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Effects of applying variable temperature conditions around inflorescences on fertilization and fruit set in date palms

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ABSTRACT

Control of pollination and fertilization in date palm is essential for the development of high-quality fruit. Pollen is harvested from male trees and mechanically applied to inflorescences on female trees. An overly high rate of fruit set may cause excessive fruit load, requiring expensive fruit thinning to prevent reduction in fruit size and marketability. On the other hand, inefficient pollination results in lower yield. Although the female flower has three separate carpels, only one develops into a fruit; the others degenerate. Non-fertilized flowers may develop into parthenocarpic singlet or triplet fruit, which have no commercial value. Environmental conditions affect fertilization and fruit development. The current study characterizes fertilization and early fruit development in date palm under different temperature conditions. The date palm is a very large tree. To study environmental effects on its reproductive biology, special units, termed "modular phytotrons", were designed for this research. They were assembled on pollinated inflorescences of whole 'Medjoul' date trees in the orchard, enabling modification of temperature regimes *in planta*. Pollen-tube growth, fertilization, fruitlet formation and carpel degeneration, as well as early development of parthenocarpic fruit were defined and characterized by macro- and microscopic analyses. Relatively low temperatures applied during plant fertilization significantly decreased pollen germination rate, enhanced formation of parthenocarpic fruit and reduced normal fruit development. The significance of these results to horticultural practices during fertilization and fruit thinning is discussed.

1. Introduction

The date palm (*Phoenix dactylifera* L.) is one of the most important fruit crops in the arid regions of the Middle East and North Africa, providing staple food, beverages, ornamentals and architectural materials (Chao and Krueger, 2007; Zaid and De Wet, 2002a). Global annual production of dates reaches 7.5 million tons (FAOSTAT 2012, http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor). In Israel, date palms are grown commercially all along the Jordan rift from the Sea of Galilee in the north to the Arava valley in the south (Cohen and Glasner, 2015). More than 30,000 metric tons of date fruit are produced annually in Israel. The date cv. Medjoul has the highest commercial value, surpassing all other varieties with regard to fruit quality and size. However, 'Medjoul' fruit quality is very sensitive to environmental conditions (Cohen and Glasner, 2015; Zaid and De Wet, 2002b).

P. dactylifera is a diploid ($2n = 36$), perennial, monocotyledonous plant of the family Arecaceae (Palmaceae). It is dioecious, having female and male reproductive structures on separate individuals. Each inflorescence consists of several dozen strands (spikelets), each carrying up to 100 unisexual flowers. The female flower consists of three sepals and three petals that are fused together, and three carpels that are separate, each carpel having a single anatropous ovule. Naturally, wind-mediated pollination—anemophily—is common in date palms. In commercial production, inflorescences are collected from male trees, and the pollen is extracted and used for artificial pollination of female inflorescences (Bernstein, 2004; Chao and Krueger, 2007). Upon pollination, only one ovule in each carpellate flower develops into

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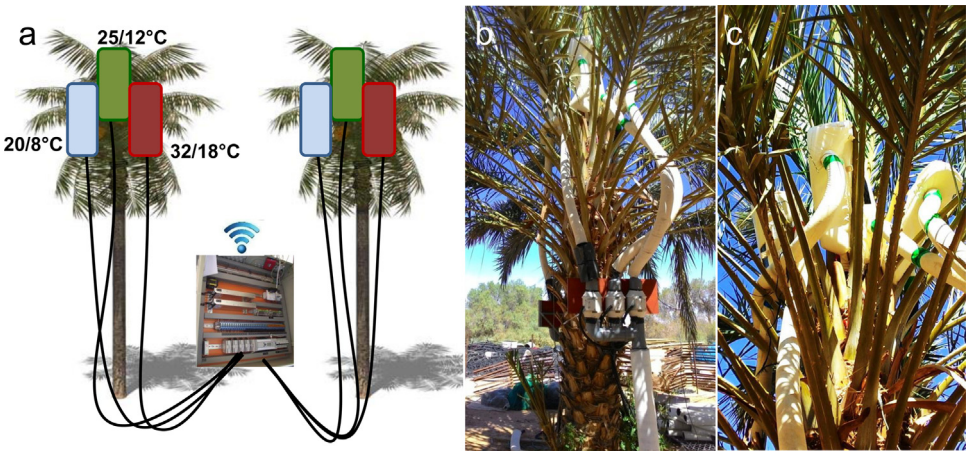

Fig. 1. Schematic representation (a) and photographs (b,c) of "modular phytotrons"—temperature-controlled units assembled on pollinated inflorescences of mature date palms in the orchard. Several different temperature regimes were controlled by Peltier elements or strong air conditioners, capable of rapid heating or cooling of the environment. Ventilators were employed to remove excessive heat within the units.

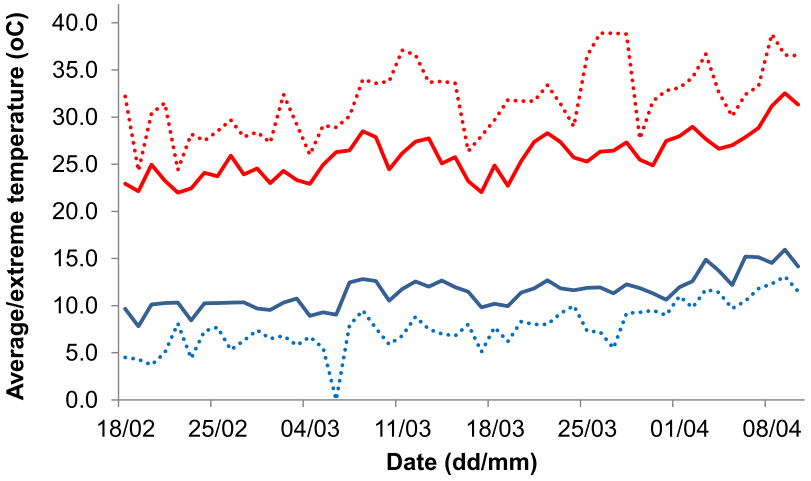

Fig. 2. Daily minimal and maximal temperatures during the pollination period in Yotvata, Southern Arava, Israel during the spring seasons of 2005–2012. For each day of the season, the daily average (solid lines) and extreme (dashed lines) values are presented.

a fruit, whereas the other two carpels degenerate (Bernstein, 2004; Zaid and De Wet, 2002a). However, when pollination is not efficient, parthenocarpic fruit can form, in which one or all three non-fertilized carpels develop (Reuveni, 1986). These parthenocarpic fruit do not ripen properly and have no commercial value. On the other hand, profuse fertilization may result in excessive fruit load, which reduces fruit size and marketability and requires expensive fruit thinning. Therefore, optimization of the levels of pollination and fruit set is extremely important for the production of quality fruit.

Pollination and fertilization processes are affected by various environmental factors. In general, 12–27 °C is optimal for date palm growth, although the trees can withstand higher temperatures, up to 50 °C, as well as short periods of frost at −5 °C (Zaid and De Wet, 2002b). Flowering occurs when the temperature in the shade increases to more than 18 °C, whereas for fruit set, more than 25 °C is required (Zaid and De Wet, 2002b). However, temperatures in some arid regions vary drastically on a daily basis, with amplitudes reaching more than 20 °C; as a result, the success of pollination, fertilization and consequent fruit set is often below optimal levels.

Unlike other fruit crops whose stress-related reproductive biology is well-known, the effects of environmental conditions, and in particular temperatures, on pollen-tube growth, fertilization and fruit set in date need to be further studied. Nevertheless, the date tree's large size makes studies of reproductive processes under controlled environmental conditions challenging. We report on the development and utilization of special units, termed "modular phytotrons", to apply controlled temperature regimes to fertilized inflorescences, thereby enabling a characterization of the effect of temperature regime on fertilization, fruit set and early fruit development in date palm.

2. Materials and methods

2.1. Plant material

Ten-year-old intact trees of date palm (*P. dactylifera* L.) cv. Medjoul grown in an orchard at the Southern Arava Research Center, Yotvata, Israel, were used in this study. In all experiments, the inflorescences were pollinated with a mixture of 50% viable pollen and 50% inert material (w/w) made of potato starch and charcoal.

2.2. In planta *pollination and fruit-setting assay in temperature-controlled modular phytotrons*

The date palm inflorescences were pollinated manually and then enclosed in 12 special modular phytotrons designed by Crystal Vision (Kibbutz Samar, Israel) (Fig. 1). Three bunches per tree in