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Date Palm (Phoenix Dactylifera L.) Cultivation: A Comprehensive Guide To Good Agricultural Practices

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Abstract
Good agricultural practices for date palms are vital foundations that directly contribute to improving production in quantity and quality, enhancing tree health, and sustaining their cultivation. These practices include two main types: ground maintenance and palm tree top maintenance, each of which plays a complementary role in supporting growth and production. Ground maintenance begins with processes such as regular fertilization, which is essential for supplying the palm with essential nutrients such as nitrogen, phosphorus, and potassium. This results in robust vegetative growth and improved fruiting. Balanced irrigation is also essential for maintaining adequate soil moisture, especially in arid environments where palms are grown. Meanwhile, tillage improves soil aeration and breaks up clumps, facilitating root uptake of nutrients. Palm tree top maintenance complements these efforts and begins with manual pollination, which is essential because palms are dioecious plants. Proper pollination results in increased fruit set and, consequently, higher yields. Trimming, the removal of dry fronds, also helps improve aeration, reduce pest infestation, and facilitates access to the clusters during maintenance and harvesting. Thorning, the removal of thorns from the fronds, reduces damage to workers or the fruit and facilitates agricultural operations. All these practices, when implemented systematically and thoughtfully, lead to improved productivity, higher fruit quality, and reduced waste, which provides farmers with greater economic returns and contributes to maintaining the sustainability of date palm cultivation as an important food and economic resource.

INTRODUCTION

All countries around the world are currently striving for agricultural growth and moving towards sustainable agriculture to achieve self-sufficiency in agricultural materials. This is in accordance with each country's objectives and the nature of its strategic crops, which also represent one of the economic tributaries and are considered a fixed input. Date palm (Phoenix dactylifera L.) is a fruit crop grown in arid regions. It has been cultivated for approximately 4,000–5,000 years in the Arabian Peninsula, the Middle East, and North Africa (Chao and Krueger, 2007; Tenghberg, 2012). Its cultivation has also spread to many other regions in South Central Asia, Europe, Australia, North America, and South Africa (Zohary and Hopf, 2000). Heuzé et al. (2016) noted that the date palm is an evergreen tree that plays a vital role in ancient and modern social life in these regions. Date palms are also believed to have a high tolerance to heat and drought stress, as confirmed by El-Juhany (2010). Moreover, date palms are considered a key species in the composition of oases agroecosystems, due to their valuable fruits and their numerous roles in enhancing the environment for growing other crops (Tingberg, 2012, Hughes et al., 2016).

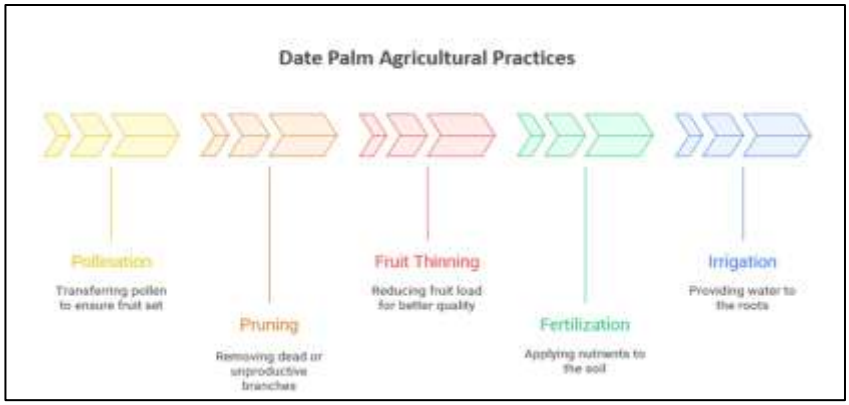

Fig (1): A diagram showing the palm tree service operations for the palm head, including pollination, pruning, and sizing, as well as ground service operations, including fertilization and irrigation.

One of the most important strategic crops, which is a tropical and subtropical fruit, is the date palm. The simple date fruit has captured the attention of a large segment of researchers. The date fruit also has ancient historical significance, and date palm cultivation dates back thousands of years. The date palm tree also has a significant

social and economic status and is of major agricultural importance in oases such as the Arab Republic of Egypt, the Kingdom of Saudi Arabia, Tunisia, Morocco, and many other date-producing countries. Dates are often used as a traditional food source and have numerous by-products created from tree waste, such as leaves and seeds. They also offer numerous environmental benefits, making date palms one of the best fruit trees to cultivate. Governments and the private sector are currently striving to establish commercial palm farms and encourage date production. Despite the important role played by the Ministry of Agriculture and the efforts made, date cultivation and the production, processing, and marketing of dates remain beset by numerous problems. These include poor quality varieties, poor farm management, and the spread of pests and diseases. Marketing constraints and insufficient applied research are also major challenges to date palm production. The date palm (Phoenix dactylifera L.) is a flowering plant grown primarily for its delicious fruit, and the variety of its varieties offers a wide range of culinary qualities. Previous studies have shown that date trees can reach more than 20 meters in height in tall varieties, including Egyptian varieties such as Zaghloul, Ummat, and Hayani. There are also medium-length varieties, such as Khalas, Riziz, and Shishi, which are Saudi varieties, while there are also short varieties, the most famous of which is Barhi. Depending on the variety, the length of the leaves can reach from 3 to 6 meters, with different ends, including two-point and three-pointed. The leaves also contain many leaflets, due to them being compound pinnate leaf, with approximately 120 to 150 leaflets. During the fruit growth period, fruits go through several growth stages, which are: (kimri, hanbok, khalal, rutab, and tamar), as they are called in the Middle East (Świąder et al, 2020).

Botanically, the date palm belongs to the Arecaceae family, a group of monoecious, dioecious plants, with male flowers on one tree and female flowers on another. It is classified within the Angiosperm family (Obón et al, 2023). The Arecaceae family includes more than 2,500 species and 200 genera, demonstrating a wide diversity of palm-family plants with unique characteristics and features (Dransfield et al., 2005). It also includes one of the palms genuses, Phoenix, which includes approximately 14 species native to tropical or subtropical regions, such as many countries in Africa and South Asia (Ayer et al., 2024). One of these species is Phoenix dactylifera L. The word "finger-bearing" in the species name "Dactylifera" refers to the clusters of fruits produced by this plant. Dactylifera is a combination of the Latin term ferous, meaning "to bear," and the Greek word dactylus, meaning "finger" (Kamal & Ghnimi, 2018).

Date palm trees are one of the most adaptable plants to grow in arid environments. Their fruits are delicious, filling, and rich in large quantities of essential minerals, vitamins, proteins, fats, and carbohydrates. As is well known, they were eaten with milk as a complete meal in ancient Islamic times. Therefore, people cultivated and planted palm trees to use date fruits as a food source, as they were available at the time. In fact, people in the Middle East consume dates throughout the year, with a special Islamic custom during the holy month of Ramadan. There are also many, many different uses for the various parts of the palm tree in industrial products. Trunk waste can be used in furniture, chairs, and table industries, and leaf stalks are of particular importance in the manufacture of compressed parquets and ceilings. Trunk and leaf fibers are also used in the manufacture of mats, paper, baskets, ropes, bags, and ties (Zhao and Kruger 2007; Al-Hadrami and Al-Khairi 2012). In addition, the production of charcoal and activated charcoal is a valuable product for its various uses in agriculture to improve soil fertility, as well as in laboratory applications in tissue culture media, and for many medicinal purposes (Al-Muslim et al. 2019; Al-Hadrami and Al-Khairi 2012; Ghanteet et al. 2018; Kulkarni et al. 2010; Tang et al. 2013). Its use for ornamental purposes and decorative works is well known, as the paper is used to make bouquets and gifts, and for some religious occasions in some non-Islamic countries. Species such as P. canariensis, P. roebelenii, P. canariensisor, and P. theophrasti are among these.

Botanically, date palms belong to the Arecaceae family, a group of monoecious, dioecious plants, with male flowers on one tree and female flowers on another. They are classified within the Angiosperm family (Świąder et al., 2020). This Arecaceae family includes more than 2,500 species and 200 genera, demonstrating a wide variety of palm-family plants with unique characteristics and features (Ayer, Santosh, et al., 2024). It also includes one of the date palm genera, Phoenix, which includes approximately 14 species native to tropical or subtropical regions, such as many countries in Africa and South Asia (Barrow, 1998). Recently, genetic studies have been conducted on the genome of date palm trees, and studies are ongoing, which have provided a deeper understanding of the diversity of date palm fruit yields (Alotaibi et al., 2023). Several studies have been cited, as mentioned by Al-Alawi et al. (2017), and some of their data are included in the following table, No. (1) and Figure No. (2).

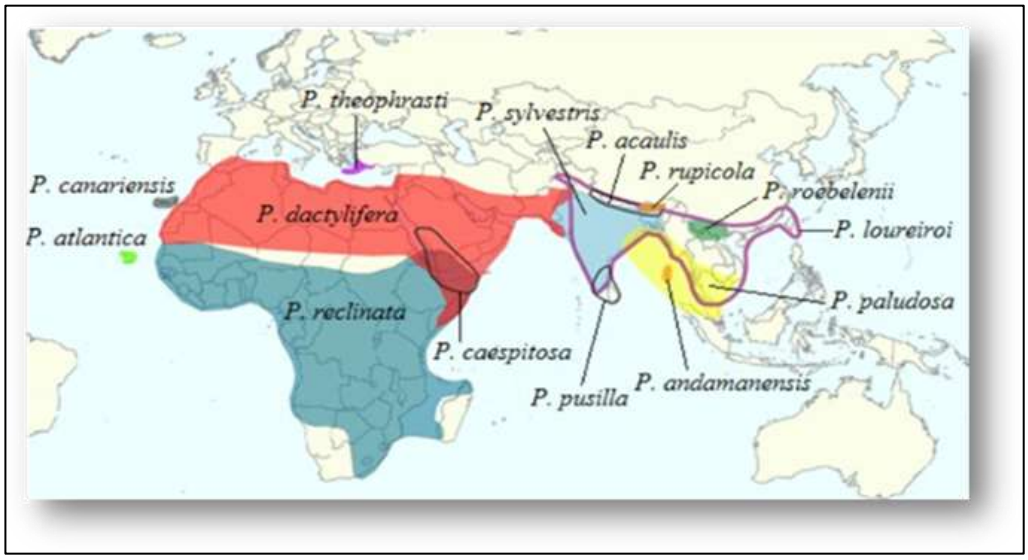

Figure 1. Distribution of the Phoenix species. (Map by M. Gros-Balthazard based on Munier, 1973; Barrow, 1998; Henderson, 2009; Balthazard, 2013).

Species	Locations	Local Name
Phoenix dactylifera L.	Egypt, Saudi Arabia, Tunisia, Arabian Peninsula, Australia, California, Pakistan, China, Iran, India, Mauritius, northern and western Africa, and Spain.	Date palm
Phoenix caespitosa	Egypt, Saudi Arabia, Tunisia, Oman, Morocco, and Djibouti.	Date palm
Phoenix rupicola	India, Andaman Islands, Bhutan.	Cliff date palm
Phoenix paludosa	India, Andaman, Indochina, Sumatra.	Mountain date palm
Phoenix loureiroi	India, China, the Himalayas, the Philippines.	Mountain date palm
Phoenix roebelenii	China (Yunnan) to North Indo-China.	Pygmy date palm
Phoenix pusilla	Sri Lanka, India.	Ceylon date palm
Phoenix reclinata	Africa, Madagascar, Arabian Peninsula, Comoros.	Senegal date palm
Phoenix theophrasti	Turkey, Greek Islands.	Cretan date palm
Phoenix sylvestris	Indian Subcontinent, China, Myanmar.	Indian date palm
Phoenix canariensis	Australia, Spain, Bermuda, Canary Islands, Italy.	Canary Island date palm
Phoenix acaulis	India, Bhutan, Nepal, northern.	Stemless date palm
Phoenix andamanensis	Myanmar.	Andaman Island date palm
Phoenix atlantica	Cape Verde Islands.	Cape Verde Island

Table (1): The table shows some types of date palms and their local names in some countries.

IMPORTANCE AND USES

Date palms have become one of the most important cultivated palm species in the world and the Arab world, in addition to their pivotal role in the economies of many countries in the Middle East and North Africa (Al-Alawi et al., 2017; Al-Hadrami and Al-Hadrami, 2009; Al-Hadrami and Al-Khairi, 2012; Jin, 2012). Dates are rich in carbohydrates, which are their main component. Carbohydrates constitute between 65-80% of the sugar content of the flesh, while fiber (2.5%), protein (2%), and fat (2%) are also present in small amounts (Al-Harrasi et al., 2014). It's worth noting that recent interest in bioeconomics has focused on increasing and highlighting the role of industrial technologies in contributing to the production of new and renewable biological resources and their reuse in the production of numerous outputs, including food products, animal feed products, and bioenergy production. This increases the added value of this important strategic crop (Scarlat et al., 2015; Lainez et al., 2018; and Alsafadi et al., 2020). Therefore, some researchers have been working to find new ways to exploit date waste and residues, which exceed the equivalent of two million tons of waste annually worldwide, and to create new industries to exploit these quantities, especially since they are environmentally friendly and do not affect human health (Basbas et al., 2009; Alsafadi et al., 2020). Among the resulting outputs are the production of amino acids from microbial fermentation products, biofuel production, and enzymes (Shawhan et al., 2007;

Abdullah and Al-Sadiq Al-Anani, 2012; Akourin; Amoush, 2012; Al-Safadi et al., 2020). There is also a scientific revolution in the reuse of palm tree waste from several angles, such as the extraction and production of cellulose materials from biomass, the production of bioplastics used in many industries, such as environmentally friendly plastic bags from oil palm trunks (Zaidi and Zuleikha, 2020), and the production of some materials that can be added to worn fabrics for reuse, such as those used in upholstery of seats and leather jackets.

NUTRITIONAL AND HEALTH BENEFITS

Studies over the past years have proven that dates have a high nutritional value, as they contain many essential minerals necessary for cell development and growth, including magnesium, silicon, calcium, copper, iron, phosphorus, potassium, and sulfur, with low or limited levels of chlorine and sodium. They are also a treasure trove of various vitamins, such as biotin, thiamine, folic acid, ascorbic acid, and riboflavin. Studies and research have shown that carbohydrates are the most abundant component, representing 65-80% of the sugar content of date flesh. Fiber, protein, and fat content have been estimated at 2.5%, 2%, and 2%, respectively. Fiber is present in very small amounts (Ahmed and Ahmed, 1995; Al-Houthi et al., 1997; Mihara et al., 1999; Al-Harsi et al., 2014). Functional foods also provide health benefits in addition to a basic diet (IFICF, 1998; Al-Farsi and Lee, 2008). From a medical perspective, studies conducted by the medical sector have shown a clear, significant association between the consumption of dates and vegetables and their association with lower mortality rates from heart disease and some common types of cancer. The numerous sources of antioxidants, dietary fiber, and other bioactive compounds in fruits have reinforced the importance of their consumption. Religious texts, such as the hadiths of the Prophet Muhammad in the Islamic religion, have confirmed this fact (Joseph et al., 1999; Dillard and German, 2000; Prior and Kao, 2000; Wargovich, 2000; Al-Farsi and Lee, 2008). There are several recently published studies on the possibility of extracts from some Saudi date cultivars, such as Khalas and Rizeez, reducing the effects of myocardial infarction (Baliga et al., 2010; Khalid, Khalid, Khan, Ahmed, & Ahmed, 2017). Date fruits undergo four stages of development and formation during their physiological growth, divided according to their physiological age, starting with the first chimeric stage, followed by the Khalal stage, then the Rutab and Tamer stages (Sawaya et al., 1982; 1983; Mustafa et al., 1986; Siddiqui and Gupta, 1994; El-Zoghbi, 1994; Ahmed and Ahmed, 1995; Al-Hooti et al., 1997; Myhara et al., 1999; Al-Shaheeb and Marshall, 2003; Al-Farsi and Lee, 2008).

PROPAGATION

This type of propagation is achieved by growing offshoots from axillary buds located at the base of the stem of the parent plant, spreading around the trunk in all directions. The same tissue as the original parent plant. Fruiting usually begins after 2 to 3 years. The lifespan of the palm tree is divided into two distinct developmental stages: vegetative, where the buds that form the leaf veins develop into branches. From the time the axillary bud of a leaf differentiates into a branch, it takes up to three years (18–36 months) to reach the ideal size for division and planting for three or four years (Hilgemann, 1954). Shoots begin to emerge around the parent trunk approximately (a line) years after the mothers are planted in the ground, depending on the variety (Nixon and Carpenter, 1978). Although a single palm tree produces 20 to 30 offspring, only 3 or 4 can be grown per year. These must be kept for a year or two before planting in a nursery to allow roots to develop, increasing their success rate. Several varieties, such as the Egyptian Hayani, Zahidi, and Briem, produce large numbers of offspring, while some varieties, such as the Barhi and Maktoum, produce significantly fewer offspring. Offspring typically emerge at a sharp angle next to the mother tree trunk. The offspring is always separated from the mother tree on one side, and the newly removed offspring is then placed in a disinfectant solution before being planted in its permanent location. The separation site on the mother tree trunk is also disinfected with micronized sulfur to prevent insects such as the red palm weevil from entering the palm trunk from the separation site on the mother tree.

Recently, through ongoing scientific research and development over more than half a century, scientific efforts from around the world have combined to improve agricultural production outcomes and maintain environmental sustainability. This effort has been achieved by innovating and developing new propagation methods and techniques that contribute to increasing the number of plants in a short period of time, regardless of a specific agricultural season. This is known as "plant tissue culture." Consequently, this science has been utilized for plant propagation, and this technology has been used to increase the quantity of date production by producing seedlings that are resistant to pests and diseases and completely identical to the variety (Al-Khairi 2005, 2007; Zaid 2002 a, b). Using this technology, female trees are propagated from selected, healthy, disease-

free trees, as well as, sometimes, male trees that are resistant and superior in the characteristics and beneficial properties of pollen, which influence fruit characteristics. Through this technology, genetically homogeneous plants can be produced.

PALM CROWN SERVICE OPERATIONS

Good agricultural practices, that are usually carried out on palm trees include transactions that are specific to the palm tree head and are carried out according to the agricultural season, starting with pruning operations that may be carried out after harvesting at the end of the agricultural season, and the timing varies according to the region and the plant variety, or they are carried out when the trees begin pollination operations at the beginning of the season, followed by pollination operations that are carried out in several ways that will be discussed later, then the bagging operations of the pollinated shoots with pollen grains to preserve the pollen grains, come the two stages of thinning the fruits, which improve the fruit shapes to a great extent, then the process of harvesting the fruits according to the nature of the variety and the geographical area in which it is planted (Anon, 2002; Akyurt et al., 2002). Agricultural practices also include a component that occurs on the soil, called soil improvement operations, which include irrigation, fertilization, weed control, and the like. These operations will be discussed in more detail in their respective sections in the chapter (Anon, 2002; Akyurt et al., 2002). For example, the development of the date industry in countries such as the United States has included significant contributions through scientific research aimed at identifying the most important agricultural practices suitable for the palm crop. Through studies conducted by Swingle (1904), specific production areas in the United States were selected based on climatic similarities with Old World date-producing regions, which are characterized by high quality. Most of the research related to improving date production in the United States was conducted by collecting information through interviews with individuals associated with date farms in the United States, which are owned by the Department of Agriculture. In particular, Cooper (1995) contributed to many developments in date cultivation and its dissemination to farmers. More recently, his work and that of others have been incorporated into the Bulletins of Date Cultivation in the United States, first published in 1945, with the final edition in 1978 (Nixon 1945, 1959, 1965; Nixon and Carpenter 1978).

POLLINATION

Pollination is an important factor affecting fruit set and fruit quality (Ahmed et al., 2022b). It is essential to have some information about the type of variety being pollinated, along with knowing the timing of female anther emergence (early, mid-late, or late). Similarly, it is important to know the male's influence on female traits (such as xinnia and metaxnia). It is also important to know the period during which female flowers are receptive to pollen grains, as female flowers do not remain receptive to male pollen grains for long, and the receptive period varies according to several factors, including environmental conditions and the nature of the variety (Shahid et al., 2017; Muralidharan et al., 2020). Previous studies have also shown that the later the pollination is after the others have split, the weaker the fruit set and productivity (Salomon-Torres et al., 2021). Through studies conducted by Maryam et al., (2015), it was found that vaccination should not be delayed for more than 3-4 days. As previously mentioned, certain environmental conditions can significantly affect the pollination and fertilization processes. Temperature plays an important role in various stages of sexual reproduction in flowering plants, such as pollen formation, pollen transfer from male to female trees, stigma readiness to receive pollen, pollen entry into the pollen tube, pollen tube growth, double fertilization, and seed development (Hedhli et al., 2003, 2005; Snyder and Oosterhuis, 2011; Zulkarnain et al., 2019; Ali Dinar et al., 2021; Alaa et al., 2022). Date palms thrive in warm and dry climates. The ideal temperature for date palm pollination is between 20 and 35°C. Climate change has a negative impact, as extreme temperatures, whether very hot or very cold, can negatively impact the success of pollination in areas where date palms are grown. Seasonal temperature variations also affect flowering timing and, consequently, pollen availability and pollinator activity (Dehghan-Shawar et al., 2010; Awad and Al-Qurashi, 2012; Karim et al., 2022).

In this area of pruning, numerous experiments and studies have been conducted to determine the optimal method for pollinating date palms, albeit with varying pollen sources, concentrations, and the degree of responsiveness of varieties to the pollination process. Most studies were conducted in the Middle East, North Africa, and East Asia, including Saudi Arabia, Iraq, Oman, Iran, Egypt, Jordan, the United States, and Pakistan. A study by (Al-Wasabi et al. 2012) compared the manual pollination technique with mechanical dusting for several date palm varieties in Saudi Arabia (Khalas and Shishi). The results showed that the highest percentage of fruit set and the lowest fruit drop occurred when pollen was used using the manual technique .Atallah et al.

1998) also studied pollination on Saudi date palm varieties and reported that different concentrations of pollen applied using the dusting technique significantly increased the percentage of fruit set (Jameela & Alagirisam, 2021).

TRADITIONAL METHOD

One of the most common methods of pollination is the traditional method, which involves placing the male panicles in the center of the female inflorescences and gently tying them together. Typically, 10-12 male panicles are placed inside the female flowers when the female stigmas are ready for pollination. This is done by having the worker climb the female trees to place the male panicles in the female flowers and tie them with a light ribbon. This is a time-consuming and labor-intensive process that has become unviable, especially on farms with large numbers of trees. This activity also requires more labor, which in turn leads to higher production costs. However, many farmers still prefer pollination using this method.

DRY POLLEN DUSTING METHOD

Hand pollination using dried pollen is more efficient, as pollen is mixed in varying proportions with inert materials such as wheat flour and talc (Salomon et al., 2021; Salomon et al., 2017; Hajian, 2005; Ullah et al., 2018) Mixing ratios are typically (1:1 to 1:10). By spraying the pollen through the pollination devices, hand pollination is generally accomplished by spraying dried pollen onto the female flowers. Sometimes, as an alternative to traditional pollination, sponge strips loaded with date palm pollen can be used. Between one and three pieces are placed in the center of a female cluster, depending on its size (Ben Abdallah et al., 2014). This method is recommended in areas where pollen is scarce and difficult to obtain, as it is one of the methods that utilizes DPP most efficiently.

LIQUID SUSPENSION SPRAY METHOD

Using hand-held or automated spraying systems, a pressurized water mixture is released, and the pollen grains are released in liquid form. The mixture is usually in proportions ranging from 0.5 to 3 grams of pollen per liter of water (Salomon et al., 2021). Approximately 100 ml is sprayed on each female inflorescence (Abu-Zahra et al., 2021). This method has been found to produce better results.

THINNING AND PRUNING

Thinning and pruning should be carried out 3-4 weeks after fruit set (late April - May), depending on the region, after the fruit begins to enter the growth phase. Thinning is an important method for improving fruit quality. There are several methods for thinning, including manual thinning, which involves selecting specific fruits and leaving others. Another method is thinning a third of the fruit cluster from the center of the cluster to improve ventilation and redistribute nutrients to the fruit, or by cutting a third of the length of the cluster. There are also chemical thinning methods, which involve the use of certain substances that help separate the fruit cone from the stalk, such as naphthalene acetic acid (Ghazzawy et al., 2010). These procedures are practiced in some countries, but not in countries with traditional oases. In most modern farms, these procedures are carried out to increase fruit size, improve quality, and restore the tree's physiological balance by addressing the phenomenon of alternating loads. Trees are subjected to an average of 8-10 leaves per fruit cluster. The recommended number of fruit clusters ranges from 10 to 12 per tree, depending on the age of the palm and the level of service. Research has shown that the use of these practices has increased fruit size, leading to an approximately 30% increase in the production of quality dates (Sedra and Zirari 1998).

IRRIGATION

In general, gravity irrigation is used on small farms for most varieties. The monthly irrigation dose per palm ranges from 6-16 m^3 during cold periods and 17-25 m^3 during hot periods. This also varies depending on the age of the palm, its density, and the irrigation method. With gravity irrigation, the average annual irrigation for 100 palms per hectare ranges from 11,000 m^3 (cubic meters) for young palms to 16,750 m^3 for mature palms. These requirements increase when other crops are grown alongside dates. Drip irrigation systems are increasingly used on new farms and large farms, ensuring the plants' needs and water availability. Irrigation of date palm trees is one of the soil care items, which also includes fertilization, which will be reviewed later. The irrigation needs of date palm trees are a basic need for the different growth stages. Strategies for rationalizing irrigation water use and conserving water resources come from managing irrigation water scheduling, and knowing the actual water

requirements is the basis for determining the water quantities required for irrigation according to the age stage and productivity of the trees. In one study, Fore and Armstrong (Furr & Armstrong, 1956) conducted a study to evaluate the annual water use of date palm trees of the Khadrawi variety to be (1300-1600 mm), with monthly totals ranging from (60 mm/winter to 190 mm/summer). Then, (Hilgeman & Reuther,, 1967) conducted another study, where they estimated the water requirements of date palm crops in California through soil samples. Several attempts have also been made to estimate the actual water use (ET) of date palms in some North African countries, such as (Hussein & Hussein, 1982) in Egypt, as well as some studies conducted in the Al-Ahsa region in the Kingdom of Saudi Arabia (Helal &Salem, 1986; Hussein, 1986) and Iran (Furr & Armstrong, 1975). A study conducted in Tunisia found that the minimum annual water requirement was 63 cubic meters per tree, while the actual water requirement, including a wide range of losses, was 95 cubic meters per tree. (Al-Amoud, 2000) determined that the average quantities delivered to date palms each year were 108 cubic meters per tree, 216 cubic meters per tree, and 324 cubic meters per tree for irrigation systems of 50%, 100%, and 150% of the evaporation rate, respectively.
(Al-Ghobari, 2000) The data indicated that short-term irrigation with large quantities of date palms performed better than long-term irrigation systems (Helal &Salem, 1986). The results of another study conducted on Scotti date palms in Egypt showed that the best irrigation period was one month, with an amount equivalent to 71 mm per irrigation (Hussein & Hussein, 1982). The total annual water quantity in the southwestern region of Saudi Arabia was determined to be 136 cubic meters per tree. (Alazba , 2004) The actual annual water use for palm trees was found to be between 137 and 55 cubic meters in the eastern region, and about 195 and 78 cubic meters in the central region for surface and drip irrigation, respectively. The total annual water depth required was estimated to be between 2,700 and 3,000 mm (Abdul Baki & Aslan, 2005). The evaporation and transpiration rates for Sukari cultivar trees aged 12-15 years and irrigated at rates of 1780 and 1640 mm, respectively. The data recorded the average daily evaporation and transpiration (average of 20 days as a minimum) between about 2.4 mm per day (at pollination) in February, and about 7.6 mm per day (at the Khalal stage - the soft fruit ripening stage) in July (Kassem, 2007). The results of experiments on the use of palm water in various locations in the Kingdom of Saudi Arabia, extending from Najran in the south to Qassim in the north, showed that the values obtained were as follows: Wadi Al-Dawasir recorded the highest annual quantity (80 cubic meters per tree), followed by Al-Hofuf (70.7 cubic meters per tree), Al-Madinah Al-Munawwarah (69.3 cubic meters per tree), Riyadh (67.7 cubic meters per tree), and Qassim (66.9 cubic meters per tree). The lowest (59.4 cubic meters per tree) was in the Najran region. The average daily use of palm water was (184.4 liters per day) for all regions of the Kingdom of Saudi Arabia, and the total net annual use of palm water ranged between (59.4 and 80 cubic meters per tree (Alamoud et al., 2012).

IRRIGATION SYSTEMS

Choosing an irrigation method is important and essential to provide ideal irrigation systems that suit the nature of environmental conditions and soil quality and are sufficient to meet the needs of agricultural development (Viala, 2008).

FLOOD IRRIGATION SYSTEM

It is one of the systems commonly used for irrigating palm trees, and it is irrigated using a surface irrigation system. In the past, palm farms in the Kingdom of Saudi Arabia were irrigated from wells using surface irrigation, especially basins, which were typically irrigated once a week in the summer and every three weeks in the winter (Carr, 2013). This typically consumes large quantities of water, as shown in (FAO, 2008). The quantities vary according to the soil type and environmental conditions of the region and are usually determined based on the farmer's experience in the area. The water requirements of mature palm trees have been estimated to be between 115 and 306 cubic meters, equivalent to 1.15 to 3.06 cubic meters per hour (Al-Amoud, 2010). In general, the proposed irrigation requirements for palm trees planted in various regions of the Kingdom ranged between 39,585 and 72,270 cubic meters per hour annually for flood irrigation (Al-Amoud et al., 2012).

BUBBLER IRRIGATION SYSTEM

Through recent experiments, the bubble irrigation system, which is a modified version of the drip irrigation system, was developed (Rawlins, 1977). Researchers (Amiri et al., 2007) studied the response of date palm trees, Zahdi cultivar, under three irrigation systems at different rates: basin irrigation, bubbler, and sprinkler. The results showed an increase in growth in line with the increase in water, and that the bubbler irrigation system

was the best. In another study, the experiment proved that bubbler irrigation was the best method, followed by basin irrigation and sprinkler (Ibrahim et al., 2015). The results indicated that about 30.94% of water was saved under the bubbler irrigation method when compared to the basin irrigation method (Soothar et al., 2015). According to (FAO, 2008), the bubbler irrigation system consumes 24,288 m3 h^{-1}, saving 9,000 m3 h^{-1} compared to the flood irrigation system.

SURFACE DRIP IRRIGATION SYSTEM

In a study conducted by Ruffini (Reuveni, 1971) to investigate the effect of adding drip irrigation compared to sprinkler irrigation on the growth and productivity of palm trees, the results showed that drip irrigation has advantages over sprinkler irrigation, as drip-irrigated trees can be grown with limited soil moisture. The results of the study showed that drip-irrigated palm trees exhibit acceptable growth rates in leaf, flower, and fruit development compared to those irrigated using sprinkler systems (Nimah, 1985). This system reduces soil erosion and ensures uniform water distribution due to complete control over quantities and timing, while reducing labor costs and disease incidence (Sivanappan, 1998). The productivity of drip-irrigated palm trees was significantly higher than that of sprinkler-irrigated palm trees (Al-Amoud et al., 2000). In addition, the system improves efficiency and reduces water losses due to evaporation and deep water infiltration (Al-Amoud, 2010). Some problems have been studied by Al-Amoud (2010) in the drip system, for example, irrigation pipe networks are damaged by sunlight and salt accumulation. These are treated by blocking the drippers with small roots, lateral installation, and fertilization by irrigation.

SUBSURFACE DRIP IRRIGATION

Subsurface drip irrigation is a modern irrigation method and is considered one of the best irrigation technologies. (Al-Amoud, 2010) demonstrated that subsurface drip irrigation is the optimal solution for water conservation and increased yield. Other studies (Phene, 1995) found significant increases in production and improved quality. There are some additional practical advantages associated with subsurface drip irrigation: the relatively dry soil surface allows access to agricultural equipment and significantly reduces weed growth (Phene, 1995). Subsurface drip irrigation reduces root rot and other soil diseases. Additionally, subsurface drip irrigation systems are not affected by sunlight or harsh weather conditions and reduce labor costs (Kalfountzos et al., 2007). Farmers have adopted subsurface drip irrigation for various reasons, including increased yield, ease of harvesting when the crop is intercropped, and the possibility of using fertilizing irrigation through pipes (Thompson et al., 2009).

CONCLUSION

Based on previous studies, good palm cultivation practices, such as ground management, which include fertilization, irrigation, and tillage, and palm tree management, which includes pollination, pruning, and thorn removal, are essential pillars for increasing production and improving fruit quality, as well as contributing to better economic returns and the sustainability of palm cultivation.

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