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Effect of mulching on soil, canopy and leaf temperature of lentil (Lens culinaris Medick.)

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ABSTRACT: In order to investigate the effect of different water stress treatments and straw mulch on soil, canopy and leaf temperature of lentil (Lens culinaris Medik.), an experiment was carried out as split-plot based on randomized complete block design with three replications at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran, in 2012. Water stress treatments (I_1, I_2, I_3 and I_4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) were assigned to the main plots and two mulch levels (M_1 and M_2: 0 and 2 ton/ha wheat straw) were allocated to the sub plots. The results of this study showed that among water stress treatments, the lowest and highest of leaf, canopy and soil temperature was observed in$I_1$and I_4 treatments, respectively. Results also showed that lentils that received 2ton/ha mulch, had a lower leaf, canopy and soil temperature. In addition, regarding to the interaction effects between water stress treatments and straw mulch, it could be concluded that irrigation of lentil after 70 mm evaporation from class A pan and application of 2 ton/ha mulch is the best combination for lentil growth and production.

***Keywords*:** water stress, lentil, straw mulch, temperature

INTRODUCTION

Water is one of the most important environmental factors regulating plant growth and development. The sensitivity of crop plants to water stress is acknowledged a major constrain in crop production. Water deficit affects many morphological features and physiological processes associated with plant growth and development (Toker and Cagirgan, 1998). The intensity of drought stress varies from year to year, depending on the amount and distribution of rainfall and on spring and early summer temperatures (Soltaniet al., 2001). When the full crop requirements arenot met, water deficit in the plant can develop to a point where many of the physiological activities of plants are impaired (Badoniet al.,2009). Thus, detection of water status is important for monitoring the physiological status of plants (Penuelaset al.,1993). Theessential factor in plant water relations is themaintenance of a sufficiently high watercontent and turgor to permit normal functioning of the processes involved in growth (Bargali and Tewari, 2004).Leaf water relations data may provide a useful indication of the capacity of species to maintain functional activity under drought (White et al.,2000). The decrease in the internal water potential results in the closure of stomata which remarkably reduces transpiration and photosynthesis rates. High leaf temperature is also a consequence of drought because plants lose the ability for transpirational cooling when water availability is limited (Lu et al., 1997). By analyzing leaftemperature and CO_2 and H_2O exchange rates, it was concluded that the decline in photosynthesis at reduced leaf water potentials was due primarily to an increase in stomatal diffusion resistance and As a consequence of the reduction in transpiration rate, leaf temperature increases and the effects of drought and heat stresses frequently combine to scorch leaves (Mohammadian et al., 2005).

Canopy temperature measurement with infrared thermometers has been an effective tool for irrigation scheduling in semi-arid and arid conditions (Evett et al., 2000). Canopy temperature can be an indicator of plant water status because a non-stressed plant transpires, cooling its environment. Stomatal closure on a water-stressed plant will suppress transpiration, raising its temperature. However, irrigation scheduling using this concept was impractical until hand-held infrared thermometers became commercially available (Gardner et al., 1992).

Agricultural management practices can change the characteristics of the soil surface and influence the hydrothermal properties of the soil. For example, mulching can affect the temperature and moisture content of the soil (Li et al., 1999; Acharya et al., 2005) and directly influence the grain yield of crops (Ramalan and Nwokeocha, 2000; Li et al., 2001a, b). Straw mulching systems can conserve soil water and reduce temperature because they reduce soil disturbance and increase residue accumulation at the soil surface (Baumhardt and Jones, 2002; Zhang et al., 2009). Soil mulching with plastic film, which results in reduced water loss and more even regulation of soil temperature, has been widely used in agriculture (Zhang et al., 2005). Supplementary irrigation would improve plant water relation as well as grain yield (Wang et al., 2001). However, a high crop yield is not the only goal, other constraints such as water availability and the costs of irrigation also need to be taken into account in the management (Kang et al., 2002).

The objective of this research was to evaluate changes in leaf, canopy and soil temperature under water stress and straw mulch.

MATERIALS AND METHODS

Site description and experimental design

A field experiment was conducted in 2012 at the Research Farm of the University of Tabriz, Iran (latitude 38°05_N, longitude 46°17_E, altitude 1360 m above sea level). The climate of research area is characterized by mean annual precipitation of 285 mm, mean annual temperature of 10°C, mean annual maximum temperature of 16.6°C and mean annual minimum temperature of 4.2°C. The experiment was arranged as split plot design with three replications. Water stress treatments (I_1, I_2, I_3 and I_4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) were allocated to the main plots and mulch treatments (M_1 and M_2: 0 and 2 ton/ha wheat straw mulch)were allocated to the sub plots. Seeds of lentil were obtained from Agricultural Research Center of Ahar, Iran. Seeds were inoculated with Rhizobiumand treated with 2 g/kg Benomyl and then were sown with a density of 80 seeds/m^2. Each plot was included5 rows of 4 m long, 25 cm apart. All plots were irrigated immediately after sowing. Water stress treatments were applied after seedling establishment. Hand weeding of the experimental area was performed as required.

Water stress treatments (I_1, I_2, I_3 and I_4) applied after (40, 70, 100 and 130 mm) evaporation from class A pan respectively and volume of used water was calculated as:

$$v = (\theta_{FC} - \theta_{SM}).\rho b.A.d$$

where v is volume of used water(Lit), θ_{FC} the soil humidity in the field capacity level(%), θ_{SM} the soil humidity before exerting treatment(%), ρb soil bulk density(gr/m^3), A plot area (m^2), d root penetrate depth(m).

Data collection

Leaf temperature

A plant from each plot was marked and temperature of leaves (top, middle and bottom leaves) was measured using an infrared radiation thermometer (TES 1327). All of these measurements were carried out at 12:00 h just before irrigation.

Canopy temperature

The canopy thermometer (Humidity and Temperature Meter AR847) was used to measure crop canopy temperatures.All of these measurements were carried out at 12:00 h, just before irrigation.

Soil temperature

The soil temperature (Surface temperature) was recorded at 12:00 h, just before irrigation. Infrared radiation thermometer (TES 1327)was used to measure soil temperature.

Statistical analysis

Statistical analysis of the data was performed with MSTAT-C software. Duncan multiple range test was applied to compare means of each trait at 5% probability.

RESULTS AND DISCUSSION

Leaf temperature

Analysis of variance showed that leaf temperature significantly affected by irrigation treatments and mulch, while interaction of irrigation×mulch was notsignificant for this trait (Table 1). Leaf temperature of lentil increased with decreasing water availability (Figure 1). Although leaf temperature in I_1treatment was generally lower than other irrigation treatments.

Increasing leaf temperature was clearly the result of dehydration and closure of stomata under water stress. Under water stress, water uptake rate cannot match the potential transpiration rate and stomata close to maintain the plant water balance (Lourtieetal.,1995). As a result, leaf temperature rises and may even exceed air temperature (Larcher, 2000). This can inhibit net photosynthesis which correlates with a decrease in the activation state of Rubisco in both C_3 and C_4 plants. Decrease in the amount of active Rubisco can fully account for the temperature response of net photosynthesis (Salvucci and Crafts-Brandner, 2004). Photosynthesis is one of the most heat sensitive processes, can be completely inhibited by high temperature before other symptoms of the stress are detected (Camejoet al., 2005).

The effect of mulch on leaf temperature wassignificant (Table 1).In M_2 treatment (2 ton/ha straw mulch) leaf temperature was significantly lower than M_1 treatment (Control) (Table 2). Mulch probably conserved moisture which was transpired by the plants, resulting in cooling and lowering of leaf temperatures. Abu-Awwad(1999) observed that at low water level, transpiration of onion in covered soil surface was significantly higher than that in open soil surface. With the decrease in soil water, actual transpiration in open surface decreased, and with further extraction of soil water, unsaturated hydraulic conductivity decreased, causing reduction in transpiration.

Table 1. Analysis of variance of leaf, canopy and soil temperature and of lentil affected by water stress and straw mulch.

S.O.V	df	Leaf temperature	Canopy temperature	Soil temperature
Block	2	0.640	0.305**	1.620
Water stress	3	11.472**	3.912**	119.387**
Error	6	0.395	0.027	1.421
Straw mulch	1	13.599**	29.238**	74.695**
Stress×Mulch	3	0.245	0.215**	0.449
Error	8	0.329	0.015	0.822

* and ** , Significant at 5% and 1% probability level, respectively.

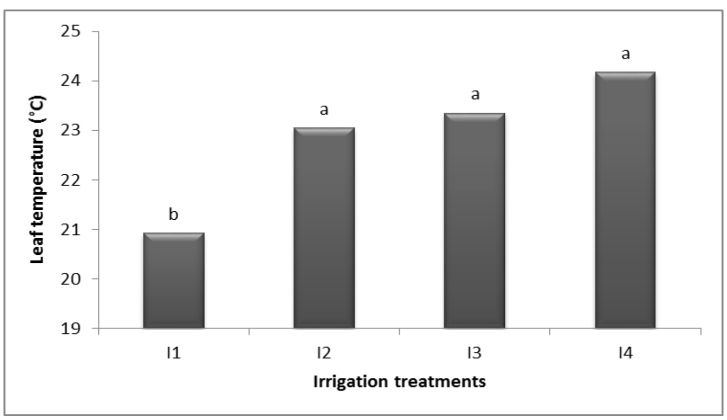

Figure 1. Effect of different water stresstreatments (I_1, I_2, I_3 and I_4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) on leaf temperatureof lentil (Different letters indicate significant difference at p≤ 0.05).

Table 2. The mean comparison of the main effect of straw mulch for selected traits.

Treatment	Leaf temperature (°C)	Soil temperature (°C)
Mulch		
M_1	23.62^a	25.03^a
M_2	22.12^b	21.5^b

The means with same letters in each column are not significantly different at $p \leq 0.05$.

Canopy temperature

Irrigation treatments and mulch had a significant effect on canopy temperature of lentil and interaction of irrigation×mulch wassignificant for this trait (Table 1).The highest canopy temperature (29.63 °C) was seen in plants under the I_4M_1 treatment, whilst the lowest canopy temperature (25.6 °C) was seen in plants under the I_1M_2 treatment. It was also observed that plants under the mulch treatment exhibited low canopy temperature in all irrigation treatments (Figure 2). A similar increase in canopy temperature under water stress was reported by Siddique (et al., 2000). As mentioned above, they suggested that leaf and canopy temperature increase under water stress is probably due to an increase in respiration and a decrease in transpiration as a result of stomatal closure. The close relationship between canopy temperature and amount of available water is consistent withthe results of (Hatfield et al., 1987) who found that cotton, sorghum, and millet that had the warmest canopies under well-watered conditions generally produced the greatest biomass or yield under drought-stressed conditions. (Hatfield et al., 1987) proposed that genotypes with high water-conserving ability will transpire less under optimal soil water conditions, thereby reducing transpirational cooling and increasing canopy temperature. The resulting lower crop water use should allow these genotypes to conserve more water for use during periods of drought.

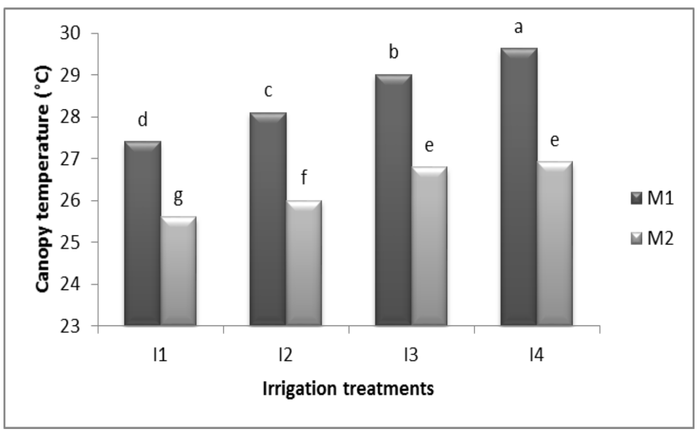

Figure 2. Effect of different water stresstreatments (I_1, I_2, I_3 and I_4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) and straw mulch (M_1 and M_2: 0 and 2 ton/ha wheat straw) oncanopy temperature of lentil (Different letters indicate significant difference at $p \leq 0.05$).

Soil temperature

Analysis of variance showed that soil temperature significantly affected by irrigation treatments and mulch, while interaction of irrigation×mulch was notsignificant for this trait (Table 1).The mean soil temperature was highest under the I_4 and lowest under the I_1 treatments, but there was no significant difference in soil temperature between the I_1 and I_2 treatments (Figure 3). The soil temperature in the upper layer under the straw mulch treatment was significantly lower (19.45 °C) than in the control treatment (29.02 °C) (Table 2).The mulch prevents evaporation of water from the soil surface. At the same time, water moves from deeper soil layers to the topsoil by capillarity and vapor transfer, thereby keeping the topsoil water content relatively stable (Wang et al., 1998; Li et al., 1999). The film mulch prevents water exchange between the soil and air, which in turn reduces the latent heat flux and also reduces the exchange of heat between soil and air (Wang and Deng, 1991). Straw mulching is regarded as one of the bestways of improving water retention in the soil and reducing soil evaporation (Baumhardt and Jones, 2002; Zhang et al., 2009). Several investigators have reported that the soil thermal regime under straw mulching was different from that of bare soil, with soil temperatures often being lower under mulched surfaces than in non-mulched soils (Bristow, 1988; Sarkar et al., 2007). Others have documented cases where straw mulching increased soil temperatures (Ramakrishna et al., 2006) although these could be largely attributed to differences in climatic conditions. (Fabrizzi et al., 2005 and Olasantan, 1999) observed that soil temperatures under straw mulching were higher during colder weather than during warmer weather when compared with non-mulched soil.

CONCLUSION

The results of this research clearly suggest that water limitation can considerably increase leaf temperature. Wheat straw mulches significantly reduce intercellular CO_2 and net photosynthesis by conserving more water. Leaf temperature and intercellular CO_2 are highest when passion fruit plants are not mulched. This result is possibly due to closure of stomata during photo-respiration as a copping strategy for water stress. Soil temperature regimes were altered by irrigation and mulches in lentil fields. Mulches were found to reduce topsoil temperature when compared with the control treatment. Integrated use of suitable irrigation and straw mulch was more appropriate and profitable. Therefore, irrigation in combination with straw mulch was found to be more effective irrigation method in improving yield and yield components of lentil.

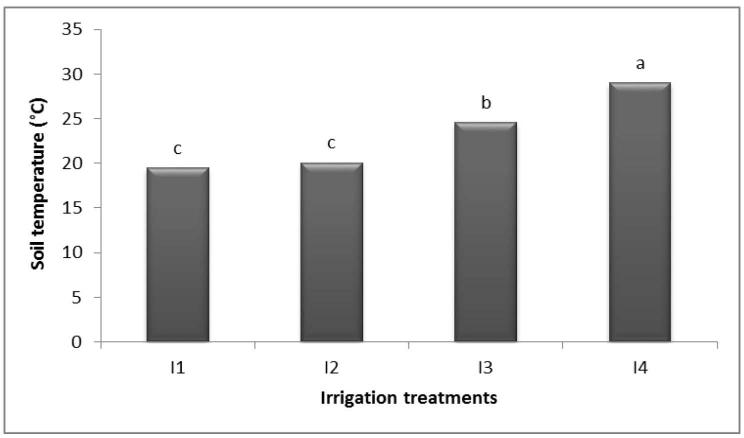

Figure 3. Effect of different water stress treatments (I_1, I_2, I_3 and I_4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) on soil temperatureof lentil (Different letters indicate significant difference at p≤ 0.05).

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