Effects of Air Temperature, Relative Humidity and Solar Radiation on Fruit Surface Temperatures and Sunburn Damage in Pomegranate (*Punica granatum L.cv. Hicaznar)*

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Abstract

A major problem in arid and semi arid regions is the excessive heating of the tree canopy and fruit, especially those exposed to direct solar radiation. Under such conditions, fruit and leaf surface temperatures may reach very high levels having undesirable effects on fruit skin properties (e.g. sunburn). The goal of this research was to determine the effect of temperatures, relative humidity and solar radiation on fruit surface temperature and sunburn damage on pomegranate (*Punica granatum L.cv. Hicaznar).* This trial was separately conducted on the most important pomegranate fruit cultivar Hicaznar, in experimental orchards of Batı Akdeniz Agricultural Research Institute in Turkey between 2003 and 2004. In these trials, temperature, humidity, radiation and amount of light values were recorded and received by means of micro metos ag. climate station in experimental area and, their effects on fruit surface temperatures (FST) and sunburn were determined. The surface temperatures of the fruits, exhibited a typical symptom of sunburn damage and no damage on ones, were measured with thermocouples throughout the season. The fruit surface temperatures that cause sunburn varies between 41^{0}C and 47.5^{0}C depending on air temperature. Maximum FST exceeded 47.5 ^{0}C in some days of July, August and September during experimental period in orchard. Maximum daily air temperatures were highly correlated with maximum FST. and it never exceeded 41-47.5^{0}C in days when maximum air temperature was below 30^{0}C. Mean solar radiation between 610 Wm^{-2} and 900 Wm^{-2} was also highly correlated with maximum FST. The ratios of relative humidity around %70 and %80 showed inversely correlation with maximum FST.

INDRODUCTION

Sunburn is physiological disorder resulting from high temperature, light and radiation and leads to losses in yield and quality (Schrader et al., 2002). On many fruits directly subjected to high sun light burns fruit surface and changes color. In this case appealing of fruits decreases results in big economic losses (Finkel and Holbrook, 2000).

Surface colors of sunburned fruits change from brown to black in pomegranate. Moreover, water content depletion and drying occur in pomegranate pieces. Sunburn which the main reason for crop losses reaching up to 40-50% notably, in Mediterranean region of Turkey that this is the most important factor that we are facing with and causes economic losses (Yazıcı et al., 2005).

We described three types of sunburn in pomegranate. We called the first type “sunburn browning”, the second type “sunburn browning with a black necrosis” and three type “blacking” (Yazıcı and Kaynak 2006). We established that sunburn browning was induced when the FST reached 35±1^{0}C, sunburn browning with a black necrosis occurred when the FTS reached 40±1 ^{0}C, and blacking was induced when the FST reached 45±1^{0}C.

In order to predict the incidence of fruit sunburn, it is essential to document the comprehensive conditions that cause this disorder. The present study was conducted to elucidate the correlations between maximum FTS and several meteorological factors so as to establish a solid basis for understanding the underlying causes of fruits sunburn and to develop a predictive computer model (Schrader et al., 2002). Schrader et al., (2001), concluded that FTS is critical to development of sunburn in apples, and that solar irradiation also is required for sunburn browning. In this paper, we report the effect of air temperature, solar radiation, light and relative humidity on FTS and the incidence of sunburn in pomegranate.

MATERIALS and METHODS

This study was conducted on Hicaznar pomegranate cultivar (these susceptible ones against to sunburn were planted in 1988) which was planted with a 3m within-row and 4.5m between-row spacing with north to south row orientation in Batı Akdeniz Agricultural Research Institute in 2003 and 2004. The experimental arrangement for trees was a randomized complete block design with 3 replications.

Surface temperatures of fruits southeast and southwest part of trees was measured using thermocouples (Testo 826-T4). These measurements were early in the morning from southeast and in the afternoon were from southwest on labeled fruits. Meteorological data was collected from a Mikro Metos ag. weather station (positioned within the experiment area) that monitored solar radiation, air temperature and relative humidity.

RESULTS

Maximum daily air temperatures were highly correlated with maximum FST, and it never exceeded 41-47.5^{0}C in days when maximum air temperature was below 30^{0}C. Particularly, in July and August between at 11:00 and 16:00 in a very hot and clear day, fruit surface temperature reaching up to 48-50^{0}C. Maximum FST was highly correlated with the solar radiation between 610 Wm^{-2} and 900 Wm^{-2}. Also, fruit surface temperature reached around 50^{0}C in the highest solarisation value by 975 Wm^{-2} in July and August. The ratios of relative humidity around %70 and %80 showed inverse correlation with maximum FST.

Air Temperature, Solar Radiation and Relative Humidity during 2003 and 2004 Growing Seasons, and Dates on Which Fruit Surface Temperature (FST) Reached at Least 40^{0}C

Temperature, relative humidity and solar radiation values in 2003 were shown in Fig. 1. In view of mean temperature in 2003, the highest temperatures were in July and August in 2003. Temperatures were usually above 40^{0}C in these months. Mean temperature of June was 26.54 ^{0}C and it increased up to 31.02 ^{0}C in July, 33.40^{0}C in August, and last 25.31^{0}C was in September. The number of days of which temperature were 28 ^{0}C and higher than this value was 27 in July and 24 was in August and September. Mean temperature of October decreased down to 21.03 ^{0}C, and the highest temperature was determined to be 24.0 ^{0}C in that month.

The highest average solar radiation was 680,65 Wm^{-2} in August, 2003 and , the highest mean value was 712.17 Wm^{-2} at 20th July. Still measured mean solar radiation value was 660.61 Wm^{-2} in August that were followed with June (555.58 Wm^{-2}), September (439 Wm^{-2}) and October (317 Wm^{-2}) values. Solar radiation values in which fruit surface temperature is higher than 40^0C in July and August were shown in Fig. 1

Relative humidity values in May, June, July, August, September and October were 56.76%, 57.31%, 49.70%, 53.87%, 58.06% and 61.87%, respectively. In these months although relative humidity ratios showed fluctuations the highest humidity ratio was in August by 77.7% and %76.3 in September (Fig. 1).

Air temperature, solar radiation and relative humidity during 2004 growing season, and dates on which fruit surface temperature (FST) reached least 40^0C were shown in Fig. 2. Mean temperature 28 ^{0}C in June reached 32.48^0C in July, still the highest temperature was determined in July by 37 ^{0}C. The hottest days were 4th , 6th, 10th, 11th, 13th of July that were 40.9 ^{0}C, 40.5 ^{0}C, 41.5 ^{0}C, 41.5 ^{0}C, 40.3 ^{0}C respectively at 13:00 - 16:00. Even mean temperature in August (30.16 ^{0}C) lower than that of July and, daily mean temperature was usually above 28^0C. Mean temperature decreased down to 25^0C in September, and 23.88^0C in October.

Mean highest solar radiation observed was 678.65 Wm^{-2} in July in 2004 and the highest value (975 Wm^{-2}) was recorded at 13:00 in 19th July. Still mean solar radiation value was 618 Wm^{-2} in June. Solar radiation ratio in August (603.81 Wm^{-2}), was lower than that of June due to high humidity. These are followed with September (516 Wm^{-2}) and October (418 Wm^{-2}) values.

Mean relative humidity values were 52%, 46%, 40%, 55%, 48%, and 56% in May, June, July, August, September and October, respectively. The highest relative humidity ratios (74.23%, 82.48%, 80.82%, and 78.43%) were recorded in 25th of June, 10th August, 25th September and 10th October, respectively. The highest humidity ratios were in August and October (Fig. 2).

Effect of Air Temperature on Fruit Surface Temperature (FST)

Air temperature between 08:00 and 16:00 hours was highly correlated (r = 0.97**) with FST between those hours (Fig. 3), and can be predicted from the equation y=1.91X–25.78 where y = FST and x = maximum air temperature. For example, when the maximum air temperature was 35 ^{0}C between 8:00 and 16:00 hours in July and August, FST was predicted to reach 41.78^0C. Between those hours, FST usually surpassed air temperature by several degrees.

Effect of Solar radiation on Fruit Surface Temperature (FST)

Solar radiation also influenced maximum FST. Solar radiation and maximum FST were highly correlated (r = 0.83**) between 8:00 and 16:00 hours in July and August (Fig. 4). Maximum FST could be estimated from y = 0.07x –12.21 where y = maximum FST and x = maximum solar radiation. For example, if solar radiation averaged 810 Wm^{-2} between 8:00 and 16:00 hours in July and August, FST was predicted to reach 44.49^0C

Effect of Relative Humidity on Maximum Fruit Surface Temperature (FST)

Relative humidity also was negatively correlated (r = - 0.62**) with FST. The ratios of relative humidity around %70 and %80 showed inversely correlation with maximum FST between 12:00 and 16:00 hours in July and August

DISCUSSION

Formation of sunburn damage was informed by different researchers, although it shows some differences according to difference in varieties, in some cases of which air temperatures are higher than 28-32 ^{0}C and fruit surface temperature reaching up to 45-50^{0}C and solar radiation around 600 Wm^{-2} (Arndt 1992, Schrader et al 2002). We observed that sunburn damage occurred on Hicaznar pomegranate cultivar when temperatures were higher than 30^{0}C and solar radiation was higher than 610 Wm^{-2}. Sunburn damage of pomegranate called as “Blacking” occurred on the sun-exposed side of the fruit when surface temperature reached up to 45-50^{0}C. Therefore, July, August and September were determined to be months carrying high risk for sunburn damage. Meanwhile, an effect of air humidity having an affect on solar radiation leading to decrease in fruit surface temperature was determined.

Schrader et al. (2002) reported sunburn of apple occurred only when the FTS exceeded 45^{0}C, and several factors influenced FTS. Maximum FST cannot be predicted from air temperature alone. They observed that factors such as clouds, wind and precipitation caused rapid fluctuations of FST. For example, appearance of a few clouds markedly decreased solar radiation, and quickly decreased FST below the “threshold temperature” required to induce sunburn browning. They have not firmly established how long that threshold temperature must be maintained to induce sunburn browning, but they expect that 30 to 60 minutes are required. It may be that a shorter period at a higher FST will have the same effect as a longer period at lower FST.

Brooks and Fisher (1926) reported fruit surface temperatures on the sun- exposed side of fully exposed apples were up to 14 ^{0}C above air temperatures and concluded injury to apples resulted from head, and not from other radiation effects. In contrast, Robinowitch et al. (1974) reported that in addition to heat, visible light was necessary for development of typical sunburn symptoms in tomatoes. They concluded that sunburn is caused by the concurrent action of two external factors, head and light.

Rabinowitch et al. (1983,1986) reported air temperature thresholds of 38 to 48^{0}C and 40.5 to 42.5 ^{0}C were essential for development of sunburn injury in cucumber and peppers respectively. However, they did not report FST. In apples, Schrader et al. (2002), found that at air temperatures between 30 and 38 ^{0}C, FST above 45^{0}C could be attained. The threshold temperature for sunburn was cultivar-dependent and in the range of 46 to 49 ^{0}C. This is for fruit that were previously fully exposed to sunlight and therefore acclimated to heat and sunlight.

We agree with Brooks and Fisher (1926), Rabinowitch et al. (1986), Arndt (1992) and Schrader et al. (2002) that solar radiation and air temperature influenced maximum FST, and sunburn necrosis is normally induced by high FST in sunlight.

CONCLUSIONS

We observed that sunburn of pomegranate occurred when the FST exceed 40^0C, and the air temperatures, solar radiation and relative humidity influenced FST. When air temperatures are higher than 30^0C, fruit surface temperatures are higher than 40^0C and solar radiation is higher than 600 Wm^2 in July, August and September months sunburn damage occurring on Hicaznar pomegranate cultivar in Mediterranean Region of Turkey.

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Figures

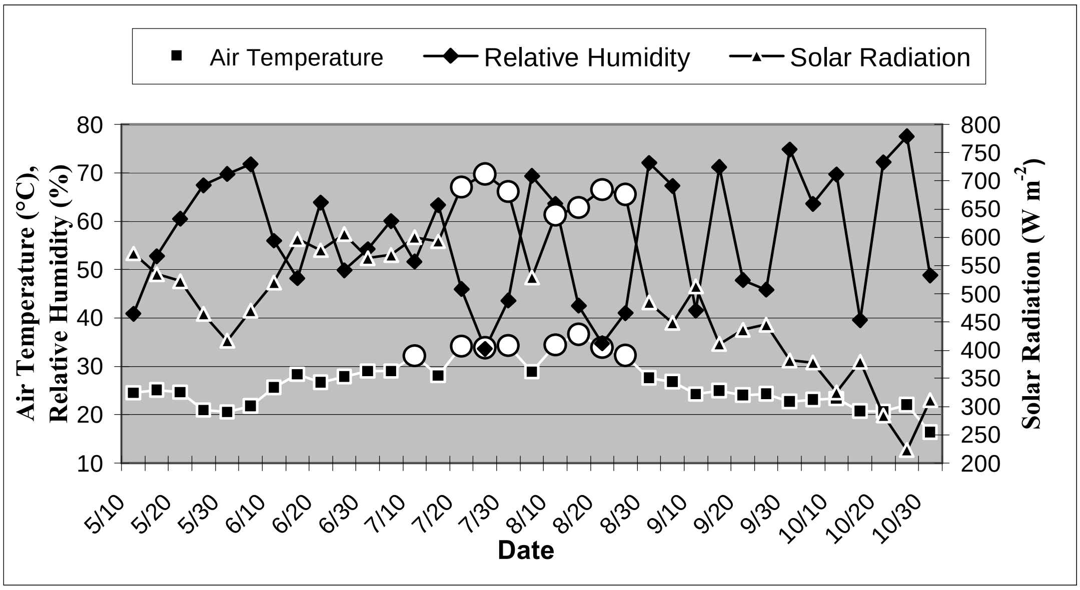

Figure 1. Mean solar radiation, temperature and relative humidity values in pomegranate orchard during 2003. White circles denote those days on which the fruit surface temperature was > 40 ⁰C

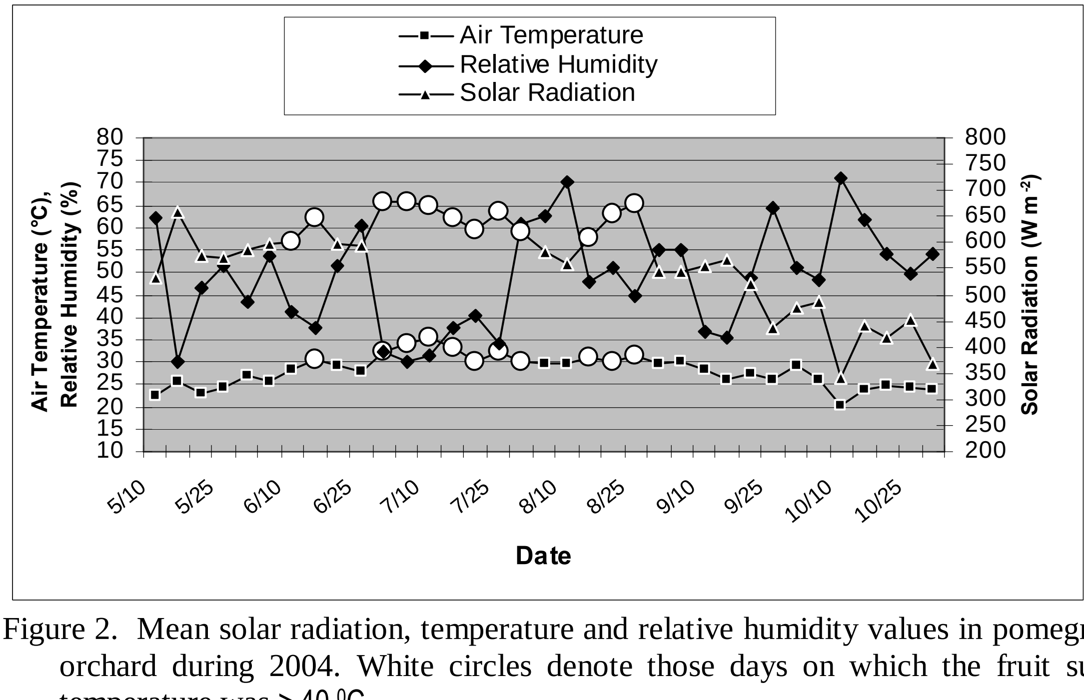

Figure 2. Mean solar radiation, temperature and relative humidity values in pomegranate orchard during 2004. White circles denote those days on which the fruit surface temperature was > 40 ⁰C

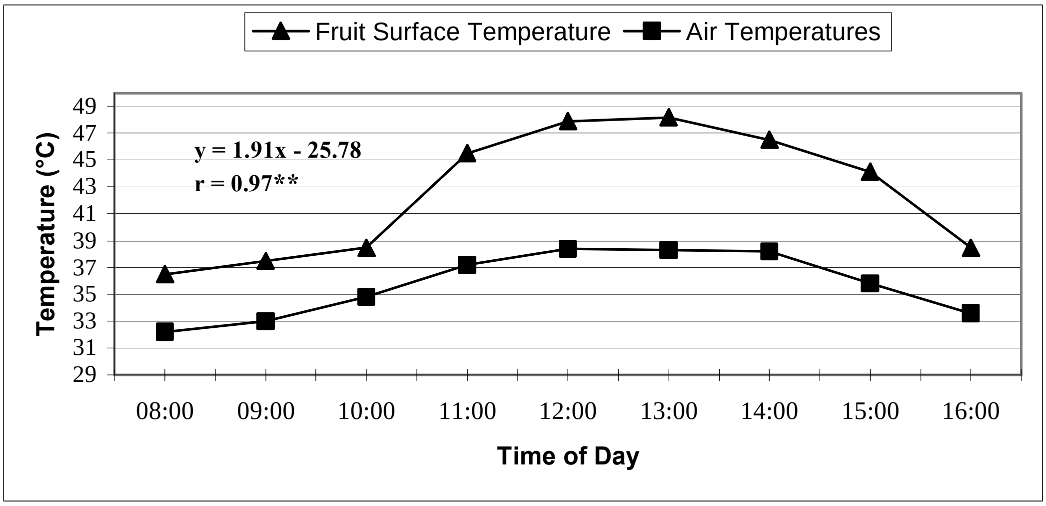

Figure 3. Air temperature versus fruit surface temperature of sunburn damaged (blacking was occurred) fruits on clear day between 8 AM and 16 PM in July and August.

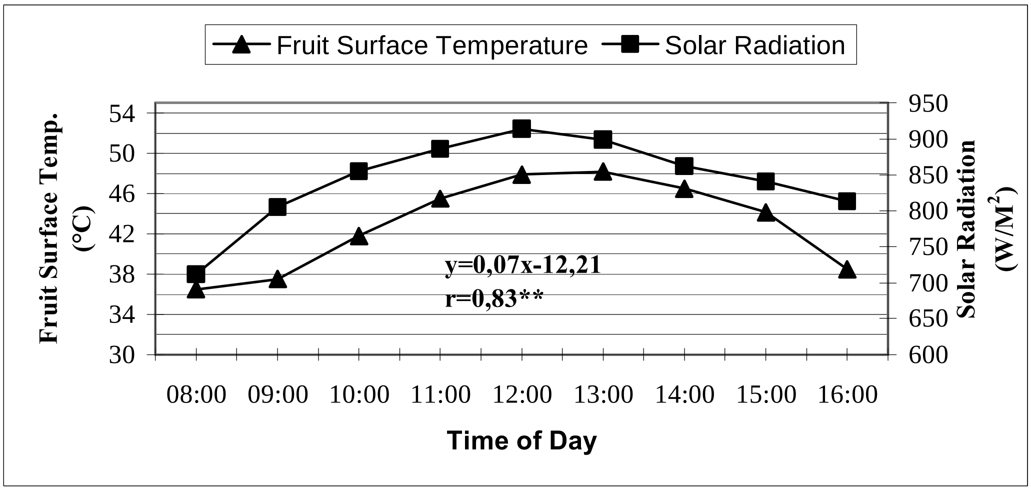

Figure 4. Solar radiation versus fruit surface temperature of sunburn damaged (blacking was occurred) fruits on clear day between 8 AM and 16 PM in July and August.