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Effect of mulching on plant water status, soil salinity and yield of squash under summer-fall deficit irrigation in salt affected soil

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ABSTRACT

Field studies were conducted for two consecutive seasons (summer and fall) under sub-temperate climatic conditions at southwest of Cairo, Egypt (29° 35′ N 30° 23′ E) in saline soil (ECe 12.6 dS m^{-1}) to investigate the effect of different mulches (without mulch, WM as a control, farmyard manure: FYM, rice straw: RSM and white polyethylene: PM) on soil salinity, plant water status, water-use efficiency (WUE), and yield of squash under three levels of irrigation ($I_{100} = 100\%$, $I_{85} = 85\%$ and $I_{70} = 70\%$ of crop evapotranspiration). Under full irrigation, seasonal water use by squash was 479 over 86 days in summer and 306 mm over 91 days in fall season, respectively. Plant water status (as evaluated by relative water content, canopy temperature), fruit quality yield and water use efficiency (WUE) were significantly ($P \leq 0.05$) affected by season and both irrigation quantity and mulching materials. Photosynthesis efficiency, total soluble sugars (TSS), leaf area index, harvest index (HI), yield and WUE were not significantly affected by interaction between growth season and both irrigation and mulching treatments. All mulching materials effectively reduced salt accumulation in the root zone. Mulching treatments markedly increased WUE and yield in the order of FYM > RSM > PM > WM. Results showed that, under different mulches, the $I_{85\%}$ strategy studied here could be successfully applied during summer and fall seasons in commercial squash production allowing water savings of 15% without any detrimental effect on plant growth or yield.

1. Introduction

Recently the available amount of water to agriculture is decreasing worldwide because the rapid population growth and the greater incidence of drought caused by climate change and different human activities (World Bank, 2006). Squash (*Cucurbita pepo* L.) is one of the most important vegetable crops, grown in many temperate and sub-tropical regions, and is highly ranked worldwide in economic importance among vegetable crops. The Middle East and Mediterranean countries, led by Turkey, Italy, and Egypt are producing one-third of the world's production (Paris, 1996). Successful management of the limited amount of water available for agricultural practices depends on better agricultural uses and enhanced understandings of water productivity (Howell, 2001; Jones, 2004). Combine practice of deficit irrigation (DI) and mulching appears to be very promising among the water management practices for increasing water use efficiency (WUE) especially at field scale.

Deficit irrigation (i.e. irrigation below the optimum crop water requirements) is a strategy for water-saving by which crops are subjected to a certain level of water stress either during a particular period or throughout the whole growing season (Pereira et al., 2002). The main goal of using DI is to increase WUE by reducing the amount of water applied with watering or by reducing the number of irrigation events (Kirda, 2002). Deficit irrigation effects on growth and productivity of many vegetables and field crops have been widely investigated (Karam et al., 2006; Badal et al., 2013; Ballester et al., 2014). Therefore, it is necessary to evaluate the impact of DI strategies with multi-years open field experiments, before generalizing the most appropriate irrigation scheduling method to be adapted in a specific location for a given crop (Scholberg et al., 2000).

Salinity has severely restricted global agriculture particularly in arid and semi-arid regions. At present, this stress is becoming even more prevalent as the intensity of land use increases throughout the world (Dong et al., 2010).

Morphological and physiological processes of plant are negatively affects by salt stress through osmotic and ionic stress, and different biochemical responses in plants (Khan, 2003). Growth of

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squash plants was shown to be moderately sensitive to moderately tolerant to salt stress depending on cultivar or growth stage (Francois, 1985).

Mulching, is a useful practice with the potential of conserving moisture, reducing evaporation, modifying soil temperature, and improving aeration as well as releasing nutrients in the soil profile (Sharma et al., 2005; Ahmad et al., 2007). Mulching involves the use of organic materials (e.g. crop residues, straw, grasses, and farmyard manure) or inorganic, synthetic materials, (e.g. polyethylene sheets, and gravels). Organic mulch adds nutrients to soil when decomposed by microbes and helps in carbon sequestration (Chattopadhyaya and Mukherjee, 1990). Straw mulch can conserve soil water and decrease temperature because it increases residue accumulation and reduces soil disturbance on the soil surface (Baumhardt and Jones 2002; Zhang et al., 2011). Zhang et al. (2005) working on winter wheat in northern China, found that mulching with straw reduced soil evaporation loss and increased WUE and grain yield. Plastic mulch has played a role in crop production by creating mechanical protection at the soil surface and a microclimate favorable in terms of temperature distribution, retention of humidity and the supply of CO_2 to the stomata of lower leaves of small plants (Otsuk et al., 2000), regulating soil temperature (Ghosh et al., 2006), suppressing weed populations (Ramakrishna et al., 2006) and decreasing nitrate leaching (Romic et al., 2003). In addition, salt accumulation in the root zone can be controlled the application of soil mulching by reducing the upward movement of salts and evaporation as a better field-management option (Zhao et al., 2014; Chen et al., 2016). We conducted a 2-cosicutive field-experiments to (1) evaluate the effects of different mulching materials on squash yield and water-use efficiency under water stress in summer and fall growing seasons and (2) Characterize the photosynthesis efficiency, canopy temperature, leaf water status and soil salinity under the combined effect of soil mulching and deficit irrigation.

2. Materials and methods

2.1. Experimental site

Two experiments were conducted in two successive growing seasons: summer season (SS) and fall season (FS) of 2013, at farmer's field located in El Fayoum province which occupies a depression west of the Nile at 90 kilometres southwest of Cairo, Egypt between latitudes 29° 02′ and 29° 35′ N and longitudes 30° 23′ and 31° 05′ E. According to the aridity index (Ponce et al., 2000) the area is located under arid climatic conditions. The soil of the site where the experiments were carried out for the two seasons had the top soil (0–100 cm depth) classified as saline (ECe = 12.6 dS m^{-1}, SAR = 11.96, and pH = 7.83 Table 1) sandy loam in texture, with a bulk density of 1.57 g cm^{-3}. Total available water was about 12.88%/60 cm depth and the soil has low fertility (0.8% organic matter and 0.05% total N). Physical and chemical properties, of the studied soil were conducted according to the methods and procedures outlined and described by Klute (1986) and Page et al. (1982)

2.2. Irrigation water applied (IWA)

Squash plants were irrigated every 2 days intervals by different amounts of irrigation water applied. IWA was determined as a percentage of the crop evapotranspiration (ETc) representing one of the following three treatments: I_{100} = 100%, I_{85} = 85% and I_{70} = 70% of ETc. The daily ETo was computed according to Eq. (1) (Allen et al., 1998) as follows:

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T_{\mathrm{mean}}+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (1)$$

where ETo: is the reference evapotranspiration (mm day^{-1}), Δ the slope of the saturation vapor pressure curve at air temperature (kPa C^{-1}), Rn the net radiation at the crop surface (MJm^{-2} d^{-1}), G Soil heat flux density (MJm^{-2} d^{-1}), γ psychometric constant = (0.665 × 10−3 × P), kPa C^{-1} (Allen et al., 1998), P is the atmospheric pressure (kPa), U_2 wind speed at 2 m height (m s^{-1}), e_s is the saturation vapor pressure (kPa), e_a actual vapor pressure (kPa) ($e_s - e_a$) is the saturation vapor pressure deficit (kPa), and T_{mean} mean daily air temperature at 2 m height (°C).

The average of daily ETo in El-Fayoum was 10.16, 10.74, 10.66, 9.9, 8.64, 6.61, 4.63 and 3.49 mm day^{-1} in May, June, July, August, September, October, November and December, respectively (Table 2). The crop water requirements (ETc) were estimated using the crop coefficient according to Eq. (2):

$$\mathrm{ETc} = \mathrm{ETo} \times \mathrm{Kc} \qquad (2)$$

where ETc is the crop water requirement (mm day^{-1}) and Kc is the crop coefficient. The duration of the different crop growth stages were 25, 35, 25, and 15 days for initial, crop development, mid-season and late season stages, respectively and the crop coefficients (Kc) of initial, mid and end stages were 0.60, 1.00 and 0.75, respectively, according to Allen et al. (1998).

The amount of IWA to each treatment during the irrigation regime was determined by using Eq. (3):

$$\mathrm{IWA} = \frac{\mathrm{A} \times \mathrm{ETc} \times \mathrm{Ii} \times \mathrm{Kr}}{\mathrm{Ea} \times 1000 \times (1 - \mathrm{LR})} \qquad (3)$$

where IWA is the irrigation water applied (m^3), A is the plot area (m^2), ETc is the crop water requirements (mm day^{-1}), Ii is the irrigation intervals (day), Ea is the application efficiency (%) (Ea = 85), Kr covering factor and LR is the leaching requirements (m^3) and determined by using Eq. (4):

$$\mathrm{LR} = \frac{\mathrm{ECw}}{2\mathrm{MaxECe}} \qquad (4)$$

where EC_w is the electrical conductivity of the irrigation water, dS m^{-1} and Max EC_e: is the maximum electrical conductivity of the soil saturation extract for a given crop, (see the table shown in according Doorenbos and Pruitt (1984) and Keller and Bliesner (1990)).

2.3. Mulching treatments

Four mulching treatments consisted of without mulch (WM) as control, white transparent polyethylene mulch (PM), rice straw mulch (RSM), and farmyard manure mulch (FYM).

2.4. Experimental design

The experiment was conducted in a Randomized Split Plot design. Treatments were divided into three levels of irrigation water applied (IWA) and four mulching treatments. The IWA, i.e.100, 85 and 70% of ETc were assisted in main plots, while the mulching treatments (WM, PM, RSM and FYM) were allocated in the sub-plots. The 12 treatments were replicated three times, making a total of 36 plots. The experimental plot area was 12 m length × 1.10 m row width (13.2 m^2) and about 0.5 m spacing between plants within rows.