Scientia Horticulturae 241 (2018) 115–123

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Effects of mulching on soil temperature and moisture variations, leaf nutrient status, growth and yield of pistachio trees (*Pistacia vera*.L)

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ARTICLE INFO

Keywords:
Barley residue
Nutrition
Nut attributes
Plastic mulch
Water management

ABSTRACT

The objective of this study was to investigate the response of leaf nutrients concentration, growth and yield of pistachio trees affected by changes in soil moisture and temperature as a result of different mulching. The experiment was conducted in a randomized complete block design with five replications in Feyzabad, Khorasan Razavi, Iran, for two years in 2014 ('off' year) and 2015 ('on' year). Treatments included sub-soil plastic (SPM_1 and SPM_2), up-soil plastic (UPM), woodchips (WM), barley residue (BM) mulches and control (CK). Treatment of SPM_2 recorded the highest shoot growth and nut splitting, and lowest bud abscission in 'off' year. However, in 'on' year, maximum bud abscission was found in SPM_2. Treatments of BM and WM were effective in decreasing flower bud and fruit abscission than other treatments during 'on' year. Mulching affected leaf P concentration in 'off' year and N, P and Mg in 'on' year, with the highest rate of these nutrients recording in BM treatment. Yield variations were not significantly affected by treatments in 'off' year, but in 'on' year, SPM_2, WM, BM and SPM_1 treatments increased yield by 29.2%, 28.7%, 19.8% and 10.5% compared to CK, respectively. Unlike other treatments, UPM had negative effect on leaf N concentration, and yield during 'on' year. This difference is attributed to high soil temperature in this treatment, so that yield reduced in soil temperature ranges over 36–37 °C in mean depth of 20–60 cm. In general, sub-soil plastic mulches, despite increasing yield in 'on' year, could not control flower bud abscission in that year. Thus, due to the increase of leaf nutrient concentration, regulation of alternate bearing phenomenon and improvement of yield, organic mulches are better options in arid and semi-arid regions with traditional irrigation methods.

1. Introduction

Pistachio (*Pistacia vera* L.) is one of the important agricultural crops in the world (Goldhamer, 1995), due to its highly nutritious value and favorable taste. It is mainly cultivated in Iran, USA, Turkey, Syria, Italy, Tunisia and Greece (Kashaninejad et al., 2006). With the highest cultivation area and exports, Iran is the biggest producer of pistachio in the world (Adibian, 2016). Therefore, this crop has high economic value for the country (Atatashafrooz et al., 2015). After Kerman and Yazd provinces, Khorasan province is the third most important area of pistachio production and cultivation in Iran (Hosseyni, 2009), where water deficient and traditional irrigation methods are the main limiting factors of pistachio production.

Water scarcity is one of the most important factors restricting the production of agricultural crops in arid and semi-arid regions (Deng et al., 2006; Hatibu et al., 2006). Soil water influences plant growth and development (Silvente et al., 2012), so that, crop productivity can be greatly affected by even a small change in soil water content (Liu et al., 2010). Furthermore, it was found that soil temperature is an environmental factor regulating the functioning of roots (Pregitzer et al., 2000). Studies have indicated that soil temperature may have a greater impact on growth than air temperature (Korner and Paulsen, 2004). Soil temperature affects water absorption and nutrient uptake by changing root metabolism, growth and morphology (Hussain and Maqsood, 2011). Thus, change in soil temperature and moisture can significantly affect crop growth, development and productivity (Liu et al., 2010).

Soil surface mulching is a useful and effective method for crop production (Ahmad et al., 2007). Different studies have indicated that inorganic and organic mulches are effective in soil water conservation, modifying soil temperature (Sharma et al., 2005; Ahmad et al., 2007), preventing weed growth, encouraging favorable soil microbial activity (Elevitch and Wikinson, 1998), decreasing the leaching of root-zone

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https://doi.org/10.1016/j.scienta.2018.06.092
Received 10 February 2018; Received in revised form 5 May 2018; Accepted 29 June 2018

nutrient (Haraguchi et al., 2004), reducing root-zone salinity (Dong et al., 2008), and releasing nutrients in soil profile(Sharma et al., 2005). Therefore, mulch application leads to greater root growth and biomass (Li et al., 2004). As a result, it increases water use efficiency (Tian et al., 2003; Zhou et al., 2009), the rate of photosynthesis (Li et al., 1999), and crop yields (Ramakrishna et al., 2006; Luis Ibarra-Jiménez et al., 2011). Increase in growth and yield under the influence of organic mulches has been reported in apple (Treder et al., 2004; Szewczuk and Gudarowska, 2004; Baxter, 1970) and peach trees (Baxter, 1970). Studies indicate that organic mulches result in higher production by reducing soil temperature and evaporation (Sarkar et al., 2007), and enhancing organic matter formation and decomposition, and soil nutrient cycling (Kennedy, 1999; Nair and Ngouajio, 2012). Moreover, use of plastic mulches in apple (Måge, 1982; Szewczuk and Gudarowska, 2004) and sweet cherry trees (Yin et al., 2007) increased growth and yield compared to non-mulched trees by improved moisture and increased soil temperature (Fang et al., 2011) that lead to the enhancement in growth and creation of more bearing positions (Yin et al., 2007). In contrast, some studies have reported that plastic mulches application for the whole growth period in spring wheat (*Triticum aestivum*) in semi-arid regions (Li et al., 1999) and in potatoes (*Solanum tuberosum* L.) in arid regions decreased yield due to higher temperatures (Wang et al., 2009; Hou et al., 2010).

Given that there is not much research regarding the influence of different mulching materials, in particular plastic mulches, on coupling changes of soil water and temperature, growth attributes, and yield of trees in regions with high radiation and temperature. Hence, the objectives of this study were to: (1) determine the influence of plastic and organic mulches on soil moisture and temperature, (2) investigate the variability of leaf nutrient concentrations, growth and yield pistachio trees in both 'off' and 'on' years in response to soil temperature and moisture variations under the influence of different mulches in arid and semiarid climate.

2. Materials and methods

2.1. Description of study site

The study was carried out in a pistachio orchard (*Pistacia vera* L. cv Akbari) located in Feyzabad, Mahvelat, Khorasan Province, Iran (34° 40´ N latitude, 58° 25´ E longitude, and around 1253 m above sea level). The climate of the experimental area was arid and semiarid. The mean annual precipitation was about 171 mm with more than 80% receiving during October–March. Mean annual radiation was 650 KJ cm^2 and annual sunshine 3207 h. The maximum temperature ranged between 6.5–44.8 °C in 2014 and 17.2–43.8 °C in 2015 at solar noon during the study period. The soil of the experimental orchard was sandy loam with the pH of 7.55. Some characteristics of the orchard soil in different depths are given in Table 1.

2.2. Experimental materials and design

The experiment was conducted in growing seasons 2014 and 2015 in an orchard with 20 year-old 'Akbari' pistachio trees grafted on Badami seedling rootstocks. The irrigation of orchard trees was in the form of surface strip, started from April and continued until harvest time at 36-day intervals. The amount of irrigation water applied to orchard during the growing season was 7260 (m^3 ha^{-1}). Irrigation water had a pH of 6.9 and an EC of 2.6 dS m^{-1}. The trees were planted at 3 × 6 m spacing. Size of each strip or trees row was 360 m^2 (6 m × 60 m). Hence, there were 40 trees on both sides of the row.

Experimental design was a randomized complete block design with five replicates and six treatments. Treatments were: Sub-soil plastic mulches using polyethylene films with 15 µm thickness that cuts with the width of 6 m at the distance of 80 cm (SPM$_1$) and circular cuts, with the diameter of 30 cm at the distance of 80 cm (SPM$_2$) along the row made on it to allow water penetration; the films were then covered with 2 cm soil; Up-soil plastic mulch (UPM) using transparent polyethylene film with the thickness of 25 µm which was pulled on water strip as a single layer so that irrigation water passes under the coverage; Woodchips mulch (WM, C/N = 350) with the thickness of 5 cm which was evenly distributed over the soil surface across the row; and Barley residue mulch (BM, C/N = 52), in which the fresh above-ground biomass of barley (*Hordeum vulgare*) was used as mulch during the two years due to its easy preparation. In this treatment, barley seeds were cultivated in the fall of the previous years (2013 and 2014) and fresh biomass of the barely harvested at flowering stage in the spring and left at the same row with the thickness of approximately 5 cm. Row without any mulching was considered as control (CK). The experimental blocks were considered perpendicular to the direction of rows due to the lack of uniformity of water volume at the beginning and end of rows, so that each row was divided into five blocks (replication) and each block contains eight trees.

Trees were selected based on similarities in their previous nut yields to minimize variability caused by differences in tree size (Rosecrance et al., 1996). First (2014) and second (2015) year of the study were light cropping year ('off' year) and heavy cropping year ('on' year), respectively. In 2015, the treatments were applied at the same site as in 2014. In each treatment, four central trees from each block were selected and one-year-old shoots with uniform size and number of cluster in four directions of each tree were considered for measuring of all traits. These selected shoots included only one cluster in 'off' year and four clusters in 'on' year. Trees received routine cultural practices for commercial fruit production including irrigation, fertilization (except for nitrogen) and pest control. Nitrogen application was as split at the rate of 250 Kg ha^{-1} year^{-1}; half the nitrogen was applied in early May and the other half in July and August. Because of high C/N ratio of organic mulches, nitrogen application was done after mulching in order to speed up the decomposition of the organic mulches (Kolb, 1990), and prevent competition between soil microorganisms and plant to nitrogen uptake in that treatments. All of the mulches were applied in late April of each year. Furthermore, in early fall of each year, organic mulches were returned to soil and plastic mulches were collected.

2.3. Soil moisture and temperature measurement

Soil moisture and temperature were determined using REC-P55 device (REC-P55, Made in Iran (Ferdowsi University of Mashhad)) at 20–30 and 50–60 cm layers of soil at 14:00 pm every 12, 24 and 36 days after irrigation. Since the trees of the experimental orchard were irrigated four times during the growing season. So, soil moisture and temperature measurements were done 12 times from early-May to late

Table 1
Some physical and chemical properties of soil profile in the experimental orchard.

Depth (cm)	Texture			EC (dS m^{-1})	pH	B.D (gr cm^{-3})	FC (%)	PWP (%)	OC (%)	Total N (%)	Available	
	Sand (%)	Silt (%)	Clay (%)								P (ppm)	K (ppm)
0–30	67	17	16	3.22	7.55	1.39	20.1	6.9	0.23	0.03	5.9	258.3
30–60	68	16	16	2.5	7.53	1.45	19.4	6.8	0.11	0.02	2.7	175
60–100	69	15	16	2.1	7.42	1.48	19	6.6	0.06	0.01	2.5	110