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IMPROVING DATE PALM PRODUCTION UNDER SALINE AND DESERT CONDITIONS

Findings from twenty-two years of research in the UAE

Citation

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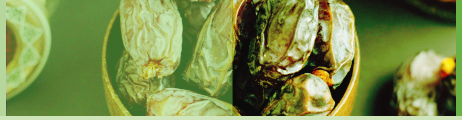

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Key messages

- Date palms are critical to food systems, economics, and culture in the Arabian Peninsula, but threats like water scarcity, soil and water salinity, low soil fertility, and pests and diseases all threaten the plant's survival and productivity – and climate change is on track to exacerbate these further.
- The International Center for Biosaline Agriculture (ICBA) has been carrying out research on the topic for 22 years in its UAE plantation – the longest-running large-scale experiment in the country – where it experiments with all main date palm varieties for the UAE and Saudi Arabia.
- Its work offers key insights for sustainable management of date palm into the future, with a specific focus on what it will take to productively cultivate the crop using irrigation from saline water – namely: conserving resilient genetic resources, promoting best farming practices, and enhancing fruit quality.
- The research also shows how the use of new technologies like drones, remote sensing, AI, and the Internet of Things offers particular opportunities for effective pest management and water efficiency in date palm plantations going forward.

Introduction

Date palm (*Phoenix dactylifera* L.) is the oldest fruit tree in the Arabian Peninsula, which makes up a key component of agri-food systems and an integral part of local cultural heritage and social and economic life. But cultivating the tree is increasingly challenging because of threats such as water scarcity, soil and water salinity, low soil fertility, and pests and diseases. As climate change advances across the planet, many of these threats are likely to intensify.

The International Center for Biosaline Agriculture (ICBA) has been conducting experiments in the United Arab Emirates (UAE) since 2001 to identify date palm varieties that are more tolerant of biotic and abiotic stresses, and apply integrated approaches that save water and other inputs, fight pests and diseases, and ensure higher yield in harsh environmental conditions.

This report outlines key findings from ICBA's two decades of work in this arena, and offers insights for ways to develop integrated management solutions that ensure that date palms, growers, and consumers continue to flourish in a warmer, more water-scarce future.

Background

About 90% of the world's dates are grown in the Middle East and North Africa (MENA) region, with the Arabian Peninsula being their center of origin. They have been an essential part of farming systems for over 5000 years, particularly in Middle East oases, where they can withstand extreme climates. The date palm has had a significant impact on the economy, society, and environment of this region.

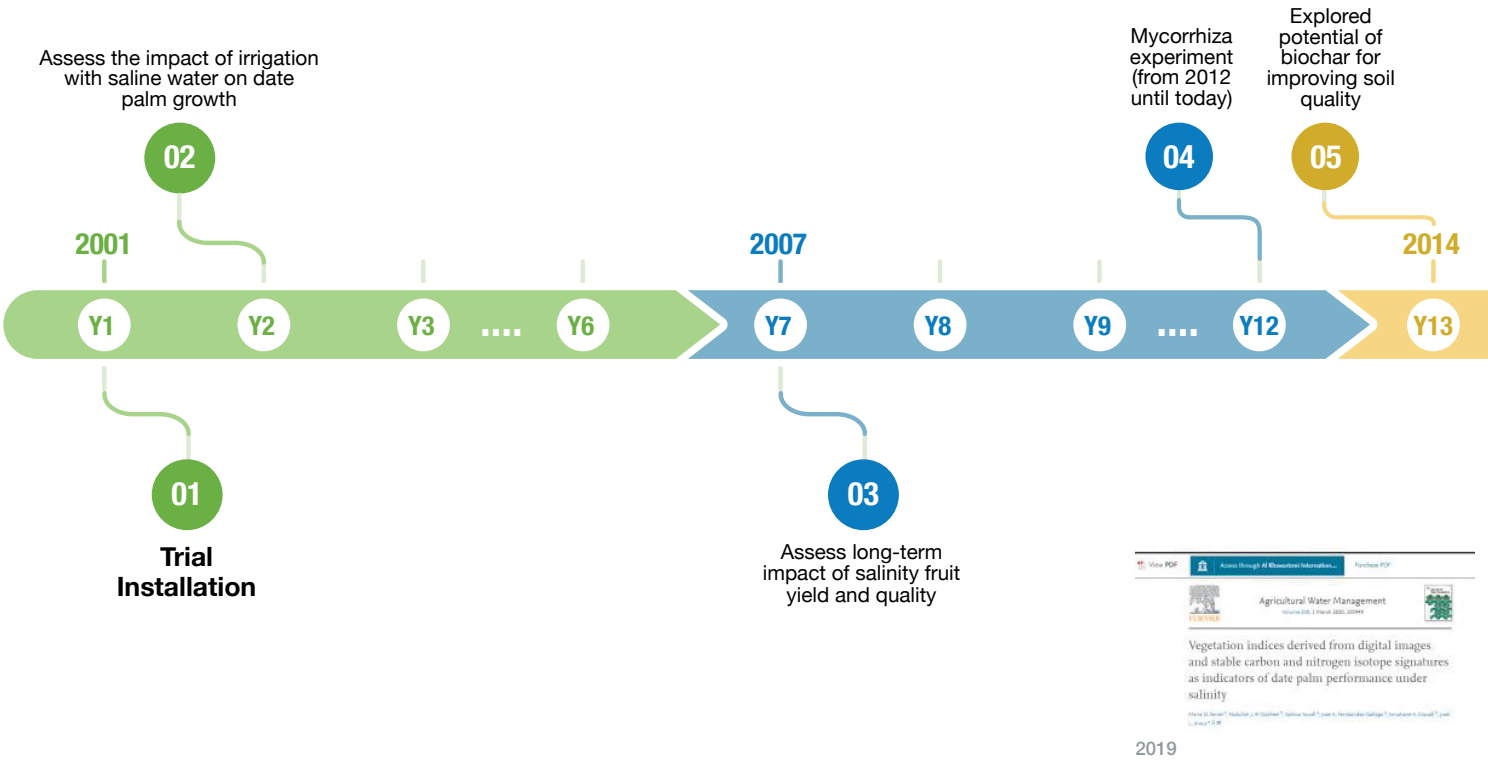
The species is well-known for its relatively high tolerance of biotic and abiotic stressors like intense heat, droughts, floods, poor soil, salinity, and pests. But it's not invincible, and careful management remains critical: sustainable agro-ecosystems need continual adjustments in their structure and management strategies to enhance production in stressed environments.

Pest control is particularly key to date palm production – the Food and Agriculture Organization of the United Nations (FAO) estimated in 2013 that the industry had suffered a loss of 30% in global production due to diseases and pests. The red palm weevil (RPW, Rhynchophorus ferrugineus), for instance, is a major threat.

With an eye to securing the long-term sustainability of this important crop, in 2001 ICBA set up a date palm plantation at its experiment station in UAE to test the various qualities of 18 date palm varieties over the longer term. The plantation covers almost three hectares and offers an ideal experimental study area to gather a comprehensive collection of datasets, and to test and develop innovative approaches.

The following timeline (Figure 1) shows some of the key steps, milestones, and achievements to date in ICBA's research within this important arena.

Figure 1: Timeline of ICBA's date palm research program to date



ICBA's research program in brief

ICBA's date palm research program involves several key disciplines:

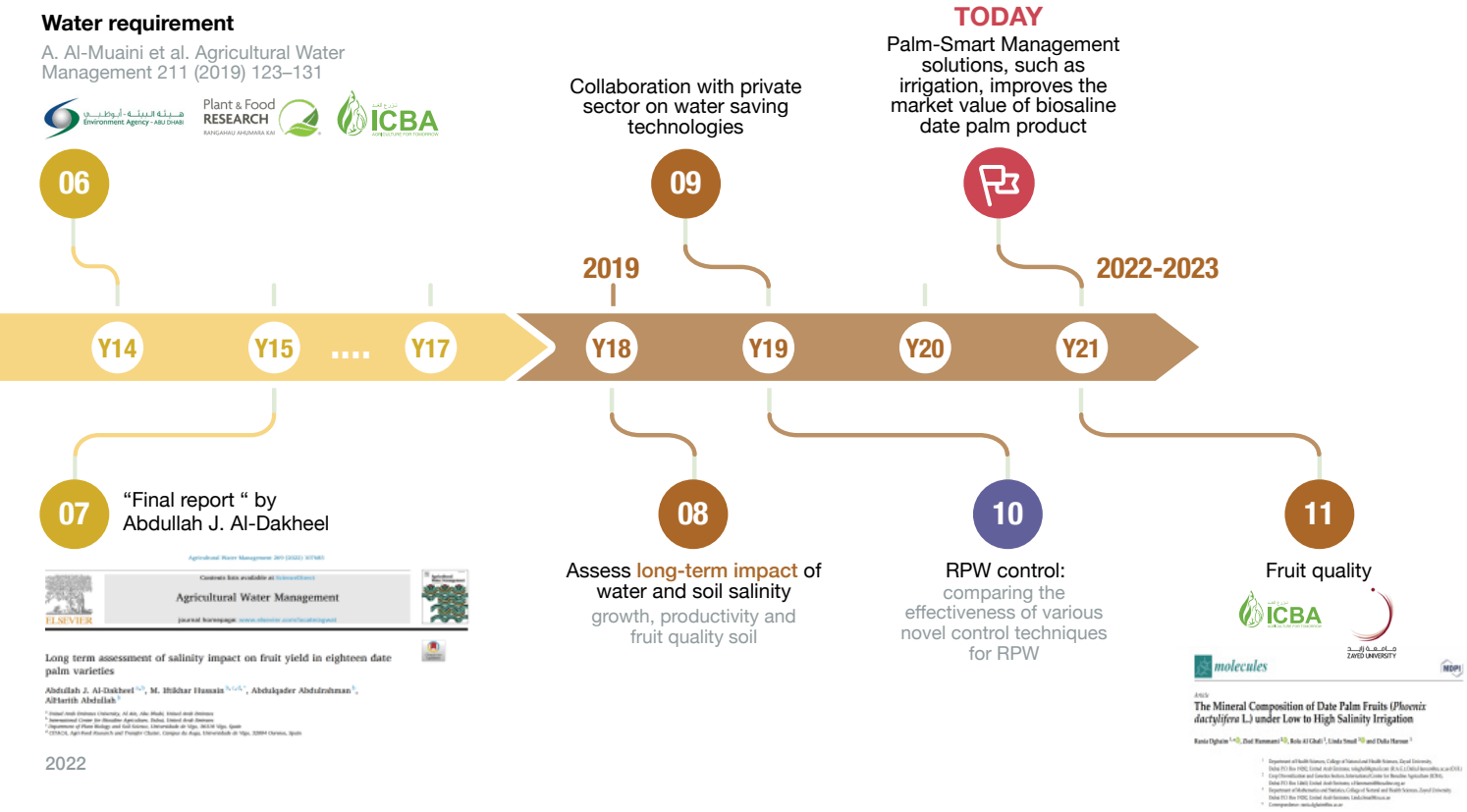
- **Irrigation**: Many quantitative data have been generated on this topic in collaboration with UAE national and international partners, and ICBA is currently working on refining and generating more data to cover more genotypes, and farming practices to determine the appropriate leaf/bunch ratio to improve fruit quantity and quality under saline conditions.
- **Water saving**: Four projects with three private companies have been implemented in the past two seasons to test new water-saving technologies.
- **Fertilization management**: This is one of the most critical factors in date palm production, but its efficacy and performance is also affected by water salinity and soil composition.
- **Pest control**: ICBA is testing and evaluating a number of pest control technologies under an internal project and in collaboration with the private sector. The FAO is a strategic partner on this topic.
- **Fruit quality**: ICBA works actively to improve date palm fruit quality under saline conditions.
- **Innovative responses to RPW**: ICBA is trialing the use of unmanned aerial vehicles coupled with other new technologies – such as artificial intelligence and the Internet of Things – for early detection, control, and management of red palm weavil (RPW) through an area-wide integrated pest management approach.

In depth: ICBA's date palm research

Since 2001, ICBA has conducted various experiments in the UAE to determine the long-term effects of saline water irrigation on date palm growth, productivity, and fruit quality, and the impact of salinity on the soil. From its research so far, ICBA believes that the successful future development of date palm irrigated with saline water mainly rests on (i) assessing, screening, and conserving resilient genetic resources; (ii) promoting the best farming practices, particularly disease control and water use; and (ii) enhancing fruit quality for better processing and marketing.

Current hypotheses being tested:

- The negative impact of using saline water to irrigate date palms can be minimized by selecting tolerant genotypes.
- Date palm water and fertilization management improve its tolerance of salinity stress.
- Date palm management practices (e.g., bunch and fruit thinning, fruit cover material, and timing) enhance fruit quality, and decrease harvest and postharvest losses.
- New water-saving technologies can significantly diminish water consumption.
- Precision agriculture improves saline water use and understands the effects of different water salinity concentrations on the quantity and quality of date palm products.
- RPW early detection based on a data-driven and sensing system helps boost effective control techniques.



Alignment with the Sustainable Development Goals (SDGs)

ICBA's date palm research to date has been a largely internal affair, but is now set to seed bigger and more substantial projects that will contribute to a number of the SDGs, including:

SDG 1: No Poverty: Many communities around the world rely on date palm as their main source of income. ICBA's research can help boost yields and livelihoods by providing better date palm management, monitoring, and assessment systems relying on accurate data, and robust analysis of yield gaps due to biotic and abiotic stresses.

SDG 2: Zero Hunger: Increasing the productivity of date palm by optimizing farming practices will preserve this rich and nutritious food for the millions of people who rely on it as a key food source.

SDG 6: Clean Water and Sanitation: Improving water use efficiency by optimizing irrigation practices using an intelligent system using real-time data from remote sensing and IoT ground sensors.

SDG 8: Decent Work and Economic Growth: New technologies can offer new opportunities for young people and gender equality (SDG 5).

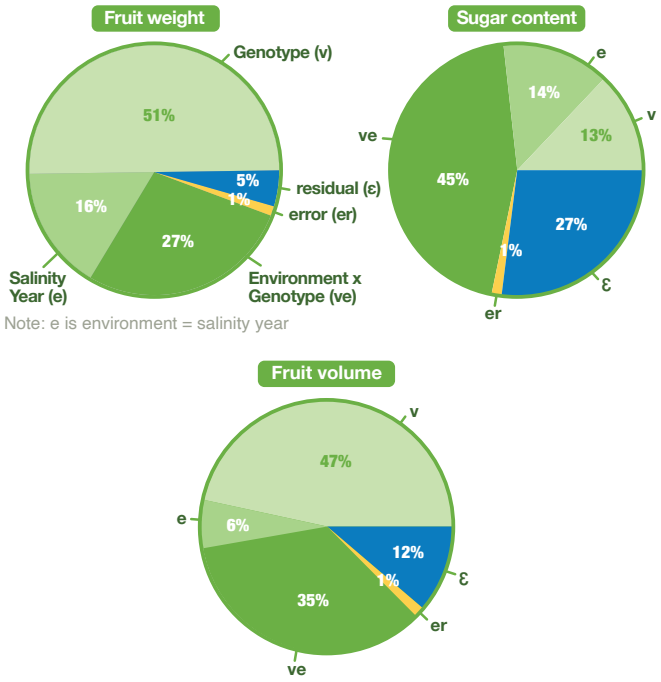
SDG 9: Industry, Innovation, and Infrastructure: Small-scale industry value is an indicator that can be targeted, since small and medium-sized enterprises led by youth and based on innovation, can be highly fructified by such types of projects.

In depth: ICBA's date palm research

Salinity tolerance

ICBA has conducted experiments evaluating the effects of irrigating date palm trees with water at four salinity concentrations on growth, yield, fruit quality, and soil. The experiments are conducted using water at three different salinity concentrations. The first eight years of production results show that the 18 genotypes being tested can be divided into four groups according to their salinity tolerance (Al-Dakheel et al., 2022). The organization has also carried out research on the impact of salinity on fruit quality. Dates are quite nutritious, and contain significant amounts of key minerals for health and growth. The researchers analyzed the nutritional qualities of each variety's fruit, and found that their responses to different salinity concentrations varied: although highly saline water significantly decreases some varieties' fruit quality, moderately saline water seems to improve the fruit quality of some others, increasing their sugar and mineral content (Dghaim et al., 2021). The figure below (Figure 2) depicts the contribution levels of factors such as genotype and environment to the variability of fruit weight, volume, and sugar content for 16 of the varieties grown in the ICBA plantation.

Figure 2: Variability of fruit weight, sugar content, and volume for quality in 16 date palm fruits explained by genotype, environment (salinity, year), block, and genotype by environment



Note: e is environment = salinity year

The researchers also ran a study evaluating date palm fruit quality under different salinity concentrations in comparison with that of the fruit available in the UAE market, in which it found that salinity did not significantly affect the total sugar content of the studied varieties (Hammami et al., 2023).

Various management practices under saline condition

The program also seeks to address farming issues through general practices and maintenance. It is continuously striving to generate more data and cover more genotypes and farming practices to achieve impactful results and improve date palm production. Maintaining the date palm tree through pruning, rachis base cutting, bunch and fruit thinning, and proper control measures can greatly enhance the plant's growth and overall health.The ICBA research program involves various disciplines and has achieved promising outcomes in water conservation, pest control, and fruit quality under saline conditions. Ongoing research efforts continue to yield positive results.

General practices and maintenance

ICBA research also aims to find solutions for farming issues, such as improving fruit characteristics by studying the effects of covering bunches, especially when irrigated with saline water. Covering the bunches with white bags rather than the standard mesh bags can also reduce the impacts of pests and diseases and prevent losses from bird attacks.


Mesh bag

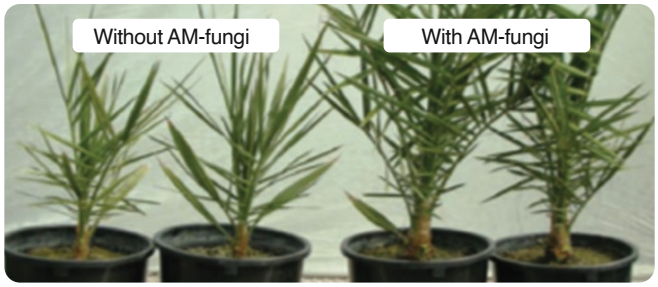

White covering bag

Soil enhancers

Mycorrhiza treatment

Arbuscular mycorrhiza (AM) is a symbiosis between plants and particular kinds of fungi that improves the supply of water and nutrients to the host plant, potentially enhancing its tolerance to salinity and drought. In the first long-term applied investigation of its kind, ICBA tested the effects of AM on date palm growth, yield, and fruit initiation at four water salinity concentrations for two cultivars. The study started by evaluating the effect of mycorrhizal colonization on tree survival, fruit initiation, and early growth. Then, the scientists explored the effect of mycorrhiza treatment on fruit yield and quality, and long-term use of marginal-quality irrigation water on soil properties with and without mycorrhiza treatment in an open field. The results showed that mycorrhiza benefits date palm trees during the early growth stage under marginal conditions (low soil fertility and salinity) (see Figure 3), and that date palms will grow better under natural conditions when effectively associated with AM fungi. Also, less chemical fertilizer and inputs are required to grow date palms when they are effectively mycorrhized.

Figure 3: Date palm seedlings grown with and without AM



Biochar from date palm waste

Biochar is a solid fine-grained material made from biomass that has been carbonized under oxygen-limited conditions. It can be applied directly to soils to improve their functioning and reduce emissions. Recycling date palm residues into biochar has shown to have a positive impact on the fertility of the sandy soils that characterize this region. ICBA has developed low-cost methods for on-farm biochar production from date palm waste, which can help to improve marginal soils and increase crop yields sustainably, including as an additive to conventional fertilisers (Alshankiti & Gill, 2013 & 2014).

Compost from date palm waste

ICBA has also intensively studied the use of date palm waste on compost (Gill et al 2020). Recently, a three-year 'Sustainable Green Waste Recovery' project explored the most efficient methods for producing compost from green waste obtained in harsh and saline environments. The research found that the best compost in such a context was made from a combination of date palm leaves and poor-quality fruit, mixed with grass and residue from the drought-tolerant Ghaf tree. Application of this compost resulted in crop yields of over 50% higher than the control group, and 20% higher than for compost from animal origin (Hammami et al,. 2023).

Water requirements

The UAE has the largest number of date palm trees of any country in the world – over 40 million. And those trees are thirsty: date palm irrigation makes up about a third of the country's total groundwater use (Al-Muaini et al., 2019). But the UAE's water tables are falling rapidly – primarily because of pumping for agriculture, which greatly exceeds natural recharge rates from the region's scant rainfall. In joint research with Abu Dhabi's Environment Agency and New Zealand's Plant & Food Research Institute, ICBA scientists have determined the actual water requirements for two date palm varieties, which could help to decrease irrigation use by up to 50%. ICBA's scientists then worked to validate this research and adjust it to different farming conditions. They installed sensory system platforms (Figure 4) to estimate the atmospheric evaporative demand, evaluated below-ground data, and used plant data to measure the date palm's response to evaporative demand and the soil water supply. This information will help to implement data-driven irrigation scheduling and determine the actual water requirements of the selected date palm varieties, enabling significant potential on-farm water and energy savings.

Figure 4: Data from sensors installed at different soil depth

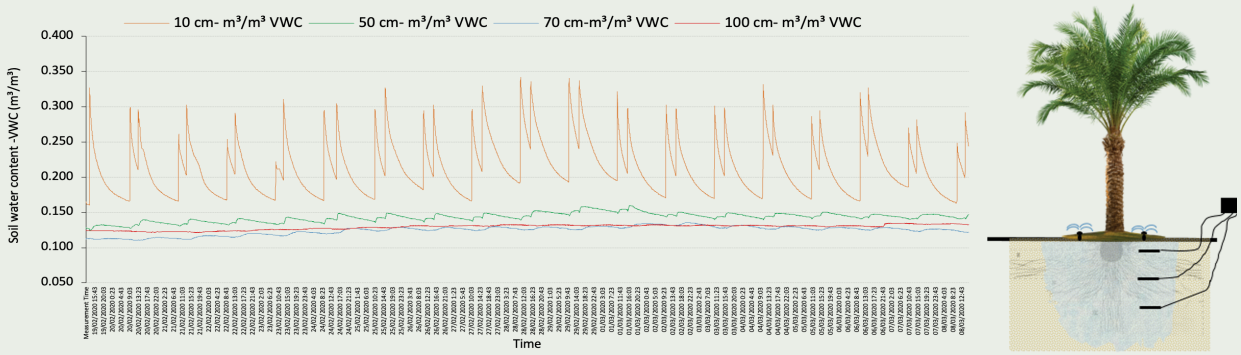
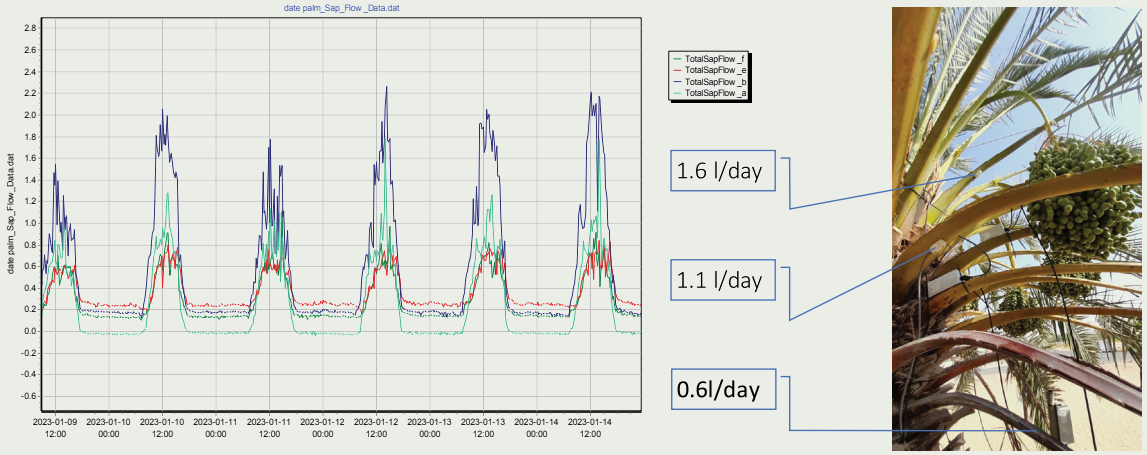


Figure: sensors at three different depths (right) And soil water content graph (left).

Figure 5: Sensory system for irrigation management

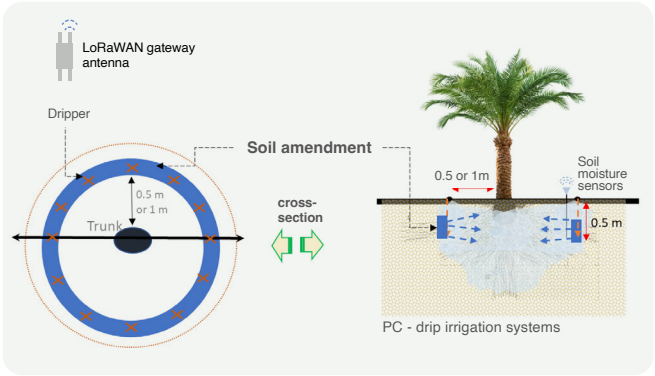


ICBA is currently working on improving and expanding water management data to cover a wider range of genotypes and farming practices. This includes determining the optimal leaf-to-bunch ratio to enhance both the quantity and quality of fruit grown under saline conditions. To achieve this, scientists installed sap flow sensors in various parts of the tree such as the roots, leaves, and fruit bunches to track water uptake and distribution throughout the growth and maintenance stages. It has been observed that, on average, the Barhi variety of date palms uses 123.5 liters of water per day, while the Khalas variety uses an average of 81.9 liters per day during the winter period.

Water-saving technologies

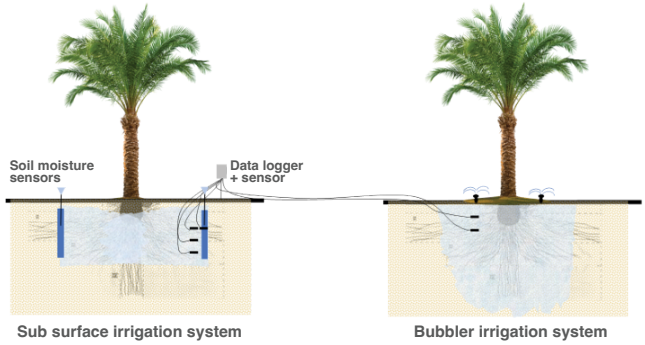
ICBA has also tested out several water-saving technologies such as soil amendments like hydrogels, biochar, sensors, and subsurface irrigation systems. It found that the use of such technologies diminished irrigation needs by 25% to 82% compared to a control group – without causing the trees stress or damage, or compromising their yields. For example, ICBA and several private companies are testing a potassium hydrogel-based polymer under the local environmental conditions (aridity and sandy soil) at ICBA's research station (Figure 6). The trial aims to evaluate hydrogel potential for improving crop yield and water productivity, determine its impact on water use efficiency of date palm trees, and identify the best application methods and rates. Preliminary results showed that the irrigation water quantity for the trees decreased by almost two-thirds compared with that of the control group, while the trees did not show any signs of dryness or damage: the real-time soil water content monitoring system enabled water irrigation based on crop requirements and soil moisture content. By the end of the experiment and after harvesting, the total water saving was 87%, and the impact on date yield and quality has been positive.

Figure 6: Hydrogel and soil-moisture sensors



Another project in colaboration with private sector in this vein is evaluating the feasibility of a subsurface irrigation system (Figure 7) developed for water conservation in semi-arid areas. The system stores water in the elements, which gradually infiltrate into the soil to meet the vegetation's evaporative requirements – thus saving labor and maintenance costs, and using less water by avoiding direct evaporation. The first year's results were encouraging: the system has water-saving potential of 35% to 45% compared with the traditional bubbler system without affecting crop yield, though it performs best with low-salinity water.

Figure 7: Subsurface irrigation system and soil-moisture sensors



Pest and disease management


Drone at ICBA research station

ICBA also evaluates the effectiveness of different techniques for controlling RPW, including pheromone traps, traditional traps, chemical treatment, eco-friendly organic treatment, and electronic devices. The results show the effectiveness of both chemical and organic treatment when used in an integrated approach. The researchers also found that the use of electronic device that is placed on the tree's trunk, showed effectiveness in monitoring and protecting against RPW activity and has high potential for large-scale use. ICBA is also testing and implementing a system of the IoT and drone-based data collection (Figure 8) integrated into a GIS-based AI analysis platform (Figure 9) for monitoring date palm plantations (the Palm Smart Management Solution). This body of work forms part of ICBA's participation in an FAO-led research consortium on RPW eradication.

Figure 8: Multispectral drone imagery at a ground sampling distance (GSD) of 8 cm

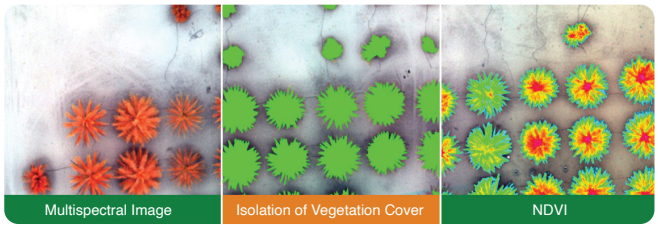
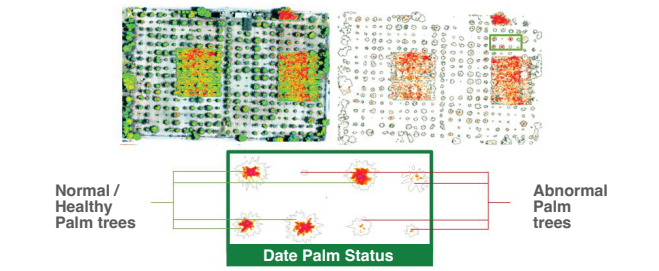
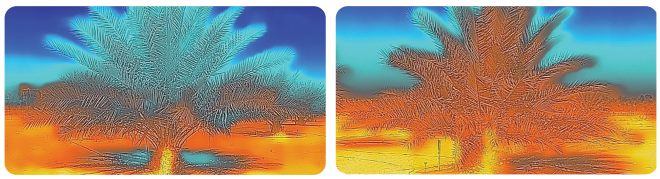


Figure 9: Machine learning to detect abnormal date palms





Water-stressed date palm (left) and a non water-stressed counterpart (right) shown with a thermal imaging camera.

Understanding genetic and molecular basis of Red palm weevil Resistance in Date palm

The program also focuses on understanding the genetic and molecular basis of host plant resistance for RPW in Date palm. RPW infestation varies among 18 date palm varieties. Some varieties are resistant due to non-preference or host-plant resistance. The experiment aims to identify the genomic region associated with the differential response of date palm varieties towards RPW. Besides, ICBA scientists published a comprehensive review on recent advances in date palm genomics (Rahman et al., 2022).

Conclusion

ICBA's research on date palm over the past two decades shows that sustainable production of the commodity requires continuous modifications in structure and agricultural management strategies to enhance production under water-scarce and salinity environments, and in response to other biotic stresses.

The organisation has evaluated new farming techniques that can decrease the negative impact of irrigation with saline water, in addition to other technologies such as soil enhancers, water-saving technologies, etc. It has found that these techniques help save resources such as irrigation water, and increase the possibility of combating crop pests such as the RPW with modern, environmentally-friendly technologies such as electronic devices and sensors.

The implications of this work for livelihoods, economies, and ecosystems across the Middle East is extremely significant. Looking forward, as the Arabian Peninsula's already-marginal agricultural environments are further compromised by climate change, ICBA's date palm research unit is committed to further work on genetic improvement and developing approaches to integrated management of the nutritious, tasty, culturally- and economically-critical crop in increasingly marginal conditions.

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ICBA is an international not-for-profit applied agricultural research center with a unique focus on marginal environments where an estimated 1.7 billion people live. It identifies, tests and introduces resource-efficient, climate-smart crops and technologies that are best suited to different regions affected by salinity, water scarcity and drought, among other factors. Through its work, ICBA helps to create jobs, and improve livelihoods, food security and nutrition for some of the poorest rural communities around the world.

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