Agricultural Water Management 167 (2016) 29–37

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Kaolin improves salinity tolerance, water use efficiency and quality of tomato

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ARTICLE INFO

Article history:
Received 14 May 2015
Received in revised form
22 December 2015
Accepted 23 December 2015
Available online 13 January 2016

Keywords:
Salt stress
Heat stress
WUE
Sunburn
Solanum lycopersicum L.

ABSTRACT

Many areas in Southern Italy covered by tomato crops suffer from problems of high salinity in the irrigation water, that adversely affects yield. The reduction in transpiration rate mitigates the adverse effects of salinity. Thus, spraying the crop with kaolin-based aqueous suspension, which has an antitranspirant effect, can help improve tolerance to salinity.

A three-year research study was carried out in open-field conditions in the Basilicata region (Southern Italy), to study the combined effect of three irrigation-water salinity levels ($EC_w = 0.5$, 5, and 10 $dS\,m^{-1}$) and spraying or non-spraying of kaolin on tomato cultivars, in terms of yield, fruit quality, biomass and yield water use efficiency (respectively B_WUE and Y_WUE). Irrigation with brackish water reduced tomato yield mainly because of declining fruit weight, but fruit quality was better in terms of dry matter content and total soluble solids. In addition, salinity increased blossom-end rot mainly on cultivars with elongated fruits.

Overall, using the average from the three years, kaolin improved total (12.7%) and marketable yield (17.7%), fruit weight (8.1%) and harvest index (10.3%), and reduced fruit sunburn by 76.4%. In addition, kaolin contributed to reducing insect attack on the fruit (58.7%), improvement in total soluble solids (6.2%) and redness (10.2% for the skin and 16.6% for the pulp) of fruits, and increased Y_WUE (19.7%). Furthermore, kaolin mitigated the detrimental effects of salinity through a smaller decrease (averaging the three years) in total yield (22.8%), marketable yield (34.4%), fruit weight (21.1%), B_WUE (22.9%) and Y_WUE (34.7%), between the control irrigated with fresh water and the more saline treatment.

Kaolin can be used to increase salinity tolerance, as well as to protect the tomato crop from pests damage, radiation and heat stress.

1. Introduction

Many Mediterranean countries suffer from the problem of groundwater salinity due to seawater intrusion caused by the overexploitation of wells for irrigation purposes. This causes problems of soil salinization, with detrimental effects on crops and yield.

The European Environment Agency has recognized that the problem of saltwater intrusion due to groundwater overexploitation is one of the major threats to coastal area freshwater resources in Europe (Rapti-Caputo, 2010; Scheidleger et al., 2004). Italy has been indicated as one of the countries where the problem is felt most severely (Capaccioni et al., 2005; Cau et al., 2002; Scheidleger et al., 2004) with several hot-spot areas in the Apulia region (Southern Italy) (Ancona et al., 2010; Polemio and Limoni, 2001).

In many irrigated areas, especially those characterized by intensive agricultural activities, dwindling supplies of quality water for irrigation and increasing demand from other users are forcing farmers to use saline irrigation waters (Rhoades, 1987; Rhoades et al., 1992; Shani and Dudley, 2001). In arid and semi-arid areas, such as those in Southern Italy, crops need high watering volumes, which in turn leads to high quantities of salt entering the soil, that are insufficiently leached by rainfall from the uppermost to the deeper soil layers.

Salinity inhibits plant growth because of its osmotic effect, which reduces the ability of the plant to take up water, and due to its specific ion toxicity (*e.g.*, Na^+ and Cl^-) (Munns, 2002, 2005; Yeo et al., 1991) which reduces net photosynthesis (Cantore et al.,

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http://dx.doi.org/10.1016/j.agwat.2015.12.021

2007; Munns et al., 2006; Munns and Tester, 2008), and ionic imbalances acting on biophysical and/or metabolic components of plant growth (Grattan and Grieve, 1999). These adverse effects result in a reduction in yield that, for a given level of salinity can vary depending on the genotype, climatic conditions and agronomic techniques (Flagella et al., 2002; Maas, 1986).

Tomato (*Solanum lycopersicum* L.) for processing is among the most common open-field crops cultivated in Southern Italy and plays a key role in the local economy. It is often grown on soils affected by salinity problems and/or irrigated with saline water.

Experimental results indicate tomato is a moderately salt-sensitive crop with differences among genotypes (Cantore et al., 2008; Cucci et al., 2000; Flagella et al., 2002), according to Maas and Hoffman's (1977) model, and also stress the negative effects of salinity on absorption and translocation of Ca^{++} (Grattan and Grieve, 1999) that is clearly connected with blossom-end rot (Adams and Ho, 1992; Belda and Ho, 1993; Cantore et al., 2008; Max and Horst, 2009).

Several authors report that air temperature and relative humidity (RH) are the main environmental factors affecting tolerance to salinity (Li et al., 2001; Rauf et al., 2010; Shalhevet, 1994). In practice, it has been shown that reducing the environmental evapotranspiration demand (low temperature and high RH) increases tolerance to salinity because of the reduction in water flow in the soil-plant-atmosphere continuum, which leads to less build-up of salts in the root zone (Helal and Mengel, 1981; Meiri et al., 1982).

Therefore, any techniques that help reduce vegetation temperature and transpiration rate may be effective at limiting the negative effects of salinity on crops.

Among these techniques, spraying with kaolin-based aqueous suspension, whose effects mitigate vegetation temperature, limit transpiration rate and improve yield, is well known for numerous crops (Le Grange et al., 2004; Lombardini et al., 2005; Pace and Cantore, 2009; Schroeder and Johnson, 2004), including tomato (Boari et al., 2015; Cantore et al., 2009; Pace et al., 2007).

Kaolin, marketed as Surround® WP, is an environmentally-friendly, clay-based compound, which is becoming more widespread because of its efficacy in the control of various pests which damage a range of crops (Glenn and Puterka, 2005). After water evaporation, kaolin creates a white protective film on vegetation (particle film technology, Pft) that reflects part of the incident radiation, reduces stomatal conductance and improves plant water status (Boari et al., 2014, 2015; Cantore et al., 2009).

Therefore, it was hypothesized that applying kaolin could help to reduce salt stress, increasing the salt tolerance of tomato, a crop widespread in many areas of Southern Italy suffering from salinity problems. To verify the hypothesis, an experimental trial was carried out in open-field conditions to study the combined effect of kaolin and salinity at physiological level (Boari et al., 2014), and on yield, quality and water use efficiency (WUE), as reported in this paper.

2. Materials and methods

2.1. Experimental site and climate

The field trial was carried out in the summer of 2007, 2008 and 2009 at the University Aldo Moro of Bari's 'E. Pantanelli' experimental farm near Policoro (MT), Southern Italy (40°10′ NL, 16°39′ EL, altitude 15 m a.s.l.).

This site is characterized by a sub-humid climate according to the De Martonne classification (Cantore et al., 1987). Climate data were obtained from a standard weather station located about 50 m from the experimental field equipped with a pyranometer, thermistor, hygrometer, anemometer, 'class A' pan, and tipping bucket rain gauge, for measuring solar radiation, air temperature, relative humidity, wind speed, evaporation and rainfall, respectively. The weather data were collected by the electronic system operated through a data-logger connected via modem to a PC.

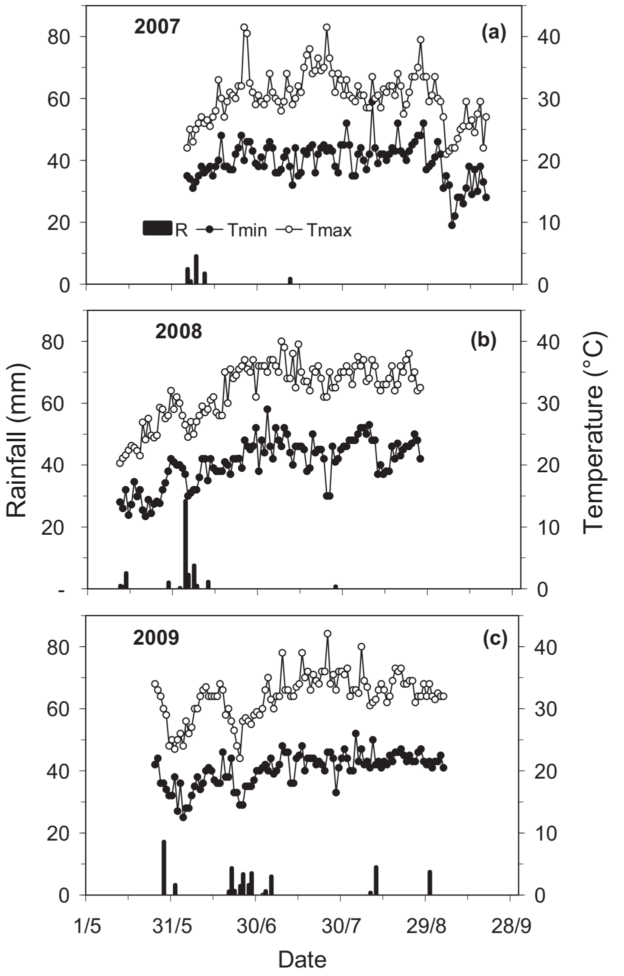

Fig. 1. Daily values of rainfall (R), minimum (T_{min}) and maximum (T_{max}) air temperature during the growing cycle of tomato in the three years.

The soil was a fine, mixed, subactive, thermic Chromic Haploxererts (Cassi et al., 2006), with the following physical and chemical characteristics: sand (2 > Ø > 0.02 mm) 30%, silt 37.1%, clay (Ø < 2 μ) 32.9%; pH 7.7; total N (Kjeldahl method) 1.67 g kg^{-1}, available P_2O_5 (Olsen method) 26.7 mg kg^{-1}, exchangeable K_2O (ammonium acetate method) 227 mg kg^{-1}, organic matter (Walkley–Black method) 36.4 g kg^{-1}, total limestone 15 g kg^{-1}, active limestone 5 g kg^{-1}; saturated paste extract electrical conductivity (ECe) 0.95 dS m^{-1}; ESP 1.9%; bulk density 1.25 kg dm^{-3}; soil moisture at field capacity (measured *in situ*) 31.5% and at wilting point (−1.5 MPa) 15% (w/w) of soil dry weight.

2.2. Climate trend

2.2.1. 2007

During the tomato growth cycle, precipitation was very low, with only 20 mm of rainfall. The minimum temperatures (T_{min}) ranged between 9.5 and 29.5 °C, with the lowest value being recorded at the end of ripening, while the highest occurred on 9 August at the fruit-enlargement stage. The maximum temperatures (T_{max}) ranged between 21.5 and 41.5 °C, almost always exceeded 30 °C from mid-June until the end of August, with values above 40 °C being recorded on 25 and 26 June, 24 July and 26 August (Fig. 1a).