on skin separation on *Khalas* dates was studied in Saudi Arabia. The trials were carried out for two seasons during 2008-09 and 2009-10 wherein 100, 50, 33 and 25% of water requirements were applied to study the effect of water stress on fruit skin separation in the cultivar *Khalas*. Results showed no significant effect on skin separation, physical properties, or chemical properties.

3. The effect of ventilation on date quality through thinning to one bunch with eight leaves, cutting 20% of the internal strands use of rings inside the bunch at 15 – 20 days after liquid pollination with 0.5 g/l concentration on *khalas* cultivar was carried on in Qatar. The results showed significant increase in fruit size by 50% and reduction in skin separation by 30% compared to conventional treatments. The technology was adopted by several growers at the end of Phase 1.
4. The effects of extraction and drying methods on yield, germination and longevity of pollen grains of date palm were studied in UAE in the 2008-09 Season. The results showed that thermal chamber drying yielded 1.4 to 1.5 kg of pollen grain from 100 spadices compared to 1.2kg from the traditional sun drying methods. For germination, the percentage was 92 to 97% compared to 85% for conventional drying. Drying in the heat room was completed in 84 to 94 hours compared to the conventional methods which require 130 hours to achieve the same results. In addition, the study results showed that microwave pollen grain drying for 10 and 20 second maintained 81% pollen viability and germination after one year of storage under ambient conditions. These results are transferred and adopted by growers across all the GCC countries.

1.1.2 Integrated pest management

Integrated pest management research focused on major pests of date palms with their natural enemies and suitable control methods. The focus was on Lesser Date Moth (LDM), Dust Mites and Borers. Pest control methods found effective in research stations were further tested in the growers' fields with full involvement of NARS in GCC countries. Through a survey, few natural LDM enemies and predators have been investigated. The key information generated is as below:

1. A survey carried out to identify insect pests and diseases of date palm in Bahrain, Kuwait and KSA resulted in identification of more than 305 pest species representing 22 genera.
2. Under the project, several insecticides have been tested against Lesser Date Moth (LDM) and found effective in reducing fruit infestation. These are Trebon® 20% EC (0.8 ml/L), Prempt 20EC (1.0 ml/L), Sumi-Alpha® 5% EC (1.0 ml/L), Vertimec 1.8% EC (0.3 ml/L), Coragen 20% SC (2.5 ml/L), and Kingbo® 0.6%SL. Out of 6 insecticides tested, Trebon®20%EC and Kingbo® 0.6%SL reduced fruit infestation with LDM by 40%.
3. Seventeen natural enemies/predators of Lesser Date Moth (LDM) from five orders were identified through the above-mentioned survey. Out of the species identified, four Parasitoid (Goniozussp, Bracon, Apanteles, Eulophid) and three Predators (*anthocorid, staphylinid, Chrysoperla carnea*) were from the sultanate of Oman.
4. An experiment in the Kingdom of Bahrain, showed that the Bio-pesticide Spinosad was more effective than *Bacillus thuringiensis* (Bt) on controlling LDM pest.
5. In UAE, two bio-pesticides (Baicao No.1 and Matrine 0.36%) were found effective against Borers and Mites in Palm plantations with potential for large scale application in the other GCC countries. The two Bio - pesticides provided a good level of control against Dust Mites.
6. The conventional insecticide “Nirone” was also found effective against LDM in the Sultanate of Oman.

1.1.3 Post-harvest techniques

Key activities focused on identifying suitable methods for date drying, packaging and storage. The techniques found effective were further tested in the growers' field with the full involvement of the NARS partners in the GCC countries involved. The following key results were generated in the thematic area of postharvest handling and processing techniques:

1. In Qatar, using locally made plastic tunnels with shelves and ventilation systems was cheaper and more efficient than the conventional method known as Mustah. The new system shortened the drying period from 14-18 days in the sun to only 5 days. Due to the short drying period, fruit infestation, deterioration and skin separation were reduced by 30%.
2. Comparison of date drying using solar energy operated glasshouses, plastic and the thermal chamber, conducted in UAE, showed that small glasshouses with a capacity of 18 tons per season proved effective in reducing drying period to only 4 to 5 days protecting the fruits from infestation and deterioration. The Ministry of Environment and Water (now known UAE Ministry of Climate Change and Environment) subsidized 50% of the total cost for the establishment of 78 units throughout the countries in 2009 and 20 units in 2010.
3. The Polycarbonate Chamber (PCC) for date drying was superior to the conventional systems in terms of reduction of fruit drying period and cost in addition to quality improvement. The required time to complete date drying and maturation was reduced by half from 8 to 4 days with moisture equivalent to 20% with a total soluble solid (TSS) of 86%. Overall values of pH were well within the acceptable range thus improving fruit quality through reduction of disease incidences, damage and dust. Based on the above results, Kuwait decided to join Qatar, UAE and Oman in the adoption and dissemination of this technique.
4. In Saudi Arabia, a study was carried out to identify new and more suitable packaging containers for dates. The results showed that 90% of producers are committed to using easy to open packaging. Consumer preference for packaged dates is as high as 90% but drops 65% for vacuum bags and 70% for the transparent ones. Consumers do not want metal containers and polystyrene dishes.

1.1.4 Biodiversity characterization and conservation

1. Facilities for genomic analyses and DNA extraction were established in all countries. In Kuwait, Bahrain and UAE fingerprinting date palm cultivars were undertaken to determine their genetic diversity level.
2. A set of 12 samples of tissue culture derived plants of *Khalas* and *Dhahra* cultivars along with their female parent, were analyzed with 20 (SSR) markers to identify the polymorphism among the test samples, and no polymorphism was detected.
3. In collaboration with Cornell University, ICARDA developed a set of 1000 simple sequence repeats (SSR) markers. Thirty markers were tested for their efficiency to amplify local date palm cultivars and found to be polymorphic as well as co-dominant, which can be used for the genetic diversity analysis of date palm
4. Genetic diversity of 12 local cultivars was investigated by using 14 loci of microsatellite (SSR) primers. The results revealed a high degree of genetic diversity among the Qatari date palm collection. Based on 11 microsatellite loci, 22 genotype markers were detected from 254 genotypes to identify the male date palm. Thirty microsatellite markers were tested to assess the genetic diversity of eleven date palm genotypes.

1.2 Technology transfer

1. A strategy for Red Palm Weevil control was formulated by an international Panel, including the date palm coordinator of this project and scientists from the GCC countries at Elche Spain in 2007 and sent to the NARS of the countries involved for implementation. The strategy covered the issues of

monitoring the pest population dynamics and targeted control using integrated pest management techniques.

2. Transfer of most recent knowledge and practices on post-harvest handling and processing techniques of dates used in the USA**.** Following a workshop on date post-harvest handling and processing held in Dubai in December 2007, it was concluded that 90% of date post-harvest problems can be overcome by the utilization of existing technologies. The Arabic and English versions of a bulletin containing the latest developments and accumulated knowledge was elaborated in collaboration with the University of California-Davis, published by ICARDA and distributed among the six countries. Other pertinent publications in this field were also purchased from University of California-Davis and distributed among the involved NARS.
3. New technology on date drying in small glasshouses has been tested in cooperation with the researchers of the Ministry of Environment and Water and found effective was thus transferred to growers in the UAE. Technology reduced the period of fruit drying and improved fruit quality at Tamar stage by reducing skin separation.

1.3 Capacity building

Ten training courses benefiting 153 trainees were organized according to the approved project annual work plan. These events were evenly distributed throughout the countries in the GCC region. An overview of these training courses and their main objectives are mentioned in Table2. The theme and programs of these courses were tailored to the needs of the NARS.

Table 2. Number of training programs organized during Phase One (2006-2011)

No	Name of the Training course	Date	Venue	# Trainees
1	Plant Tissue Culture and Its Applications	2011	Kuwait	6
2	Biometrics and Statistical data Analysis	2011	UAE	19
3	DNA Marker Applications for Genetic Diversity Analysis	2011	Qatar	18
4	Training course in biotechnology	2010	Oman	20
5	Specialized short course on date palm for Afghans	2009	Oman	10
6	Advanced biotechnology course with statistical analysis	2009	Oman	17
7	Date Palm Integrated Pest Management	2009	Bahrain	14
8	Date post-harvest handling and Processing	2007	UAE	14
9	Date palm in-vitro culture: Applications and Prospects	2007	Oman	17
10	DNA Marker Technology for Crop Improvement	2006	Oman	18
	Total			153

Figure 1. Light traps to assess prevalence of the insect and number of its generations

Figure 2. Test of chemical fertilizers

Figure 3. DNA separation using gel electrophoresis

Figure 4. Thermal chamber for drying pollen grains (left) and glass chamber for drying date (right)

1.4 Publications

The total number of publications generated in the first phase was 35 including 23 in Arabic, 5 in English, and 5 posters.

Copies accessible here: https://drive.google.com/drive/folders/1_DHz4pXphMvcdvfY6_302DKIQ51Cezi1

2. Phase 2: 2012-2018

Introduction

Upon request of project partners, The project was extended to Phase 2 with the aim of consolidating and scaling out the outputs and enhancing the outcomes. Phase 2 of the project allowed further expansion of research activities, as well as out scaling of technologies to growers in GCC countries. The project objectives for Phase 1 were largely maintained in Phase 2 but transformed to focus more on scaling out and more on-station and on-farm reconfirmation trials. The activities that proved effective, such as subsurface irrigation, bunch thinning, liquid pollination, and use of rings to improve ventilation, were transferred to growers and follow-up actions taken. The best extraction, drying and storage methods giving the highest pollen yield, viability and germination percentage obtained in Phase 1 were also transferred to the NARS across the GCC countries. The activities that proved less effective such as the use of Ethrel to accelerate ripening were suspended. Some of the research activities such as fertigation continued to reconfirm the preliminary results generated during the first phase. The number of applied research activities carried out increased from 45 in Phase 1 to 73 in Phase 2, the number of researchers, extension agents and growers trained jumped from 153 to 794, and the number of publications increased from 35 to more than 160. The main project activities and achievements in this phase are summarized in the highlights below.

2.1 Applied Research

During Phase 2 the project conducted a total of 73 applied research activities (Table 3). The activities covered propagation and crop management (16), crop protection and integrated pest management (21), Post-harvest handling and processing (13), biodiversity monitoring and conservation (13) and Socioeconomics (10).

Table 3. Applied research activities in the second phase

Research Area	Bahrain	KSA	Kuwait	Qatar	UAE	Oman	Total
Crop management	2	3	4	4	5	4	16
Integrated pest management	3	5	3	1	2	7	21
Post-harvest techniques	1	2	3	2	2	3	13
Biodiversity conservation	2	3	2	1	3	3	13
Socioeconomics	0	2	1	0	3	4	10
Sub Total	3	7	7	3	4	5	73

2.1.1 Crop management

Development of liquid pollination techniques

The initial research experiments on liquid pollination were launched from the first phase of the project and have reached a determination of the conditions for preparing the aqueous suspension and the percentage of the pollen grains per liter of water. The experiments conducted on the amount of pollen showed that a concentration level of 0.5 to 1 gram of pollen per liter of water is enough to achieve a good rate of fruit setting comparable to that of the traditional (hand) pollination. Liquid pollination improves efficiency, reduces cost by about 80% and gives a fruit set rate which is at the level of the traditional by hand pollination method (Figure 5).

Figure 5. Liquid pollination process (drying pollen grains, mixing and spraying)

Water management

The subsurface irrigation method showed high potential in water saving and productivity during the first phase. Therefore, it was maintained, consolidated and promoted during the second phase. Structured experiments on subsurface irrigation have been conducted in the Sultanate of Oman, the Kingdom of Saudi Arabia, and the State of Qatar during the second phase (Figure 6)

Figure 6. Preparing the subsurface water distribution system at a depth of 50cm

Sultanate of Oman

A trial on efficient irrigation methods on the *Khalas* cultivar was conducted in Al-Kamil Research Station in Al-Sharqiyah North governorate, during the 2013-2016 growing seasons with different levels of water requirement measured using evapotranspiration coefficients (ETc) with four treatments as listed below:

- Irrigation with 100% of ETc using bubbler system (67.8 m^3 /year)
- Irrigation with 60% of ETc using Subsurface drip system
- Irrigation with 40% of ETc using Subsurface drip system
- Irrigation with 20% of ETc using Subsurface drip system

The results showed that there is no significant difference in fruit production between date palm trees irrigated at 100% of the water requirements using the bubbler system and those irrigated with 60% of the water requirements using subsurface drip irrigation system (Figure 7). The average fruit production reached 79.0 kg per tree in the bubbler system and 78.3 kg per tree in the Subsurface drip system. The results proved that a sub-surface drip irrigation system contributes to 40% water saving without reduction in fruit production of date palm trees.

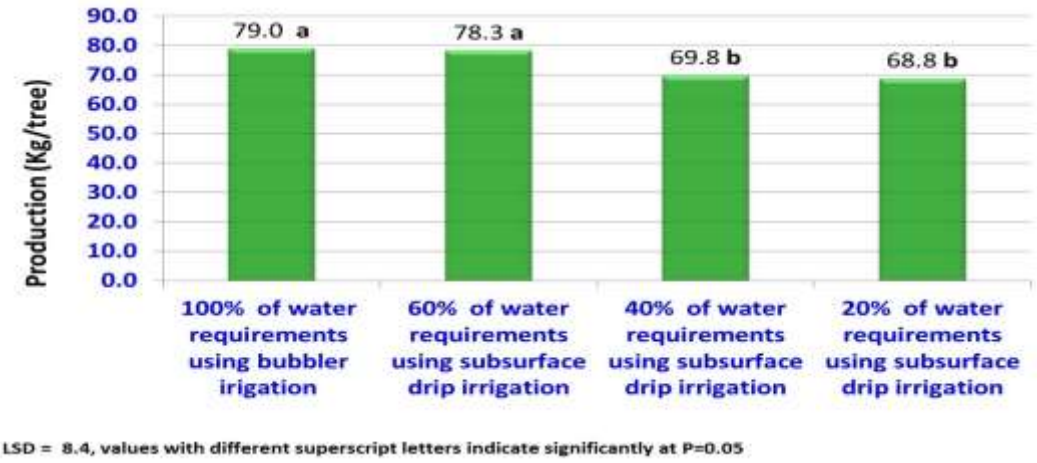

Figure 7. Water productivity and use efficiency in the Sultanate of Oman

Kingdom of Saudi Arabia

The net profit for subsurface irrigation from a trial carried out in the Kingdom of Saudi Arabia was USD 9021ha^{-1} compared to 11573 Ha^{-1} for subsurface drip irrigation (Table 4).

Table 4. Comparison of net profit from 100% surface and 60-70% subsurface drip irrigation in KSA

Parameters	Surface (100% ETc)	Subsurface (70% ETc)
Total return ha^{-1}	18,450	19200
Variable costs	5,400	5400
Water costs	3,968	2,227
Net profit	9,082	11573

Comparison of surface drip irrigation (DI) and subsurface drip irrigation (SDI) Systems in the KSA using the *Khalas* Al-Hassa cultivar was conducted in Al-Hassa Region with two treatments:

- Irrigation with surface drip system (DI)

- Irrigation with subsurface drip (SDI)

The decreased water supply from 100% of crop evapotranspiration via SDI to 70% of it did not show any significant decrease in yield, fruit weight, fruit length and fruit diameter (figure 8). The importance of SDI in this trial is on water productivity increase established at 27%. The net profit was higher with SDI (Table 4).

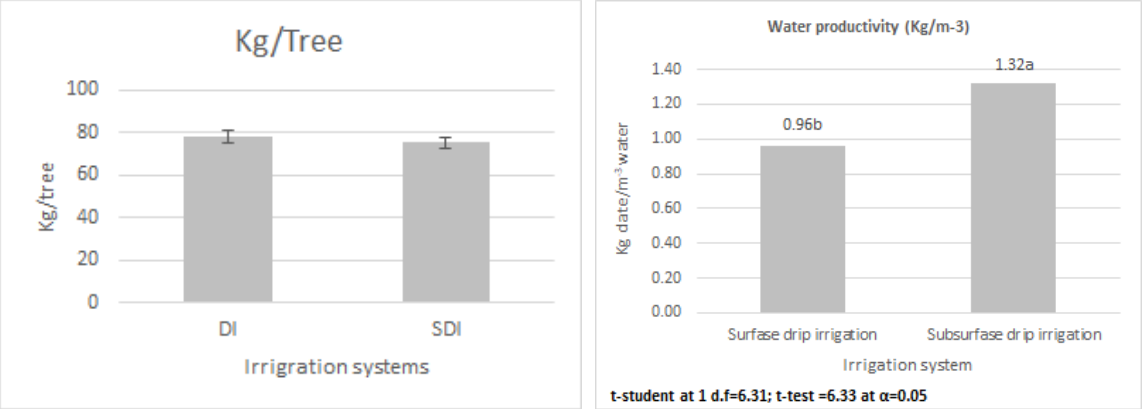

Figure 8. Water productivity (Kg of fruit/tree) and use efficiency Kg/m-3 under DI and SDI systems

Source: date palm project team in KSA (2017).

State of Qatar

The study investigated the effectiveness and performance of the subsurface drip irrigation (SDI) and Eco-tube (or smart hose) irrigation systems in comparison to bubbler irrigation system (BIS), in terms of water use, vegetative growth and soil moisture on *Khadhrawi* cultivar in Raoudhat Al Faras research station, Qatar. The results from the analysis of water use efficiency under the two irrigation systems showed a water consumption rate of 56.6 m^3/ha/year for the bubbler (BI) and 31.2 m^3/ha/year by subsurface drip irrigation method (SDI). This shows a rate of 55.1% water saving which is equivalent to 3962.4m^3/ha.

In conclusion, subsurface drip irrigation technology has enabled a significant reduction of water needs by 40 percent in the Sultanate of Oman, 55% in the State of Qatar and 37% in the Kingdom of Saudi Arabia without affecting the growth and productivity of date palms. The organic farm of the Date Marketing Company (Al-Foah) in the United Arab Emirates currently uses subsurface irrigation technology on 7000 palm trees, which can save 41% of irrigation water.

Fertigation

The effect of using fertigation by hydraulic injectors on the productivity of four date palm cultivars in the United Arab Emirates was studied compared to the traditional manual spreading of compost (Figures 9 and 10). The results showed the superiority of using modern technology at the level of all growth and production indicators, as well as a difference in the response of target date palm cultivars to fertilization, as the highest rate of fruit weight was obtained in the *Medjool* and *Sukary*, which increased by about 42 percent and 75 percent, respectively.

Using fertigation technology saves 30-50% of fertilizer and 20-25%water compared with traditional fertilization methods.

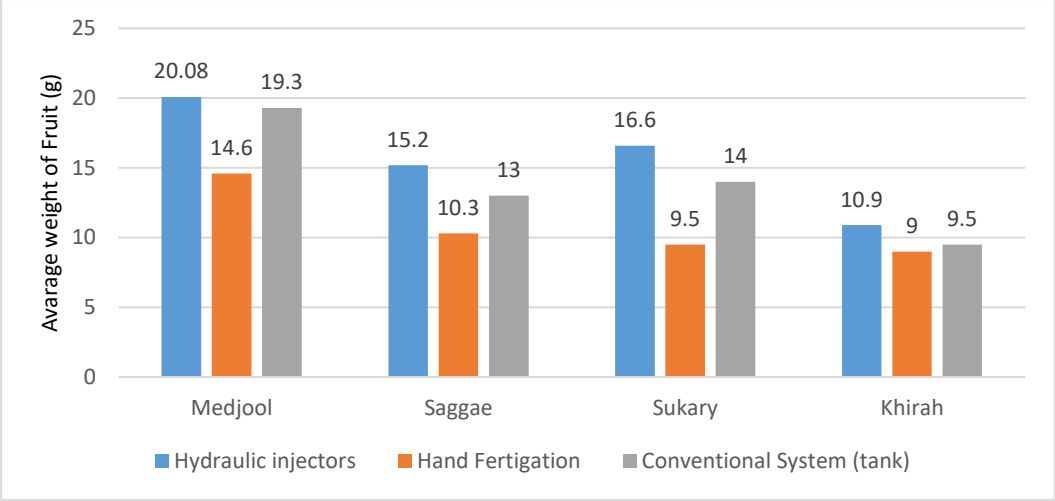

Figure 9. The effect of fertigation on fruit weight of four date palm cultivars in UAE

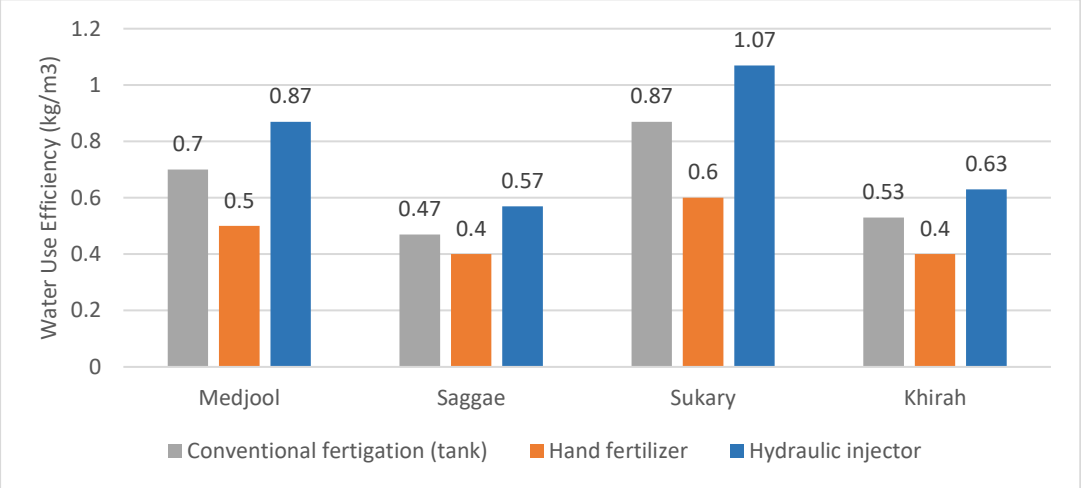

Figure 10. Comparing fertilization methods on water use efficiency of 4 date palm cultivars in UAE

Use of Mycorrhiza to improve rooting

The mycorrhizal fungus was added to organic fertilizers on tissue seedlings under plastic greenhouses in the United Arab Emirates and on date palm trees in the process of production in the State of Kuwait. This addition aims to assist the growth of date palm roots and thus make maximum use of irrigation water and fertilizer to accelerate vegetative growth and improve date palm production.

In the UAE, date palm seedlings obtained from tissue culture propagation were inoculated with mycorrhiza to improve their rooting and stimulate their growth at the Date Palm Research Station in Al-Hamraniyah during the years 2015-2017. The Fungi were added to seedlings of *Barhi, Khalas, Sultanah*, and *Medjool* at the same size and age, chemical and organic fertilizers were added in different amounts and with repeated combinations of mycorrhiza with the organic and chemical fertilizers, in addition to mixing them in comparison with seedlings without fertilization. The results showed that there were no significant differences between the cultivars (Figure 12), the use of mycorrhiza with organic fertilizers alone led to a significant increase (between 23 and 25%) in seedling growth compared to other treatments. The use of mycorrhizal fungus also reduces the total volume of the organic fertilizers by up to 50% without affecting the nutritional value.

Figure 11. Effect of Mycorrhiza on groth ofr date palm seedlings

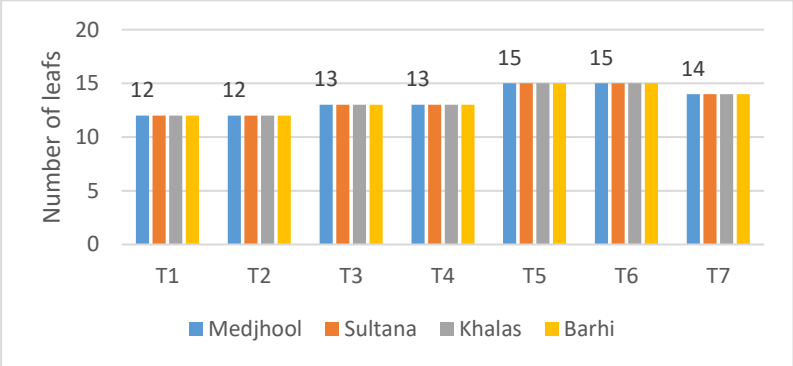

Figure 12. Effect of Mycorrhizae and fertilizer on number of date palm seedling leaves in UAE

Legend – Figure 12: (T1) chemical fertilizer with 100% of the fertilizer recommendation without adding mycorrhiza, (T2) organic fertilizer with 100% of the fertilizer recommendation without adding mycorrhiza, (T3) mycorrhiza without fertilization, (T4) chemical fertilizer with 50% From the fertilizer recommendation with the addition of mycorrhiza, (T5) organic fertilizer with 50 percent of the fertilizer recommendation with the addition of mycorrhiza, (T6) organic fertilizer 100 percent of the fertilizer recommendation with the addition of mycorrhiza, (T7) chemical fertilizer with 25 percent and organic fertilizer 25 percent From the recommendation of compost with the addition of mycorrhiza.

In the State of Kuwait, the experiment was carried out in a farm with poor sandy soils by inoculating the date palm produced with mycorrhizal fungus with the addition of organic fertilizer or sludge during the three seasons 2013-2016. The results showed a noticeable increase in production compared to adopting the technique of inoculated plants with mycorrhiza and fertilizing them with organic manure or sludge, compared to the control (Figure 13 & 14). This increase was 22.6% when adding sludge and 19.3 percent when adding organic fertilizer. A conclusion can be reached that increasing mycorrhiza concentration in soil clearly improves plant absorption of nutrients from organic matter.

Figure 13. Adding mycorrhizae with organic fertilizer and sludge on the date palm in Kuwait

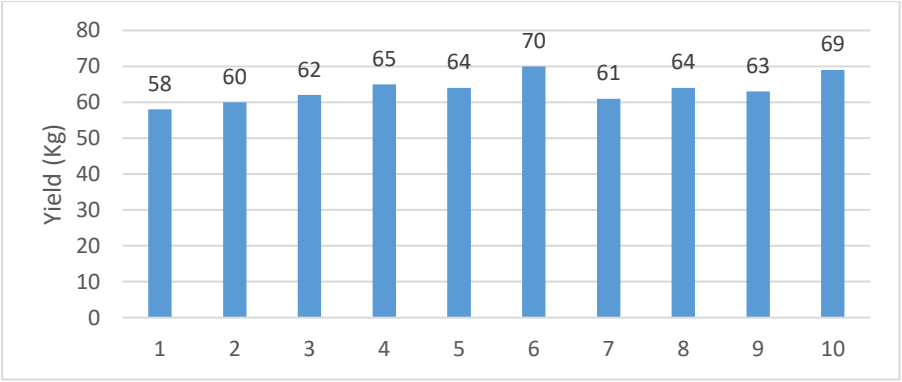

Figure 14. The effect of mycorrhiza date palm production in Kuwait

Legend – Figure 14: *(1) control, (2) mycorrhiza, (3) sludge of 5 tons per hectare, (4) sludge of 5 tons per hectare with mycorrhiza, (5) sludge of 10 tons per hectare, (6) sludge of 10 tons per hectare with Mycorrhiza, (7) organic fertilizer 5 tons per hectare, (8) organic fertilizer 5 tons per hectare with mycorrhiza, (9) organic fertilizer 10 tons per hectare and (10) organic fertilizer 10 tons per hectare with Mycorrhiza.*

2.1.2 Integrated Pest Management

As a response to the recommendations of the project performance evaluation committee, completed at the end of Phase 1, Phase 2 focused on the importance of integrated pest management, and valued the results of the survey of natural biological enemies of pests and recommended them as much as possible as a part of biological control. Among these promising results are the isolation and characterization of local and pathogenic insect fungi for use in integrated pest management and the development and testing of applied strategies against Lesser Date Moth, Dust Mites and borer insects which are widespread in the GCC countries causing heavy losses.

Insect pest monitoring

The monitoring of insect activity and the damage level on the plant to determine the critical limit of damage is the main rule of integrated pest management. The study showed that Lesser Date Moth insect and the Dust Mite in Bahrain, Saudi Arabia and Oman, as the most harmful from an economic point of view.

Therefore, light traps were used in one trap for each farm to collect the adult stage of insects once or twice a week.

Table 5. monitoring of insect activity and damage level to guide the control measures

Country	Insect	Fruit infestation (percent)
KSA	Lesser Date Moth	64.3% in Hababuk stage, and 87% in kimry stage
	Dust Mite	In the last week of June, the incidence of dust mite infection on date palms was about 87%
Kingdom of Bahrain	Root borer Oryctes agamemnon arabicus Fairmaire and Fruit stalk borer Oryctes elegans	The peak in activity was during June.

Estimation of economic insect damage level

The percentage of infestation (Table 6) and economic loss due to Lesser Date Moth *Batrachedra amydraula* Meyer was estimated on the date palm. Seasonal activity was also studied and the incidence of Dust Mite (*Oligonychus afrasiaticus* McGregor) was assessed on *Hilali* cultivar.

Table 6. percentage of infestation with Lesser Date Moth Batrachedra amydraula Meyer

Infestation with	Country		
Lesser Date Moth	Sultanate of Oman	Kingdom of Bahrain	Kingdom of Saudi Arabia
	70%	75%	77%
Dust Mite	----------	62%	30%

Additionally, it was found that the economic profit of adopting biological control in the 2016 figures saved about USD 918 per hectare per year in Bahrain, USD 3,612 in the Kingdom of Saudi Arabia, and USD 8,936 in the Sultanate of Oman.

Use of Bio pesticides to control pests

Environmentally friendly bio pesticides continued to be adopted in various countries of the project, especially in the field of Dust Mite and Lesser Date Moth resistance, including: Abamectin, Sulfur and Matrine, where very encouraging results were obtained (Figure 15). Regarding the borers, follow-up studies concluded that the pest community should be monitored in the field to determine the peak periods before entering the control programs and setting dates. Studies confirm the importance of field operations to reduce damages on stems and roots.

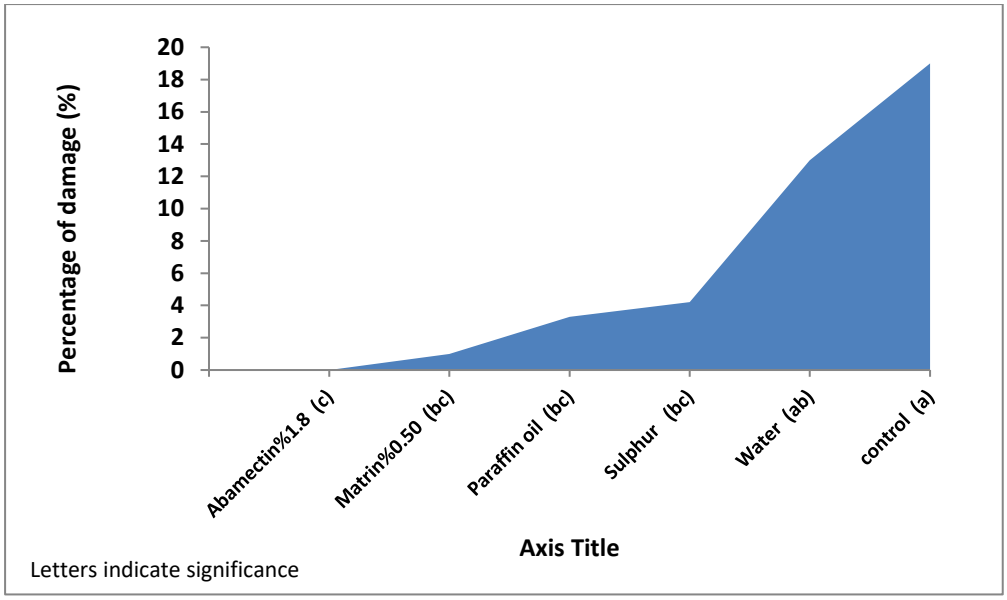

Figure 15. Reduction of dust mite infestation and damages with different biopesticides

Biological control of insect pests

In addition to the encouraging results achieved in the Sultanate of Oman, especially in the field of the Dubas egg parasite *(Psedoligosita babylonica)* present in the local agricultural environment and the parasite *(Goniozus sp.)* on the larvae and nymphs of Lesser Date Moth, the process of multiplying two strains of the *Trichogramma* parasite was also undertaken. Some of them are from Tunisian and German laboratories (*T. cacoeciae)* with 25,000 parasites per hectare in the Kingdom of Saudi Arabia, where a biological protection laboratory has been developed for breeding this parasite. The *Trichogramma* parasite was released in Qatif oasis in KSA to parasitize the Lesser date moth insect. The initial results are very promising, as the reduction in infection was estimated at about 40% for the first year of launching in the field (2017), and the preliminary results for the second year (2018) were close to 50%. In the Sultanate of Oman, the presence of 4 parasites in the local natural environment against the Lesser Date Moth insect, including the parasite on the Dubas eggs *(Goniozis)* has been identified. A breeding program for the *Trichogramma* parasite has been launched to combat the Lesser date moth insect, as well as on the pomegranate worm, while the Dubas egg parasite is being bred for its wide release in the *Sultanate*.

2.1.3 Post-harvest technology

Polycarbonate chambers

Drying dates by solar energy under the Polycarbonate Drying House (PDH) was developed by the project. The PDH is a drying chamber covered by a polycarbonate sheet equipped with an exhaust fan. The polycarbonate sheet has superior properties in terms of transparency, transmissivity, property, anti-corrosion, tensile properties, tear-resistant, anti-puncture, water and moisture proof. Figure 16 shows the design of the date drying chamber. The chamber is made of steel frame covered with polycarbonate sheets, and has many advantages over polyethylene sheets and glass: transparency of around 95%, shatter proof, tolerant to temperatures from - 40 to 160 °C, coated with a UV proof layer, break proof as compared to glass, light weight, flexible and easy to shape, and guaranteed for 10 years color change proof. The chamber

is equipped with 2 exhaust fans to assist in the drying process. The fan's opposite wall at a lower level than the drying trays is covered with screens for aeration.

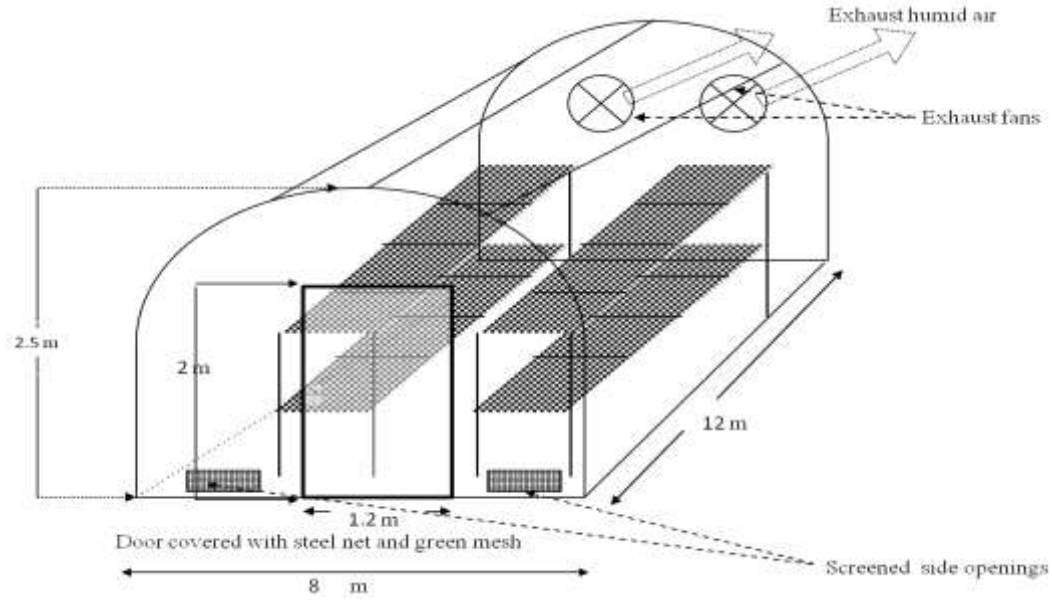

Figure 16. date drying chamber design

The advantages of using improved PDH technology (Figure 17) are the following:

1. Improves the quality of the dates, especially in humid areas
2. Avoids the contamination of dates by insects, birds, dust, and rain
3. Accelerates the drying process
4. Reduces the loss rate.

Figure 17. Different methods of date drying

Dates packing and storage

To study the effect of storage on packed dates under vacuum, the water activity and the microbial load of dates were monitored in five factories in Al-Ahsa, Kingdom of Saudi Arabia, for two cultivars *Khalas* and Shishi under refrigerated storage (5°C) and normal storage temperature, for 12 months' period, and repeated for three years. The presence of coliform bacteria and fungi was detected in one of the five date factories in the 2015 season. It was observed that packing dates under vacuum and storing under 5°C have a positive effect on controlling microbe levels. It has been proven that the source of the microbial load is mostly the result of post-harvest treatments in the field and washing lines.

2.1.4 Biodiversity characterization and conservation

The project studied the diversity of 190 date palm cultivars using 19 simple sequence repeats (SSR) primers. These cultivars were collected from the Kingdom of Saudi Arabia (50), the Kingdom of Bahrain (50), the State of Kuwait (40) and the Sultanate of Oman (50). In the study, the polymorphic SSR loci and the polymorphic information content value (PIC) of each primer has been measured. The results showed high polymorphisms among the cultivars in the GCC countries ranging from 84.2% to 94.7% with high PIC values ranging from 0.052 to 0.96. This study made it possible to identify haplotype, assess similarity/dissimilarity among the GCC date palm cultivars and sex identification at early stage.

This technology could be useful for:

1. Documenting date palm cultivar DNA facilitating early identification of quality and matches the expected specifications.
2. Studying genetic variances and determining the genetic similarities between cultivars, which enables the selection of suitable cultivars for different agricultural environments and determines the genetic variation of tissue culture seedlings.
3. Exploring sex genes linked to (male or a female cultivar) and to quality and tolerance to various environmental stresses such as drought, salinity and infections.

Molecular Genetic Diversity of Some Date Palm Cultivars in GCC Countries

The preparation of an Atlas for the most important Cultivars in the GCC was also undertaken. A genetic fingerprint study was conducted on the 10 most popular cultivars from each country using 30 SSR primer pairs specially designed for date palm (*Phoenix dactylifera L.*) and they have proven to be very powerful due to their locus-specificity, co-dominance, high reproducibility as well as revealing highly levels of polymorphism. Table 7 shows the cultivars studied in each county.

Table 7. Date Palm Cultivars covered in the molecular genetic diversity in the GCC Countries

Country	Cultivars
Sultanate of Oman	(*Khalas A'Dahra, Naghal, Khalas Oman, Farad, Khasab, Bunaringa, Khinaizi, Zabad, Hilali Oman, Bahlani)*
Kingdom of Saudi Arabia	*(Khalas, Khasab, Sagae, Sukari, Barhi, Safri, Safawi, Ajwa, Anbara, Khodry*)
United Arab Emiratis	(*Farad, Khalas, Barhi, Khasab, Naghal, Lulu, Jabri, Abu Maan, Shahlah, Khnaizi*);
Kingdom of Bahrain	*Strawi, Barhi, Khalas, Merzaban, Ereziz, Khasbat Asfoor, Ghurh, Hilali, Hulaw, Khinaizi*);
State of Qatar	(*Ghur, Barhi, Hilali, Reziz, Khalas, Shishi, Khinaizi, Nabtat Saif, Khadhrawi, Lulu*)
State of Kuwait	*Nabtat Saif, Sa'amran, Khalas, Barhi, Khasab, Braim, Al Jawza, Um Al Dehen, Sukari, Medjhool*)

The results of the phenotypic analysis showed three main groups (Figure 18), the first of which included the cultivars (*Safari, Strawi, and Jab*ri), while the second included most of the cultivars from Kuwait. It was also found that the two cultivars *Khinaizi and Halaw* from Qatar were located close to cultivars from Kuwait. The third group included the rest of the cultivars in the GCC countries including sultanate of Oman, state of Qatar, the Kingdom of Saudi Arabia and United Arab Emirates. The results of Principal Coordinates

Analysis (PCA) in Figure 19 were consistent with the results of phenotypic analysis as most of the cultivars were distributed in the coordinates as three main groups.

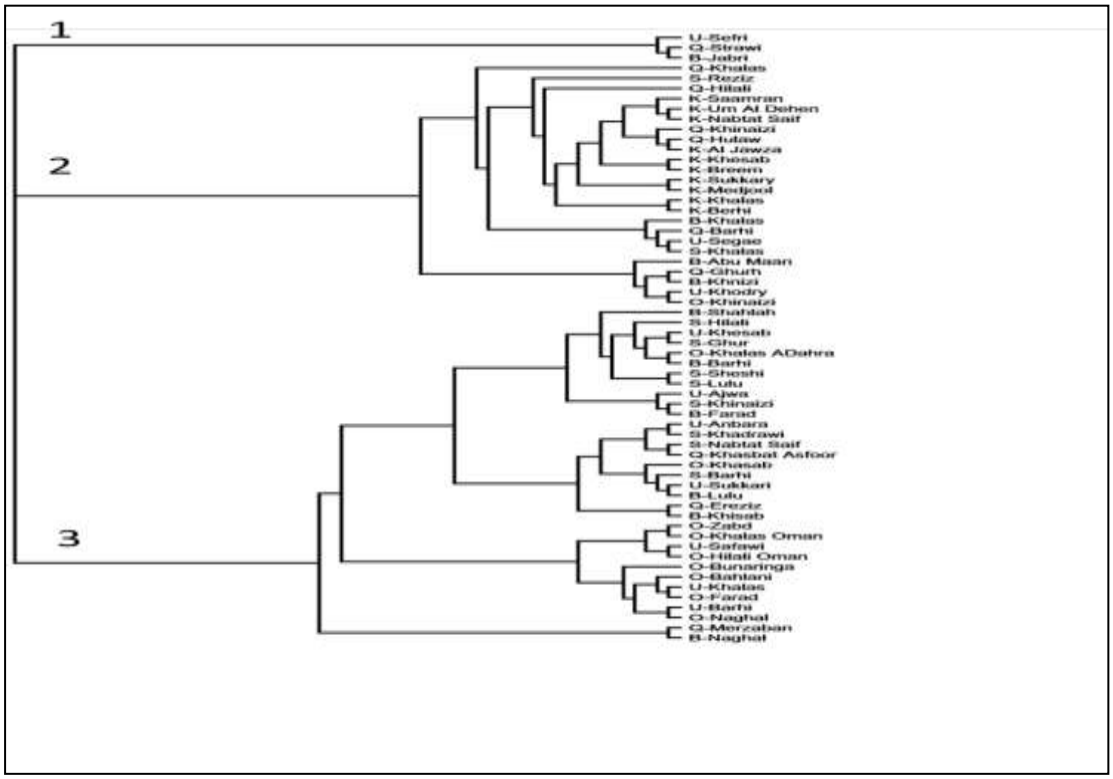

Figure 18. Neighbor-Joining analysis based on Nei's genetic distance between date palm cultivars

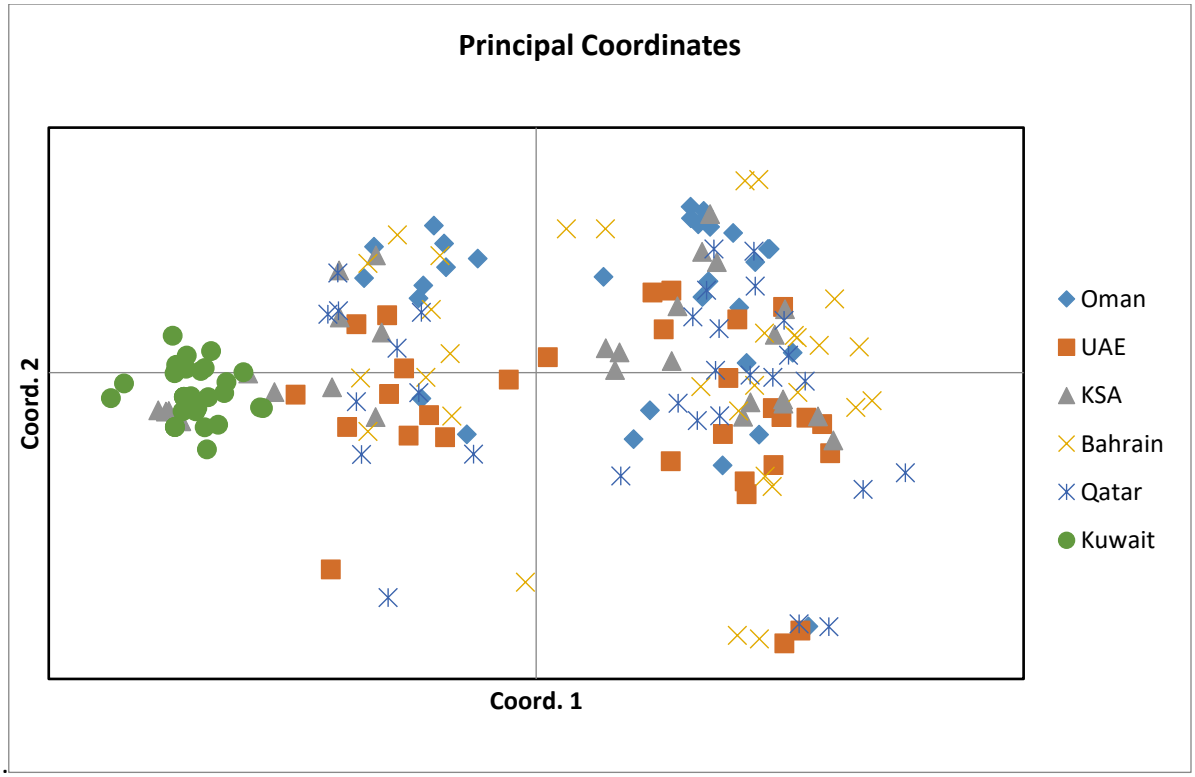

Figure 19. Principal Coordinates Analysis (PCA) for all date palm cultivars used in this study

Genetic studies related to environmental stress

The project initiated a study on genetic resistance to environmental stresses (salinity and drought) in late 2017. This was a part of a cooperation protocol between the ongoing project and the Emirates University in Al Ain and the American University in Abu Dhabi. This was used to determine the single base variation (SNIP) indicators of date palm resistance to environmental stresses on 18 cultivars , *Khalas, Naghal , Jabri, Farad, Sukary, Sagae, Lulu, Khasab, Barhi, Khainaizi, Abu Maan, Umm al-Hammam, Ruthana, Ajwa Madinah, Nabut Saif, Shalala, Maktoum and Nabtat*. The preliminary results of this research are very encouraging. Genes responsible for tolerance to salinity have already been identified in some date palm cultivars, which require further analysis. These results were presented and discussed during the training course on the use of microstructure primers and single base variation indices in the date palm genome in May 2018 in the Sultanate of Oman.

2.1.5 Socioeconomics of date palm

Date palm Value Chain Analysis and Marketing Opportunities

In the framework of the "*Development of sustainable date palm production systems in the GCC countries of the Arabian Peninsula*", this study aimed to analyze the date value chain in the GCC countries. Through the mapping of the chain, the overall objective was to identify the processes where values are created and how they are distributed among stakeholders along the date palm value chain. Of special interest for the analysis were the policy instruments used by the Governments to solve specific problems characterizing the chain and consequently enhance the development of the sector and see in particular to what extent those instruments are value creating. The method used in this analysis was an assessment of the data gathered from the multi-stakeholder surveys implemented in the three case studies of the GCC countries: Saudi Arabia, Oman, and Kuwait. The surveys conducted targeted the following date palm stakeholders: growers, consumers, retailers, wholesale traders, processors, transporters, importers, decision makers, research and extension staff, and input providers. The method was based on a synthesis summarizing the key messages issued from each one of the key actors involved in the date palm value chain.

The empirical findings reveal several problems and constraints that might affect the future of the GCC date palm sector. Problems include:

- Low quality varieties, low product quality, low exported quantity, and consequently low returns;
- Poor farming management (Inefficient use of date products and by-products);
- Pests and diseases and inadequate IPM;
- Harvesting, processing and marketing (high post-harvest losses);
- Lack of an efficient processing system (storage, transportation, etc.);
- Shortage in national qualified and trained staff and labors;
- Insufficient research and development activities in the date palm sector.

The data was collected through semi-structured questionnaires targeting the main actors in the date palm sector. Data were gathered for three countries: Saudi Arabia, Oman and Kuwait. Table 8 illustrates the number of surveys conducted in each country mentioned above.

Table 8. Nature and number of surveys conducted in each country

	Interviewees		
Nature of the survey	**Saudi Arabia**	**Oman**	**Kuwait**
Date palm growers	40	38	62
Date palm consumers	09	-	11
Date palm retailers	08	04	10
Date palm wholesale traders	08		
Date palm processors	08	-	-
Date palm transporters	08	14	-
Date palm importers (production input)	09	18	-
Decision makers	07	-	-
Researchers and extension staff	10	47	-
Date palm input providers	20	-	-
Total interviewed stakeholders	127	121	83

Source: Dhehibi from surveys conducted in the GCC countries (2017).

The assessment of the date palm supply value chain, on the basis of the data collected from the different actors, allows us to identify the following elements (Table 9):

Table 9. Date palm supply value chain synthesis

Item	Assessment Indicators
Fresh dates for local consumption	High in all GCC countries
Fresh dates for exports	Almost high in KSA and UAE
Industrial dates for exports	Low in Oman, Kuwait, and Bahrain
Industrial dates for domestic consumption	Low in Oman, Kuwait, and Bahrain
Animal feeding dates	Important in Oman, Kuwait and UAE
Utilization of by-products	Low in all countries
Farm management	Low in all countries

Source: Dhehibi from surveys conducted in the GCC countries (2017).

Effective value chain analysis is an important issue facing the agribusiness sector of the GCC economy dominated by the sale of raw agricultural products date palm fruits as the major cash crops in the majority of these countries. Dates could provide a greater contribution to the GCC economy if producers paid more attention to marketing. Date palm production is no longer a way of life but is considered an investment option and source of revenues for many stakeholders. To be more efficient, three development strategies are to be considered:

- Supply chain development and management
  - Improving date palm farming practices and initiation of better post-harvest handling procedures.
  - Processing and production of value-added products by focusing on added value varieties.
  - Export premium date products with consistency in the supply of high-quality varieties.

- Marketing and marketing development
  - Establishing basic data on the local and export date marketing sector;

- Improve the efficiency of the marketing process to guarantee good prices to the farmers and to decrease the final market prices by limiting the number of intermediate operators;
- Producing in-demand products at competitive prices;
- Pre-harvest Best Management Practices (BMPs) will certainly ensure that the quality standards for exports are met.

❖ Agri-business development

- Introducing new potential uses of dates and date products in the pharmaceutical industries, confectionaries, agri-food industries, handcrafts and furniture,
- Support the investment in Small Business Enterprises (SBE's);
- Promoting the use of applied scientific research methods to improve processing quality and develop new processing and storage techniques.

Economic Evaluation of Liquid Pollination Technologies in different GCC countries

The Sultanate of Oman

The data obtained from farmers for the *Khalas* cultivar on yield and related price-quality, presented in Table 10 indicate an increase in the value of production of about 20% from using liquid pollination rather than the manual pollination. The analysis showed that using liquid pollination reduced the pollination operation costs by 89.05% (which is the equivalent of OMR (Omani Rial) 1,273.95/ha) compared to traditional pollination. The reduction in pollination induces a reduction in the total variable costs of 22.10%. Economic analysis revealed that the net benefit to date palm farmers, using the cultivar *Khalas*, and applying liquid pollination was OMR 15,310.5/ha (an increase of around 42.60% over that when using manual pollination).

Table 10. Partial budget analysis for applying liquid pollination to the Khalas cultivar

Variable	With technology option (liquid pollination)	Without technology option (manual pollination)
Yield (kg/tree) [(a)]	100	100
Number of date palm trees/ha	165	165
Yield (kg/ha)	16,500	16,500
Price (OMR/kg) [(b)]	1.2	1
Total value of production (OMR/ha)	**19,800**	**16,500**
Cost of pollen (OMR/ha)	125	935.55
Cost of devise (OMR/ha)	11.6	0
Labor cost for pollination (OMR)	20	495
Total cost of pollination (OMR/ha) [©]	156.6	1,430.55
Other costs (irrigation, fertilization, pruning, thinning, harvesting, and post-harvest handling) (OMR/ha) [(d)]	4,332.9	4,332.9
Total variable costs (OMR/ha)	**4,489.5**	**5,763.45**
Net revenue (OMR/ha)	**15,310.5**	**10,736.55**
Economic indicators (1)		
Reduction of pollination cost per ha over manual pollination (%)	89.05	
Reduction of total variable costs per ha over manual pollination (%)	22.10	
Variable costs between the two technologies (OMR/ha)	-1,273.95	-
Increased net revenue over manual pollination (OMR/ha)	4,573.95	-
Economic indicators (2)		
Net returns (NR)	**15,310.5**	**10,736.55**
Change in net returns (NR) (%)	42.60	
Change in total costs (TC) (%)	22.10	
Internal rate of return (IRR)	1.92	
Benefit-cost ratio	3.41	1.86

Source of information: Farmer from Wadi El Maouel region

The UAE

A study conducted in the United Arab Emirates confirmed the results from Oman, as various economic indicators showed a remarkable decrease in the cost of pollination when using liquid pollination compared to traditional manual pollination by about 89%, and from there a reduction in the total variable costs per hectare by about 56.71%. Moreover, the analysis reveals a total reduction in the variable costs of AED (United Arab Emirates Dirham) 12,194 from using liquid pollination. This reduction in total variable costs results from an increase in the net revenue over that resulting from manual pollination of AED 36,514/ha.

According to farmers in the UAE, and researchers in project locations in the country, there are several advantages for using liquid pollination as it reduces time and reduces the risk of low fruit set by pollinating during the peak period of flowering of the date palm trees.

Economic and financial analysis of polycarbonate drying houses

The Capital Cost of the polycarbonate dryer house system is the sum of all the components (collector, drying house, and distribution system) and installation costs. Table 11 & 12 show the capital costs of the two polycarbonate dryer houses (small and large) considered in this economic analysis in Oman and UAE:

Table 11. Estimated capital cost for polycarbonate dryer house for dates

Total Capital Cost (OMR)	Farmer 1 (large dryer house)		Farmer 2 (small dryer house)	
	With subsidies (OMR)	Without subsidies (OMR)	With subsidies (OMR)	Without subsidies (OMR)
	1,000	3,000	2,700	4,700

Table 12. Estimated capital cost for polycarbonate drying chamber for dates in the UAE

	With subsidies (AED)	Without subsidies (AED)
Total Capital Cost (AED)	20,000	40,000

Note: The governmental subsidy for this type of drying chamber is around 50 percent (20000 AED).
the value of the subsidy is about 50 ,In UAE .The governmental subsidy for this type of drying house 66 percent in Oman :Note

Table 13. Economic and financial indicators of polycarbonate chambers in Oman and the UAE

	OMAN		UAE	
	No subsidies	With subsidies	No subsidies	With subsidies
Net Present Value (USD)	7,487	12,764	116,436	187,923
Internal Rate of Return	76%	+100%	44%	+100%
Pay Back Period year	2.31	0.7	1.8	1.8

2.2 Technology Transfer

Through field demonstrations, workshops and extended efforts, technologies tested in the project were disseminated to beneficiaries.

Table 14. Technology Transfer activities during phase two (2012-2018)

Technology	Status	Beneficiary Countries
Liquid Pollination	Transferred	Oman, Bahrain, Qatar, KSA
Date's Solar Drying in the Polycarbonate Chamber	Transferred	Oman, UAE, Kuwait, Qatar

Transferring liquid pollination technology to farmers

Field days were organized to transfer liquid pollination technology to farmers in all the countries of the GCC to more than 350 farmer participants and adopted by 84 pioneering farmers. The projections show the possibility of more than 600 farmers adopting the various technologies developed and introduced by the project, indirectly resulting from field days, bulletins and the methodology of extension farmer-farmer. The project focuses on small farms, which are dominant in the various Arab Gulf States. Large farmers' and investors' conviction of the important economic feasibility and added value of these advanced technologies are evident through the number of date palms treated with liquidation technology at several big farms (Table 15).

Table 15. Some of the large date palm farms adapted the liquid pollination technology

Project	Year	# date palms
Sheikh Saleh Al-Rajhi in Al-Qassim Farms in Al-Qassim in Saudi Arabia	2016	200,000
Duaij Al-Anzi Farm in Al-Wafra. Kuwait	2016	5,000
large farms in Qatar	2017	26,000
One Million date Palm Project, Diwan of Royal Court in the Sultanate of Oman	2017	50,000

Estimates of the number of date palms on which the liquid pollination technique has been applied exceeds 300,000 palm trees in the Gulf Cooperation Council countries. Following the project's steering committee's recommendation to approve the Sultanate of Oman as a hub to be a specialized center in the field of liquid pollination, an integrated unit was designed to collect pollen and store it in a mobile room and has been in use since the 2017 season in the research station in the South Al Batinah region.

Transferring polycarbonate technology to farmers

In the field of post-harvest transactions, a subsidy program for polycarbonate chambers was adopted in the United Arab Emirates at half the market price, and 100 chambers were distributed.

In the Sultanate of Oman, more than 74 chambers were distributed to farmers in a first batch, after about 16 polycarbonate chambers were purchased from the local market without going through the subsidy system, convinced of their usefulness to improve the quality of dried dates. According to the estimates of the agricultural extension centers in the governorates of South and North Al Batinah, where dates require drying more than other governorates of the Sultanate, the requests in the states of Baraka and Al Awabi for polycarbonate houses supported by each state are estimated at about 30. If this is generalized only to the states of the two provinces, the demand would be close to 360 chambers.

In Qatar, another method has been adopted to spread the technology, which is the farmers' demand to dry their dates in the drying chambers of the Rouadat Al Faras research station. The number of farmers is expected to increase due to the intention of the station supervisors to increase the drying capacity by completing a new large facility. In addition, the Ministry of Municipality and Environment has prepared an ambitious program to support and distribute 200-300 chambers for drying dates during the coming period.

In the Kingdom of Saudi Arabia, the Date Palm and Dates Center acquired a house for drying dates, located in the Research Center in Qatif. The polycarbonate chambers were used to train farmers in the technique of drying dates. Observation was made that some cultivars entered the marketing cycle for dates in the Eastern Province where the *Khalas* and *Khainaizi* are found after the drying technique was adopted. Technicians have noticed a great improvement in the quality of dried dates, which were previously hardly suitable for use except as animal feed.

2.3 Capacity building

Ten regional training courses (in the form of seminars, training courses and field days) were completed during the second phase of the project, for which 194 engineers and technicians and 600 farmers benefited (Table 16).

Table 16. Number of training programs organized during second Phase

Name of the Training Course	Country	Year	# trainees
Use of microsatellite primers for genetic diagnosis of date palm varieties	Oman	2018	8
integrated Pest management and Agricultural Statistics	Oman	2017	20
Liquid sugar production	UAE	2016	18
Vegetative and fruiting characterization to prepare date palm atlas	Oman	2015	11
Agricultural Statistics and application on integrated pest management	UAE	2014	14
Good Agricultural practices in date palm cultivation	Oman	2014	26
Date palm genetic fingerprint	Qatar	2013	29
Date palm value chain analysis in the GCC	Oman	2013	17
Date palm Modern irrigation using treated water	Oman	2013	25
Date Palm pest monitoring and control	UAE	2013	26
Total			194

2.4 Publications

A total of 84 project scientific and technical manuscripts have been developed and published during its second phase (Table 17). The publications included the two highly appreciated manuals listed below:

Date palm pests and diseases Integrate Pest Management Guide: This guide presents the latest information on integrated date palm pest management programs (IPM) in the Arab Gulf Cooperation Council countries. This guide for IPM is suitable for adopting a sustainable and scientific approach to managing date palm pests and diseases for farmers, extension technicians and others concerned with the date palm sector in the field of pest control.

Atlas of Main date palm Cultivars in the Arab Gulf Countries: Characterization and description of the most important 10 date palm cultivars in each country, including integrated and unified characterization key for the morphological and fruiting characteristics. The achievement of the Date Palm Atlas is in the characterization and preservation of genetic resources and the adoption of biotechnology for the genetic study of date palm cultivars.

Copies accessible here: https://drive.google.com/drive/folders/1_DHz4pXphMvcdvfY6_302DKIQ51Cezi1

Table 17. Project Publications (2012-2018)

Type of media	Amount
Books and chapters of books	4
Scientific papers published in journals	8
Scientific papers submitted in scientific and technical conferences.	31
Lectures and field days	17
Project activities posters	2
Extension brochures	10
Audio-visual media (see links below)	3
Technical reports	9
Total	84

https://youtu.be/sqerZ2fTna4
https://www.youtube.com/watch?v=EO7LPg36TDA
https://www.youtube.com/watch?v=CtJA9uBmZcw

3. Phase 3: 2020-2022

Introduction

At the 11th meeting of the Steering Committee of the project in November 2016, it was agreed that there was a need for the GCC countries and ICARDA to continue working as a team to face the challenges and impediments in the sustainable production of the date palm in the region. The Steering Committee members unanimously decided to submit a proposal for a new project phase 2018-2022 with a focus on enhancing and scaling out of achievements from Phases 1 and 2 on the areas of improved crop management practices, water use efficiency and integrated pest management. These issues were tackled in the first two phases at the level of applied research, technology transfer and capacity development with a lot of success. However, R&D is an ever-evolving process in which new challenges and opportunities continue to be appear.

Based on the above, at their Twenty-ninth meeting, the Agriculture Council Committee of the GCC Ministers of Agriculture approved the Steering Committee's recommendations to extend the project for a third phase from 2018 to 2022. The implementation of this phase started with the specific objectives below and their implementation is ongoing:

1. Technology packages and management practices that improve date production and quality while reducing vulnerability to climate change adopted by end users.
2. Enhanced capacity of national research and extension programs to promote adoption of technologies.
3. Recommended development strategy for date palm value chain, from producers, traders, markets and consumers.
4. Enhanced communication and knowledge sharing among all stakeholders.

3.1 Applied Research

1. Measuring water use and scheduling irrigation according to the different growth stages of the date palm and fruits (in progress in Oman).
2. Evaluation (technical and economical) and transfer of technology of very low-pressure drip irrigation system for date palm irrigation.
3. Utilizing geographic information systems and artificial intelligence in monitoring and early warning of date palm pests (what is required of each country determined during the training workshop).
4. Study the effect of nematodes on date palm trees.
5. Using solar energy in dates drying chambers and evaluating their economic feasibility
6. Complete the study on marketing, value chain and date consumption in Qatar, UAE, Bahrain (in progress for Bahrain and UAE).
7. Economic feasibility study of date palm plantations and projects.

Table 18. Applied research activities during Phase 3 (2020-2022)

Research Area	Bahrain	KSA	Kuwait	Qatar	UAE	Oman	Total
Propagation and Crop management	2	2	2	2	2	2	12
Crop protection pest management	1	1	1	1	1	2	7
Post-harvest handling and processing	1	1	0	1	0	0	3
Socioeconomics	2	1	1	2	2	1	9
Total	6	5	4	6	5	5	31

3.2 Technology Transfer

1. Application of liquid pollination technique (technical guideline + extension manual)
2. Transfer of subsurface irrigation techniques, irrigation rates and scheduling (in progress in Oman)
3. Review fertilizer rates in different countries and soils and develop an integrated guideline for the fertilization of date palm trees in each country according to the production stages (in progress in Oman)
4. A guide for mineral nutrient deficiency symptoms on date palm
5. Effect of soil and water salinity on date palm (in progress in Oman)
6. Transfer the outputs of the previous project phases with regard to pest control (publish explanatory guides + manuals during field days)
7. Transferring the outputs of GIS and artificial intelligence technologies in monitoring and early warning for date palm pests to farmers
8. Two workshops on using modern applications in the survey of insect pests (Red Palm Weevil) and developing an alarm system to control them
9. Continuing to disseminate the dates drying chambers technology (publishing illustrative guides + manuals during field days)
10. Create a website that collects all palm research and studies and mechanism for dissemination

3.3 Capacity building

An E-Learning Course on IPM of Date Palm Pests and Diseases was undertaken November-December 2020 (15 trainees)

Table 19. Project training activities in the third phase (2020 - 2022)

Name of the Training Course	Countries	Total
Modern irrigation techniques	All	6
Organizing a regional course on modern techniques in irrigation and fertigation	All	6
Training workshop on diagnosing symptoms of nutrients deficiency and pathological and insect injuries on integrated pest management of date palm	All	6
Two workshops on using modern applications in the survey of insect pests (red palm weevil) and developing an alarm system to control them.	All	12
Twelve field days (average of 2 in each country) to train farmers in drying chamber technology and date quality	All	24
Three national training workshops for technicians on drying dates using solar energy	Qatar, Bahrain, KSA, Kuwait	4
Regional workshop on date quality control practices and procedures for obtaining product safety and quality certificates	All	6
A training course on calculating the economic return of a palm tree according to service, production and market price processes	All	6
A training course in analyzing and developing the value chain of date palm and linking it to the market	All	6
Training workshop on developing programs to adopt project technologies through the “Scaling Scan Framework Tool”	All	6
Total		82

Undeterred from the ongoing COVID-19 global pandemic, and in continued response to the needs of participating six GCC countries and stakeholders in this project, the project activities are moving forward and building on the solid foundation established during the first two phases.

4. Value for money

Over the past fifteen years, the investment made in this project by its investors has been USD 6,000,000. An initial evaluation on the Rate of Return on Investment for this work (*ROI= (Current Value of Investment−Cost of Investment)/ (Cost of Investment)* has been calculated as ranging from 5.03 to 15.58 times the initial investment (Annex 1). The value of this project, however, cannot only be counted solely in terms economic impact, and must also be accounted for in terms of the cultural and social importance of the date palm in the GCC – something which is much harder to enumerate, and is of equal importance.

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Annex 1: Synthesis – Potential Returns on Investment to GCC

Scenarios/Hypothesis	Added Value (USD 1,000)	Investment (USD 1,000)	Rate of Returns on Investment GCC
Scenario 1 • An adoption rate of 1% (harvested area) for the liquid pollination technology • An adoption of 400 polycarbonate drying chambers (250 small and 150 large) in KSA, Oman, UAE and 150 (100 small and 50 large) in Bahrain, Kuwait, and Qatar. • 50% of the polycarbonate drying chambers are subsidized for both categories (small & large) and in both categories of countries) • An adoption rate of 1% (harvested area) for the subsurface drip irrigation • Date palm area and production is the average of 2000-2017 (FAO database) • 30% of the produced date palm area is planed with variety *Khalas* in each one of the 6 GCC countries	51,287.07	8,500	5.03
Scenario 2 • An adoption rate of 3% (harvested area) for the liquid pollination technology • An adoption of 400 polycarbonate drying chambers (250 small and 150 large) in KSA, Oman, UAE and 150 (100 small and 50 large) in Bahrain, Kuwait, and Qatar. • 50% of the polycarbonate drying chambers are subsidized for both categories (small & large) and in both categories of countries) • An adoption rate of 3% (harvested area) for the subsurface drip irrigation • Date palm area and production is the average of 2000-2017 (FAO database) • 30% of the produced date palm area is planed with variety *Khalas* in each one of the 6 GCC countries	71,215.69	8,500	7.37
Scenario 3 • An adoption rate of 5% (harvested area) for the liquid pollination technology • An adoption of 400 polycarbonate drying chambers (250 small and 150 large) in KSA, Oman, UAE and 150 (100 small and 50 large) in Bahrain, Kuwait, and Qatar. • 50% of the polycarbonate drying chambers are subsidized for both categories (small & large) and in both categories of countries) • An adoption rate of 5% (harvested area) for the subsurface drip irrigation • Date palm area and production is the average of 2000-2017 (FAO database) • 30% of the produced date palm area is planed with variety *Khalas* in each one of the 6 GCC countries	91,144.3	8,500	9.72
Scenario 4 • An adoption rate of 10% (harvested area) for the liquid pollination technology • An adoption of 400 polycarbonate drying chambers (250 small and 150 large) in KSA, Oman, UAE and 150 (100 small and 50 large) in Bahrain, Kuwait, and Qatar. • 50% of the polycarbonate drying chambers are subsidized for both categories (small & large) and in both categories of countries) • An adoption rate of 10% (harvested area) for the subsurface drip irrigation • Date palm area and production is the average of 2000-2017 (FAO database) • 30% of the produced date palm area is planed with variety *Khalas* in each one of the 6 GCC countries	14,0965.8	8,500	15.58

Annex 2: Participants at different training courses, demonstrations and field days

Field training on liquid pollination in the United Arab Emirates, Qatar and Oman

Field training on fruit thinning in UAE and Oman


Laboratory training on isolation of DNA in the Sultanate of Oman and State of Qatar


Field training on subsurface irrigation in Oman


Field training on date drying in KSA