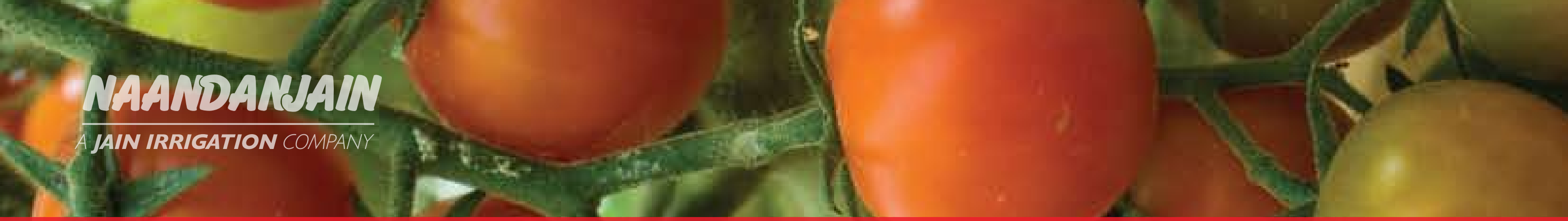

The Effect of Mean Daily Temperature and Relative Humidity on Pollen, Fruit Set and Yield of Tomato Grown in Commercial Protected Cultivation

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Abstract: The research trial was carried out in the Mediterranean region where high summer temperatures have been proved to have a detrimental effect on the delicate tomato fruitset process. The flower to fruit set process was simultaneously monitored in fogged and unfogged shelters during the three-month Mediterranean summer season. Comparisons of pollen quality, fruit set rates and fruit yield revealed that mean daily temperatures of 25–26°C are the upper limit for proper fruit set and fruit yield for tomatoes grown in protected cultivation during the hot Mediterranean summer period. A moderate reduction of 1–1.5°C in mean daily temperatures together with the increased RH (relative humidity) from 50% to 70% during day time improved the pollen grain's viability.

1. Introduction

Mean daily temperature plays an important role with regard to proper anther and pollen development and their function in tomato (Solanum lycopersicum L.) flowers. Studies that tested the relationship between mean daily temperatures and the reproductive stage of tomato plants, found that at daily mean temperatures of 29°C, fruit number, percentage fruit set and fruit weight per plant decreases in comparison with those at 25°C. This reduction in yield is mainly due to impaired pollen and anther development and reduced pollen viability. Sensitivity of the reproductive stage of the flower to above optimal air temperature can cause a reduction in percentage fruit set and thus decrease the fruit yield during commercial tomato growth. Another climatic factor that might influence pollen viability is relative humidity in the air. Pollen grains of different species exhibit diverse reactions to changes in relative humidity. Relative humidity between the range of 50%–70% is generally considered to be optimal for tomato pollination. Trials that tested tomato pollen quality and fruit set at several air humidity levels found that increased humidity (60%–70% RH) improved pollen and fertilization in comparison with 30%–40% RH. However, increasing humidity to 90% may increase pollen susceptibility to heat stress.

Most of the data regarding the response of tomato fertilization and yield to heat stress and different rates of humidity, originates from trials that were conducted in controlled environments and growth chambers along relatively short time periods. In many cases tomato is planted under protected cultivation including regions where the summer is hot and arid. Insufficient ventilation inside the shelters during summer leads to above optimal air temperature and continuous moderate heat stress. These conditions damage the fertilization process which leads to a reduction in fruit yield and in the grower's profits.

One way to cope with sub optimal conditions during commercial growth is to use an inexpensive low pressure fogging system in the shelters during the hot season. Operation of low pressure foggers during tomato growth under suboptimal conditions (high temperatures), succeeded in reducing the daily mean air temperature by 1–1.5°C, which resulted in improved pollen viability and fruit set ratio. Nevertheless, information is still limited concerning the efficient operation of these systems under commercial conditions.

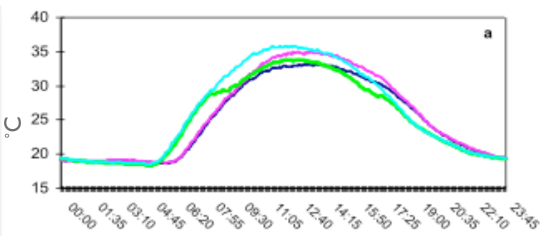
In this study we used a low pressure fogging system during commercial tomato growth throughout the summers of 2012–2013 in order to evaluate its influence on fertilization and yield in comparison with an unfogged treatment. The data that was collected from this bi-annual field trial was analyzed with regard to the findings described in literature from trials conducted in controlled environments.

2. Results and Discussion

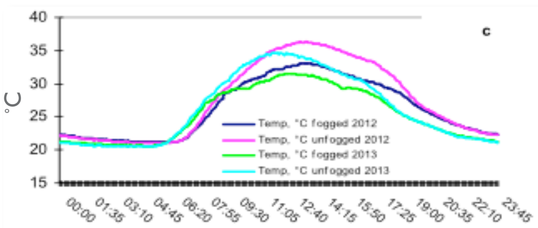
2.1. Daily Mean Air Temperature and Relative Humidity

Mean daily air temperatures plotted along a 24 h period axis in both treatments (fogged and unfogged) are presented in Figure 1. Each figure represents the mean values of one month during the summers of 2012 and 2013: (a) June (c) August. Comparing day temperatures in both treatments shows a 2–4°C reduction obtained by the fogging system during the measurement period. Night temperatures were identical along the whole period in both treatments.

Figure 2 shows the mean daily air relative humidity plotted along a 24 h period axis in both treatments-fogged and unfogged in the years 2012 and 2013:



Time of day



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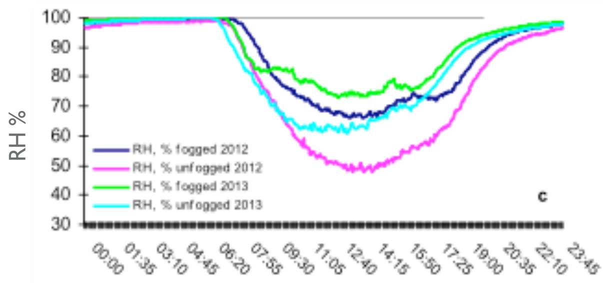
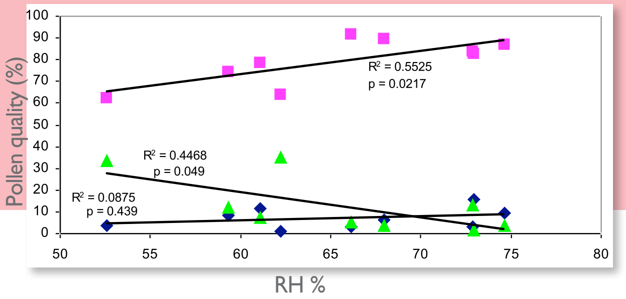


Time of day

2.2. Pollen Quality in Relation to Mean Daily Temperatures and RH

Under fogged cooling conditions pollen viability increased significantly in comparison with the unfogged plots. In most cases the germination percentage of the pollen was not affected by the fogging treatment.

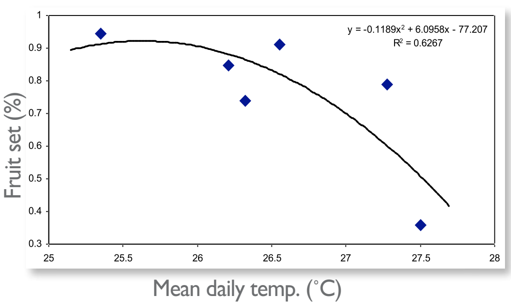
Figure 3. Correlation between pollen germination (blue diamonds), pollen viability (pink squares), non-viable pollen (green triangles) and minimum relative humidity during day time inside the net house. Statistical analysis results (F test) and regression coefficient of the first order regression equation for each data set are presented in the figure.



2.3. Fruit Set and Fruit Yield in Relation to Mean Daily Air Temperature

Figure 4 shows the percentage of flowers that turned into fruit. The data presented in this figure consists of the fruit set and mean daily temperatures data that was collected from both treatments during the 2012 and 2013 growth seasons and were combined into one continuous data set

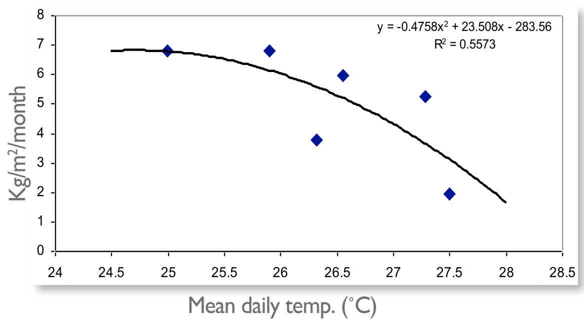
Figure 4. Relationship between mean daily air temperature and fruit set percentage.



The fruit set is at its peak >90% at 25 °C. At 26 °C the fruit set rate ranges between 70% and 90% but at 27.5% the fruit set rate drops to 50%. This would suggest that temperatures of 2.5 °C above the optimal mean daily temperature reduce the ability of the plant to reach its potential fruit set by up to 40%.

Figure 5. shows the amount of fruit as the number of kilos that were picked per square meter per month. As in the previous figure the data presented in Figure 5 is composed of data collected from both treatments during the 2012 and 2013 growth seasons. Each point represent total yield from flowers that were pollinated during July and August of 2012 and 2013, in both treatments-fogged and unfogged. This number was plotted against the average daily temperature of the summer months when pollination occurs, in order to evaluate its affect on the yield of that period. At 25°C, the tomato yield is at its peak at 7 kg/m²/month and remains there until temperatures exceed 26.5°C when they drop to 5 kg/m²/month. This diminishing yield mirrors the 40% fruit set reduction in Figure 4.

Figure 5. Relationship between mean daily air temperature and monthly fruit yield in kg/m².



2.4. Discussion

Mean daily temperatures of 25–26°C were found to be the upper limit for proper fruit set and fruit yield for tomatoes grown in protected cultivation during the hot Mediterranean summer period (June–August).

With regard to the operation of low pressure foggers during tomato production under suboptimal conditions (high temperatures), the findings from the 2013 summer were similar to those of the summer of 2012 reported in Harel et al. In that year, air temperature also decreased during the day time by 2–3°C in comparison with the unfogged treatment and the RH increased by 10%–30%. This moderate reduction in heat stress together with the elevated RH improved the pollen grain's viability.

With regard to the conclusions of this study that in field conditions, even relatively small increases of 2°C in the mean daily temperature can cause a yield reduction of up to 60% should be acknowledged, taking into consideration the global warming process.

The importance of the data presented here is in its applicative aspects for tomato growers in regions where tomatoes are grown in protected cultivation during hot seasons which often causes sub optimal conditions inside the shelter. We propose that a daily adjustable threshold value for the fogging control system will be calculated by basing the mean daily temperature of 26°C as the optimal target condition, for achieving the most efficient operation of the system in commercial tomato growth. Based on the findings in this bi-annual trail we recommend this flexible method of controlling protected tomato cultivation in order to enhance pollen viability and fruit yield. The proper daily set point temperature can be calculated when the mean (or minimum) night temperature of previous night is known. Of course, in parallel to this temperature set point, a maximum RH value (>90% for example) should be fixed into the control system.

3.2. Net House, Fogging System and Climate Data Collection

Technical details of experiment are as described in Harel et al. In brief, a naturally ventilated, north/south oriented net-house with a gutter height of 4m, a ridge height of 4.5 m and a double slope roof was used. The net house was covered (roof and walls) with 50 mesh insect proof net. A commercially available low pressure fogging system (NaanDanJain Irrigation) was installed in the net house on a 700 m^2 area. The system consisted of nozzles (Super fogger 13 l/h, NaanDanJain Irrigation) with average droplets sizes of 60–70 µm configured in rows.

4. Conclusions

It can be concluded that in the hot Mediterranean summer months, the mean daily (day/night) temperature of up to 26°C and 70 RH% during day time should be achieved when using evaporative cooling such as low pressure fogging systems in shelters. Pollen quality and fruit sets benefit under such growing conditions, which in turn increases the yield of tomatoes.

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