Date Palm Fruits (Phoenix dactylifera L.)

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The date palm (*Phoenix dactylifera* L.) is traditionally cultivated in arid regions of the world, including the Arabian Peninsula. It is one of the oldest fruit trees, a key component of the food system, and is recognized as a symbol of prosperity in the Arab world.

Keywords: date palm ; salinity ; mineral

1. Introduction

The date palm (*Phoenix dactylifera* L.) is traditionally cultivated in arid regions of the world, including the Arabian Peninsula. It is one of the oldest fruit trees, a key component of the food system, and is recognized as a symbol of prosperity in the Arab world. Accordingly, the date palm is appreciated for its high nutritive, economic as well as social values. The production, use, and processing of dates are continually increasing in all parts of the world. There are over 1500 known date palm varieties, and nearly 250 of those are produced in the Arabian Peninsula. The United Arab Emirates (UAE) has the largest number of date palms of any single country in the world. It has over 40 million date palm trees, with more than 200 cultivars, 68 of which have commercial importance. The UAE ranks among the top five major date producing countries in the world [1]. The export of dates from the UAE exceeded 275,862.901 tons in 2016 [2]. The UAE is also among the countries with the highest consumption of dates. Tamar and Rutab are the most consumed dates in the UAE. The average daily consumption per capita ranges between 8 and 10 dates (72–114.3 g) [3][4].

The physical scarcity of water and salinity represent a serious concern for food production in the Middle East and North African (MENA) region. The date palm is known to tolerate several biotic and abiotic stresses and is known to be the most salt-tolerant of all halophyte crops. The palm tree has a minimal water demand, and tolerates harsh weather and high salinity [5][6]. Nevertheless, due to the large number of date palm trees grown in the UAE, a large amount of water is used for irrigation. For example, the irrigation of date palms currently accounts for about one-third of all groundwater used in the UAE [7]. Moreover, the salinization of both surface and groundwater systems has been exacerbated by high evapotranspiration rates. The salinity is further exacerbated by the noticeable effects of climate change on increasing temperatures and declining rainfall [8]. Date palm growth and production are adversely affected by increasing soil and water salinities.

Soil salinity poses a serious threat to agricultural productivity and food security worldwide. More than 6% of the total land area is affected by salt, which pertains to more than 800 million hectares of arable land [9]. Soil salinity is more pronounced in arid and semi-arid lands, which face other agricultural impediments such as water shortage and land degradation [10]. This is particularly true for the UAE. The UAE is facing multiple challenges in managing water resources. These include the scarcity of freshwater resources, a saltwater intrusion of aquifers, and overexploitation of groundwater resources. The concern over water scarcity and its impact on the environment and agriculture has prompted researchers to explore other water source alternatives, including saline (brackish) water for irrigation. Therefore, to exploit saline water and/or salt-affected land, it is critical to identify appropriate crops of plant species and varieties that have a good range of salt tolerance. Plants that adapt to saline soils and attain normal growth and development are known as halophytes [11].

Adaptability to salinity in plants is a complex process that varies among plant species, cultivars of the same species, and even among individuals of the same cultivars [12]. The physiological basis of this tolerance and sensitivity is not fully known. In general, two types of adaptation mechanism to soil salinity are proposed: (1) dilution or exclusion and extrusion, and (2) osmoregulation [11].

Salt stress significantly affects and limits crop production and growth. In low–moderate salinity conditions, plants metabolize normally with no symptoms of injury. However, they need more energy to maintain a normal metabolism, causing a reduction in growth and yield. The effect on growth is attributed to osmotic effects, ion toxicity, nutrient uptake imbalance, or combinations of these factors. Additionally, high salinity can cause significant morphological changes in the plant response, such as in the plant height, leaf production, and collar girth of different varieties [5][13][14][15]. Date cultivars are classified into two distinct groups based on their growth response to salinity: a salt-sensitive group with a significant reduction in shoot growth, and a salt-tolerant group [16].

In 2001–2002, a long-term experiment was launched by the International Center for Biosaline Agriculture (ICBA), Dubai, UAE in collaboration with the UAE Ministry of Environment and Water, to evaluate the salt tolerance of elite date varieties that are common to the UAE and the gulf region. Salt tolerance studies on the date palm have focused on the effect of salinity on growth and yield, with little or no data available on the mineral quality of the date fruits irrigated with highly saline water. Generally, information on the salt tolerance of date palm varieties and assessments of the impact of long-term use of marginal quality irrigation on fruit quality are scarce and limited. A large gap in understanding the impact of salinity on date palms is therefore evident.

2. Discussion

Dates are an integral component of the Emirati daily meal plan and make a crucial contribution to the population's nutritional intake. Dates are consumed as snacks, or as an ingredient in savory and dessert dishes. Dates are an important source of sugars, mainly the monosaccharides fructose and glucose, and the disaccharide sucrose. Moreover, dates are a rich fiber source, mostly insoluble, with small amounts of protein and fats [17]. In addition, dates are a rich source of a variety of vitamins and minerals, mostly vitamin B complex, vitamin C, selenium, copper, potassium and magnesium [18].

The impact of the irrigation of date palms with saline water on fruit quality, mainly in terms of the mineral content, is a very important indicator for their quality and our understanding of the physiological and biochemical processes involved under saline conditions. The results obtained showed that the mineral content in the varieties evaluated under all salinity levels was within the ranges reported by several other studies [19][20][21]. The 13 varieties of date palms exhibited diversity in their fruit mineral content. Significant variations for only a limited number of minerals were observed due to different varietal responses and the effects of salinity.

Overall, significant variations across the varieties were observed for most minerals. However, the impact of salinity was not similar for these varieties. A total of eight of the investigated varieties, mainly Ajwat AlMadinah, Naghal, Barhi, Shagri, Abu-Maan, Jabri, Sukkari, and Rothanwere were not affected by increased salinities up to 15 dS m^{-1}.

An increase in the salinity level resulted in slight changes in some minerals, but these were mostly not significant. The concentrations of iron, zinc, magnesium, and sodium remained unchanged in all date varieties as salinity levels increased. On the other hand, salinity stress did influence certain mineral compositions in specific varieties. Significant changes were observed in the boron concentration in the Farad variety, calcium in the Makhtoumi variety, copper in the Khnizi and Makhtoumi varieties, potassium in the Nabtat-Saif variety, manganese in the Khnizi and Farad varieties and phosphorus in the Khisab variety. The plant's response to sodium is one of the critical influences of salinity. Results showed that most varieties have a low sodium concentration even at high salinity levels except for the Sukkari, Naghal and Barhi varieties. This indicates the latter varieties are not capable of excluding sodium.

The fruit mineral composition varies within the same cultivated variety and partly responds to genetic effects. However, the performance may also vary depending on the environment. In addition, the variation in date palm minerals is largely due to the effects of abiotic constraints. As a result, some varieties display a high performance with some salinity levels, and a poor performance in others and the rankings between varieties are sometimes changed. This variability in the response of genotypes to salinity corresponds to the genotype–environment interaction.

The performance of all genotypes is highly variable as detected through the interaction matrix. This is the origin of the genotype x environment interaction (GEI), which is further confirmed by the reversal of classification for most genotypes according to the environment (qualitative interaction). This interaction, which induces a variable performance depending on the environment, is attributed to the differences in sensitivity levels to the irrigation water's salinity vs. the plant's defense mechanism. In arid environments such as in the UAE, the genotype x environment interaction is high; therefore, it is impossible to attribute the variation in mineral content between date palm varieties to the single effect of variety or salinity. Hence, it is important to take into account the adaptive characteristics which produce stable production in variable environments, i.e., large adaptability, or stable genotypic expression in a specific environment, i.e., specific adaptation [22][23]. The search for the genetic potential of mineral content in produced food must be accompanied at the same time by the search for performance stability and stress tolerance in the presence of a high GEI [24][25][26]. Moreover, the analysis of the behavior of genotypes according to the characteristics of the environment has long been a priority research topic.

The fluctuation in results from the phenotypic expression of tolerance to salinity through a complex set of biochemical and morpho-physiological properties is attributed to multiple mechanisms, including Na^+ exclusion, Na^+ sequestration in vacuoles, K^+ retention, osmotic adjustment, and xylem control. The general sodium and potassium content, according to the three irrigation water salinity levels, are reversed. The average potassium content is higher in a salinity of 15 dS m^{-1} and the average sodium content is low under the same salinity level and vice versa.

In fact, the tolerant varieties try to limit Na^+ and Cl^- while maintaining the absorption of nutrients such as K^+, NO_3^-, and Ca^{2+} [15][27]. The mineral concentration in the fruits can be maintained under 10 dS m^{-1} and then it decreases or increases depending on the concentration in the soil root zone and the plant's ability to take up minerals under a specific salt content in the root zone. Several regulatory mechanisms, based on the presence of calcium and potassium, and their role in stress signaling, such as that of Ca^{2+}, have been identified as salt tolerance indicators [28]. Salinity tolerance was correlated with sodium-calcium or sodium-potassium selectivity based on a simple exchange of ions on the plasma membrane's surface [29][30]. Therefore, the Na^{+}/K^{+} pump works very well under 10 dS m^{-1}. Consequently, the concentration of an element becomes higher as salinity increases to 5 dS m^{-1}. However, above 10 dS m^{-1}, this tolerance mechanism can no longer work; consequently, the concentration of particular beneficial elements for plants will be reduced. This nutritional stress becomes one of the significant effects of salinity after osmotic stress. Consequently, a specific mineral can increase when salinity increases from 5 to 10 dS m^{-1} and this is probably due to a tolerance mechanism such as potassium retention; then the specific mineral decreases when salinity increases to 15 dS m^{-1}. This indicates that the salinity tolerance threshold is 10 dS m^{-1} for this specific genotype. However, for other varieties, we may observe a decrease as salinity increases from 5 to 10 dS m^{-1}, indicating a tolerance threshold of 5 dS m^{-1} due to inactivation of the potassium retention mechanism.

This study of the long-term effect of saline water irrigation on date palm fruit quality highlighted the instability of Jabri, Fard, Khisab and Nabtat-Saif varieties in terms of their mineral content. Meanwhile, Maktoumi, Barhi Ajwat Al Madinah, Khinizi and Shagri varieties showed fewer interactive behaviors with the salinity variation, and their mineral content was similar to the general mean. Thus, varietal experimentation and varietal performance analysis is an approach that has been widely used for breeding and selection with noticeable results [31]. It involves the establishment of trials as the main tool of research. Experiments are based on varietal trials (grouping several genotypes or varieties), multi-local, very general multi-year and multi-treatment trials, to evaluate the performance of different genotypes.

The %DV, among all the date varieties, remained within the same category (low, good or high) despite some observed changes in the %DV with increased salinity. The only changes in %DV categories were observed for copper in the Khnizi and Makhtoumi varieties (high to good), and for managenese in the Farad variety (good to low), as salinity increased from 5 to 10 dS m^{-1}. Calcium, iron, sodium, and zinc showed a low %DV. Phosphorus was marginally a good source; magnesium and manganese recorded a good contribution to the dietary intake. Boron, copper, and potassium showed a high %DV across the different date varieties.

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