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Growth, yield, fruit quality and nutrient uptake of tissue culture-regenerated 'Barhee' date palms grown in a newly established orchard as affected by NPK fertigation

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ABSTRACT

A field experiment was conducted during 2013 and 2014 seasons to compare fertigation and conventional soil broadcast fertilization on growth, yield, fruit quality and nutrient uptake of tissue culture-regenerated 'Barhee' date palm grown in sandy loam calcareous soil in a newly established orchard. In the conventional treatment (CT), the recommended dose (450 g N, 225 g P and 225 K g/tree) was applied as a soil broadcast in three equal doses. In the fertigation treatments, the NPK fertilizers were injected with irrigation water in 12 equal doses, (T2), (T3) and (T4), represent all NPK amounts of CT, 2/3 CT and 1/3 CT, respectively. The highest fertilization regime either applied as soil broadcast or as fertigation produced the highest total yield per palm compared with other fertigation treatments. However, fruit physical quality parameters were higher at T3 and T4 than other treatments. On the other hand, fruit biochemical quality characteristics showed unspecific trend. Palm growth parameters, chlorophyll a, b, and total chlorophylls concentration as well as chlorophyll a/b ratio were not affected by the fertilization treatments. The CT and the fertigation treatments T2 and T3 increased nitrogen availability without, however, a further increase in leaves, except for T2. At the end of the sixth growing season (third flowering season from transplanting), all the cultivated 'Barhee' palms were rapidly and strongly growing without any losses in all the treatments. However, some flowering abnormalities were observed such as multiple carpels formation, a relatively low fruit set percentage and albinism that were lower in 2014 than 2013 season. In conclusion, fertilization is critical to increase yield of young tissue culture-regenerated palms which might have a relatively high nutrient demand.

1. Introduction

Date palm (*Phoenix dactylifera* L.) is broadly cultivated in hot arid regions of the Middle East and North Africa being one of the most successful and extremely important subsistence crops in these regions (Botes and Zaid, 1999). The kingdom of Saudi Arabia (KSA) is a leading date palm producing country being the third of the top 10 date palm producers (982 546 tones/year) (FAO, 2010). However, there are many regions in KSA which suffer from aridity, salinity and limited water resources (Watanabe et al., 2004; Youssef and Awad, 2008). Moreover, most of agricultural soils in KSA are sandy or sandy loam with high calcium carbonate and poor fertility. Accordingly, both date palm productivity and fruit quality are negatively affected in such conditions. There is a growing demand in international market, for excellent quality dates of cultivars such as 'Barhee', 'Medjool', 'Deglet Nour', 'Hayany' and 'Zaghloul' (Botes and Zaid, 1999; Al-Qurashi and Awad, 2011a). 'Barhee' is a commercially important mid-season cultivar being extensively cultivated in KSA. 'Barhee' dates are different than other cultivars in which fruit are marketed and consumed fresh at the mature full yellow (bisir) stage as a crispy apple-like fruit due to low contents of soluble tannins (Botes and Zaid, 1999). Accordingly, there is a high demand for 'Barhee' offshoots for the new plantations but the number of offshoots which are naturally produced by mature fruiting palms is scarce. Thus, there is a special interest in 'Barhee' date palms regenerated by tissue culture since this technique can provide a great number of homogenous plants that are true to type and free of diseases and can be produced in large scale (Zaid and de Wet, 1999; Alkhateeb, 2008). However, one of the major weaknesses of mass tissue culture propagation technique is the appearance of

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undesired off-type plants, such as dwarfism, fruit set failure, abnormal and/or delayed flowering time especially during the early seasons of flowering (Zaid and de Wet, 1999; Al-Ghamdi, 1993; McCubbin et al., 2000; Cohen et al., 2004; Awad, 2007). Such abnormalities are possibly based on either changes in the DNA during tissue culture processes, climatical factors and/or cultural practices such as pollination process and fertilization regimes. Fertilization is one of the most important cultural practices of date palm orchards to optimize both yield and fruit quality and maintain regular yearly bearing of the palms. However, in the past, most date palm producers mistakenly thought that fertilization is not a critical since; date palm can grow and relatively produce under a wide range of soil and climatic conditions. The efficient use of water and fertilizers is a major aim in all agricultural systems (Dinnes et al., 2002). Accordingly, most date palm orchards were converted from conventional flood irrigation into drip irrigation system that allow applying fertilizers to the palms through the irrigation system, a process known as fertigation. However, the recommended optimum rate of conventionally applied NPK for mature date palm is greatly variable among scientists, possibly due to variations in soil and climatic conditions, irrigation system, tree age and cultivars. For full mature fruiting date palms, Sinclair et al. (1981) recommended addition of 1100 g N and 800 g P/fruitful tree yearly for the highest yield and quality of dates. Bliss and Mathez (1983) recommended 930 g N and 620 g P/tree yearly. While, Dialamia and Mohebi (2010) recommended 700 g N, 500 g P and 1300 g K/tree yearly for the highest yield and quality of 'Sayer' dates in Iran. However, about 2300 g N, 1200 g P and 1400 g K/tree yearly was recommended for Iraqi dates (Al-Rawi, 1998). A similar NPK rate was reported for full mature date palms growing in the United Arab Emirates (Awad et al., 2006). Based on available literature, Klein and Zaid (1999) calculated an average world-wide fertilization rate for mature date palms as 650 g N, 650 g P and 870 g K/tree yearly. In some experiments, date palms showed either little or no response to conventional soil fertilization with NPK (Bacha and Abo-Hassan, 1983; Abdalla et al., 1987; Gehgah et al., 1993). This is possibly due to unfavorable soil conditions for nutrients solubility/availability that limit nutrients uptake by date palm roots (Al-Qurashi and Awad, 2011b; Tripler et al., 2011). Fertigation enables adequate application of water and nutrients in multiple applications during the growing season. Distribution of fertilizers with fertigation could place the nutrients in the desired location of the root zone and thus reduce the fertilizers amount (Clark et al., 1991). Scheduling fertilizer application on the basis of crop nutrient demand also offers the possibility of reducing nutrient element losses associated with conventional application. Compared to conventional fertilization, fertigation may save fertilizers to the extent of 50% with an increase in yield for several horticultural crops (Solaimalai et al., 2005). Fertigation showed success in several fruit crops like citrus (Boman, 1996), olives (Morales-Sillero et al., 2007) and pomegranates (Idate et al., 2001). However, there is little available information on the effect of fertigation on young tissue culture-regenerated date palms in a newly established orchard. Therefore, the aim of this study was to evaluate the effect of fertilization regimes (fertigation at different rates vs. soil broadcast) on growth, yield, fruit quality and nutrient uptake of 5-years-old tissue culture-regenerated 'Barhee' palms growing in a sandy loam calcareous soil as an attempt to enhance orchard establishment and increase economical output.

2. Materials and methods

2.1. Plant materials and experimental procedure

During 2013 and 2014 growing seasons, 20-uniform tissue culture-regenerated palms of 5 years old of 'Barhee' date palm cultivar were selected in a newly established orchard at the experimental station of the Faculty of Meteorology, Environment and Arid land Agriculture at Hada Al-Sham (110 km north east of Jeddah 21° 48′ 3″ N, 39° 43′ 25″ E), KSA. The soil of the experimental site is classified as sandy loam calcareous soil with an average field capacity of 22%. The average soil bulk density is 1.54 g cm^{-3} while its EC and pH are 2.2 dS m^{-1} and 8.0, respectively. The experiment was designed as a randomized complete block design with five replicates (one palm/replicate). The full water requirement of date palm trees during the growing season was calculated based on the recent Penman–Monteith equation for dry land condition as described by Ismail et al. (2014). The required amount of water was supplied three times a week through drip irrigation network using groundwater source with EC_w of 4.7 dS m^{-1}. All the trees were hand pollinated from one male tree in both seasons. Following fruit set (about 4 weeks from pollination), the crop load was adjusted to four bunches per palm in 2013 and seven bunches per palm in 2014 season (representing leaf/bunch ratio of about 8:1). Based on the literature review, the recommended dose required for full mature date palm was about 2300 g N, 1200 g P and 1400 g K/palm (Al-Rawi, 1998; Awad et al., 2006). However, for the young palms (5–7 years old) the recommended amounts are less than those required for full mature palms. Accordingly, and based on the soil fertility of the experimental location, an expected proper dose of 450 g N, 225 g P and 225 g K/palm was determined. The conventional control treatment (CT), included 450 g N, 225 g P and 225 g K/palm that was applied in three equal doses (February, April and May) as soil broadcast around the trunk of each tree and close to the drippers. While, three fertigation treatments, (T2), (T3) and (T4), applied all NPK amounts of CT, 2/3 CT and 1/3 CT, respectively, and were injected through irrigation water in 12 equal doses during each growing season. The injection was scheduled based on the critical stages of flower buds formation and fruit development. This injection schedule was as follow: two injections were applied in the second and fourth week of February; the third and fourth injections were applied in the second and fourth week of March; during April and May the fertilizers were injected once a week. Each dose from each fertilizer (N, P and K) was dissolved separately in 5 l of water, and then all of the three fertilizer solution mixed in one container with a capacity of 20 l. The mixed solution of NPK was injected through a small fertigation unit installed on the dripper lines of each treatment. For better and homogenous distribution of applied fertilizers the injection started at the beginning of last hour of irrigation time and completed within 45 min. The remaining 15 min of irrigation time was used to flush the injection system and distribute the fertilizers efficiently in the root zone area of the trees. The source of nutrients were Urea (46% N) for nitrogen, potassium sulfate (52% K_2O) for potassium and super phosphate (16% P_2O_5) for phosphorus in soil broadcast and phosphoric acid (85% P_2O5) for fertigation treatments. The trees received the other regular cultural practices. Before starting the experiment and at the end of each growing season, soil samples were collected from 0 to 50 cm depth for NPK determination. Pinnae (leaflets) samples (8 leaflets/palm) were randomly collected for chlorophylls and NPK determinations. These samples were collected from the middle part of fully expanded leaves which bear the fruit bunches in their axiles around the head of each tree at early beginning of the bisir stage (fruit color break). At the bisir stage (full yellow color), all bunches on each palm were harvested and total bunch weight was recorded. Fruit samples (25 fruit of each) were also collected for quality characteristics determinations as described below.

2.2. NPK determination in leaves

Total nitrogen in leaves was determined according to the Kjeldahl method (Jackson, 1973) using Kjeltec auto 1030 analyzer. Total