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Root growth, yield, and fruit quality responses of *reticulatus* and *inodorus* melons (*Cucumis melo* L.) to deficit subsurface drip irrigation

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ABSTRACT

Water scarcity associated with intense and frequent droughts has increased the need for the implementation of drought adaptation strategies that can save water and sustain crop productivity in water limited environments. A two season (2011 and 2012) study evaluated root growth, yield and fruit quality responses of cvs. Mission (muskmelon; *reticulatus*), Da Vinci (tuscan; *reticulatus*) and Super Nectar (honeydew; *inodorus*) of melon (*Cucumis melo* L.) to two irrigation rates (100% and 50% crop evapotranspiration (ETc)) on a silty clay soil under the semi-arid conditions of Texas. Deficit irrigation (50% ETc) increased root length density (RLD) in Mission, decreased in Da Vinci and did not affect in Super Nectar. Marketable fruit yield at 100% ETc irrigation was 77.1 t ha^{-1} in 2011 and 78.7 t ha^{-1} in 2012, but deficit irrigation caused a 30% decrease in marketable yield in both seasons, mainly due to a reduction in fruit size. Yield responses to deficit irrigation also varied with cultivar. A significant yield reduction of 43% in 2011 and 33% in 2012 was measured in Super Nectar, while for cvs. Mission and Da Vinci the reduction in yield was 24% and 30%, respectively in 2012. Deficit irrigation had no adverse impact on melon fruit quality; rather it increased total soluble solids content (23%) in Mission and β-carotene content (25%) in Da Vinci in 2011. At 50% ETc, agronomic water use efficiency (WUE; kg ha^{-1} mm^{-1}) was improved in Mission (13%) in 2012 while it decreased in Super Nectar (21%) in 2011. These results showed that deficit irrigation can save 37–45% of irrigation water in Mission and Da Vinci cultivars (*reticulatus*) with a moderate reduction in economic yield. This practice may not be applicable for cv. Super Nectar (*inodorus*), as it reduced yield without improving water use efficiency.

1. Introduction

Melons (*Cucumis melo* L.) are an important horticultural crop with a worldwide production of 27.3 million metric tons, with China, Iran, Turkey, Egypt and United States accounting for 68% of the world production (FAO, 2013). In the U.S. muskmelons and honeydew melons were grown on 31,360 ha with 925.1 thousand tons of total production in 2012 (USDA-National Agricultural Statistics Service, 2013).

Among the seven horticultural melon groups, *reticulatus* and *inodorus* are the most important for commercial cultivation. Tuscan type, and netted muskmelons commonly known as 'Cantaloupes' in the U.S. belong to the *reticulatus* group whereas, honeydews, are included under the *inodorus* group (Munger and Robinson, 1991). Usually all melon types are cultivated with similar cultural practices particularly irrigation, but the acclimatization response to deficit irrigation varies among the cultivars or genetic make-up (Leskovar et al., 2004; Leskovar and Piccinni, 2005). Thus, the genetic diversity and morphological dissimilarities among melon groups suggest the need to consider water requirements by cultivar.

Melon plants are highly productive under adequate irrigation conditions, but water scarcity is a major constraint to horticultural production in arid and semiarid regions around the world. In 2011, the southern US experienced the most severe drought in 50 years (USDA, 2012). Groundwater supplies have declined severely, and in the future the region is likely to face more strict water regulations (Leskovar et al., 2004; Leskovar and Piccinni, 2005). High energy costs, falling water tables, and increased demand from competing urban, municipal, and rural sectors are dictating the need to implement water saving practices which can optimize water productivity rather than maximizing crop yields (Pereira et al., 2002).

Deficit irrigation, a practice that supplies water below evapotranspiration (ET) demands, deliberately exposes plants to a certain

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level of moisture stress (Fereres and Soriano, 2007). Although deficit irrigation can save a significant amount of irrigation water, there is also a risk of yield reductions in some crops and cultivars.

The feasibility of applying deficit irrigation to vegetable crops has been previously reported in the literature. In watermelons (*Citrullus lanatus* (Thunb) Matsum & Nakai), deficit irrigation (75% ETc) saved 25% of irrigation water with a 34% reduction in yield (Leskovar et al., 2004). Reduced irrigation volumes also caused a reduction in fruit size and yield in muskmelon cvs. Piel de sapo and Sancho (Fabeiro et al., 2002; Cabello et al., 2009). In contrast, studies by Patanè et al. (2011) in tomato (*Lycopersicon esculentum* Mill.), Enciso et al. (2009) in onion (*Allium cepa* L) and Jovanovic et al. (2010) in potato (*Solanum tuberosum* L.) reported 46%, 10% and 38% water saving respectively, without any negative impact on yield.

Besides water savings, deficit irrigation may also have positive effects on fruit quality. Larger irrigation volumes have been reported to decrease melon fruit quality, especially soluble solids content (SSC) (Fabeiro et al., 2002; Sensoy et al., 2007). Water deficit before or at the ripening stage increased (Lester et al., 1994), decreased (Long et al., 2006), or had no effect (Hartz, 1997) on SSC of melon fruits. Moisture stress can induce changes in secondary metabolism of plants (Gill and Tuteja, 2010), which may enhance the levels of health promoting bioactive compounds in fruits. For example, deficit irrigation (75% ETc) caused a 7% increase in lycopene content with no impact on vitamin C content of watermelons (Leskovar et al., 2004). Most irrigation studies in muskmelon quality are related to its effects on SSC, but no information is available on its effect on vitamin C and β-carotene levels.

Subsurface drip irrigation ensures precise application of water directly into the root zone through emitters that are placed beneath the soil surface (Leskovar et al., 2001). Roots generally follow the wetting patterns around emitters (Oliveira et al., 1996); however, deficit moisture supply may cause plants to allocate more resources to roots promoting deeper penetration in the soil profile (Sharp and Davies, 1985) and thus, changing root growth patterns. Although root biomass may decrease or remain unchanged, total root length and growing depth can increase under water deficit conditions (Blum, 2005). Root growth responses also vary among cultivars. Sponchiado et al. (1989) reported that drought resistant cultivars of common beans (*Phaseolus vulgaris* L.) produced higher root length at deeper layers (1.3 m), while drought sensitive cultivars at shallow or intermediate layers (0.8 m). Therefore, knowledge of root growth patterns of melon cultivars under water deficit is not only critical for understanding drought tolerance mechanisms but also in achieving efficient crop management and breeding strategies (Chaves et al., 2003; Machado et al., 2003). There is no guarantee that root traits selected on nursery seedlings will translate into a stronger root system under field conditions (Franco and Leskovar, 2002), which further justifies in situ field evaluations of root growth of muskmelon cultivars under deficit irrigation.

In this study, we evaluated three melon cultivars namely Mission (*reticulatus*; muskmelon type), Da Vinci (*reticulatus*; tuscan type) and Super Nectar (*inodorus*; honeydew type) under two irrigation rates (50% and 100% ETc). Since each cultivar belongs to a distinct horticultural group, these differ widely in morphological traits. For example, Mission has a yellow flesh and netted skin, Da Vinci has an orange yellow flesh and sutured-netted skin and Super Nectar has a greenish white flesh and smooth creamy white skin fruits. Owing to these differences, we expected that deficit irrigation may enhance root growth and fruit quality through elevated levels of vitamin C and β-carotene, responses that may be cultivar dependent. Thus, the overall aim of this two-year study was to determine the impact of deficit irrigation on root growth, fruit yield and quality, and water use efficiency of melon cultivars from diverse horticultural groups grown under subsurface drip irrigation. We expect this information will be useful for developing water saving and eco-friendly irrigation technologies for melons in southern regions of the U.S., such as in southwest Texas.

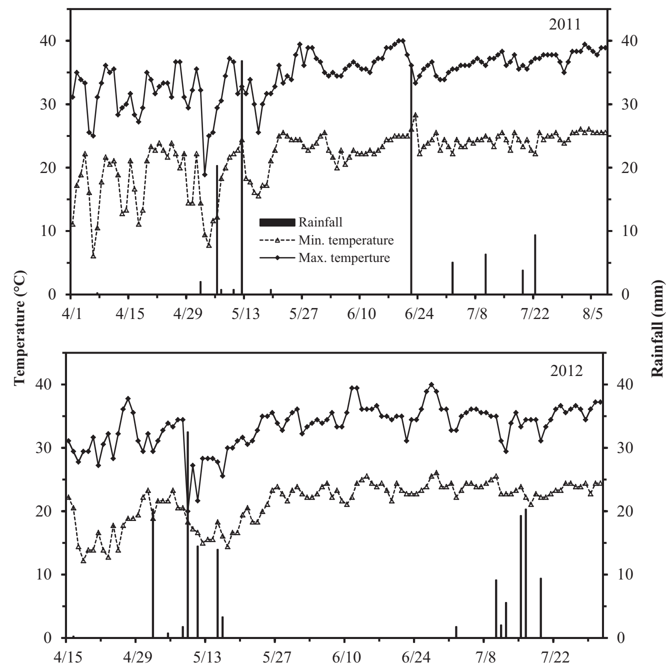

Fig. 1. Rainfall, minimum and maximum temperature during 2011 and 2012 seasons, Uvalde, TX.

2. Materials and methods

2.1. Experimental site

The field experiment was conducted at the Texas A&M AgriLife Research and Extension Center at Uvalde, TX (longitude 29°13″N, latitude 99°45″W; msl 283) on a clay soil (Hyperthermic Aridic Calciustolls) of the Uvalde series during the 2011 and 2012 seasons. The site has a semi-arid climate with a long term average annual rainfall of 663 mm, average annual high temperature of 27.4 °C and average annual low temperature of 13.6 °C. The mean annual evapotranspiration is 1506 mm which is 2.3 times higher than the average annual precipitation, making supplemental irrigation necessary for crop production. Rainfall and maximum and minimum temperature during the 2011 and 2012 seasons are provided in Fig. 1. The precipitation received was only 250 mm in 2011 and 349 mm in 2012 which represented 37% and 52% of the total annual average, respectively. Soil samples were collected (up to 15 cm soil depth) before planting and analyzed for soil physical and chemical properties at the Texas A&M soil testing laboratory. Soil data for 2011 and 2012 are provided in Table 1.

2.2. Experimental treatments and procedures

The crop was direct-seeded on high-rise beds (2.03 m between, 0.30 m with in row spacing) covered with black plastic mulch on 1 and 15 April 2011 and 2012 respectively. The experiment was laid out in a split plot arrangement with irrigation rates viz. 50% ETc and 100% ETc assigned to the main plots and cultivars to the sub plots with three replications. Each sub plot had an area of 18.55 m^2 (9.14 m × 2.03 m). To avoid the impact of irrigation through lateral movement from the neighboring plots a 2.03 m (one bed) bare space was left between the beds. Irrigation was applied with a subsurface drip system based on the daily ETc, which was calculated as