https://dx.doi.org/10.22161/ijhaf.2.6.1 ISSN: 2456-8635

Effect of Greenhouse Cooling Methods on the Growth and Yield of Tomato in a Mediterranean Climate

Sedat BOYACI[1*], Adil AKYÜZ[2]

[1]Department of Biosystems Engineering, Kırşehir Ahi Evran University, Kırşehir, Turkey
Email address: sedat.boyaci@ahievran.edu.tr
[2]Department of Biosystems Engineering, Kahramanmaraş Sütçü İmam University, Kahramanmaraş, Turkey
Email address: adilakyuz@ksu.edu.tr
***Corresponding author:** Sedat, BOYACI, Kırşehir Ahi Evran University, Agricultural Faculty, Department of Biosystems Engineering, Kırşehir, Turkey
Email address: sedat.boyaci@ahievran.edu.tr

***Abstract*— *Tomato (Solanum lycopersicum L.) plant was grown in three different greenhouses during the first period (May-August), second period (March-July) and the third period (August-November). The cooling methods used in greenhouses covered with polyethylene film were Fog and natural ventilation (Fog+NV) system in the first greenhouse, a Fan and pad cooling (FP) system in the second greenhouse, and natural ventilation (NV) system in the third greenhouse. Temperature inside the greenhouse was not suitable for plant growth when outside temperature was around 40 °C. The PD system reduced the inside temperatures up to 15 °C depending on the outside temperature and kept the greenhouse inside temperature within the appropriate ranges for plant growth. Yield per plant, marketable fruit percentage and marketable fruit yield obtained in the 1st, 2nd and 3rd periods for Fog+NV treatment were 1734.83, 2568.11 and 2376.30 g plant-1, 67.20, 72.00 and 58.20% and 1165.81, 1849.04 and 1383.00 g plant-1, for FP treatment 2187.51, 3525.69 and 4028.21 g plant-1, 80.00, 81.60 and 85.20% and 1750.00, 2876.96 and 3432.03 g plant-1, for NV treatment 1281.77, 1961.13 and 1314.07 g plant-1, 60.00, 64.00 and 55.20% and 769.06, 1176.68 and 725.37 g plant-1, respectively. The results revealed that proper designed FP systems reduced the high temperatures inside the greenhouse and increased tomatoes yield compared to the other two treatments.*

Keywords*— *Cooling effect, Fan pad, fogging, natural ventilation.

I. INTRODUCTION

Expanding the production season is one of the most important issues in modern greenhouse cultivation to maximize the utilization of greenhouse equipment, extend the export season, and increase the annual yield per unit area and profitability. However, such a practice is limited in greenhouses located in regions with Mediterranean climate, because the cooling techniques used (ventilation and shading) do not meet the conditions required especially in hot summer months [1]. The greenhouses, in this period, should be cooled to reduce plant stress and offer quality products to the market [2].

Tomatoes is one of the most popular and commonly consumed vegetables grown in worldwide. The popularity of product comes from its acceptable taste, nutritive value (high in vitamin C and A), short life cycle and high productivity [3]. The most suitable temperature for tomato cultivation is between 17 and 27 °C. Temperatures below 13 °C and above 30 °C reduce the plant growth, formation of flower pollens, viability of flower pollens and germination ability [4]. Relative humidity in tomato cultivation should be around 50 to 60%, stigma dries under 50% relative humidity and the flower pollens are damaged when relative humidity is over 80% [5]. Heat stress caused by high temperatures also negatively affect the vegetative and generative growth of tomato plants. Extreme temperatures cause stomata closing that leads to decrease in transpiration and photosynthesis. In addition, high temperatures considerably reduce the flowering, pollination and fruit setting of tomato plant, causing to increased number of parthenocarpic fruits and thus lower marketable yields. Similarly, high relative humidity negatively affects the quality of tomato fruit by preventing transpiration, pollination and fruit setting [6,7,8,9].

Therefore, evaporative cooling systems for the greenhouses have been introduced to provide the desired growing conditions in a greenhouse during the hot period of a year. The basis of evaporative cooling systems is the transformation of sensible heat into latent heat. The

https://dx.doi.org/10.22161/ijhaf.2.6.1 ISSN: 2456-8635

evaporative cooling systems have been used by different researchers to cool the greenhouses [10, 11, 12, 13, 14, 15, 16] and successful results have been reported in reducing the high temperatures of the greenhouses.

The aims of this study were to investigate the availability of natural ventilation (NV) when temperatures inside the greenhouse exceed the optimum conditions desired by the tomato plant, to determine the effectiveness of evaporative cooling (fogging + natural ventilation (Fog+NV) and fan pad (FP)) when NV is insufficient, and to investigate the effects of cooling differences between methods on plant growth, fruit quality and yield.

II. MATERIALS AND METHODS

2.1. Location of the study area

The study was carried out in 2011 and 2012 on the research fields of Agricultural Faculty, Kahramanmaras Sutcu Imam University, located in the south of Kahramanmaras province (37° 35'31''N latitude and 36° 49' 25.13''E longitude, altitude 503 m) which has Mediterranean climate.

2.2. Air conditioning requirements of the study area

Climate data of the central district indicates the heating requirements of greenhouses for about 4.5 months starting from the end of October till the middle of March (Fig. 1). Greenhouses need for about 3.5 months natural ventilation from mid-March to mid-May and from around mid-September to the end of October. Cooling is required for about 4 months from mid-May to the second half of September in the region where the temperatures start to rise.

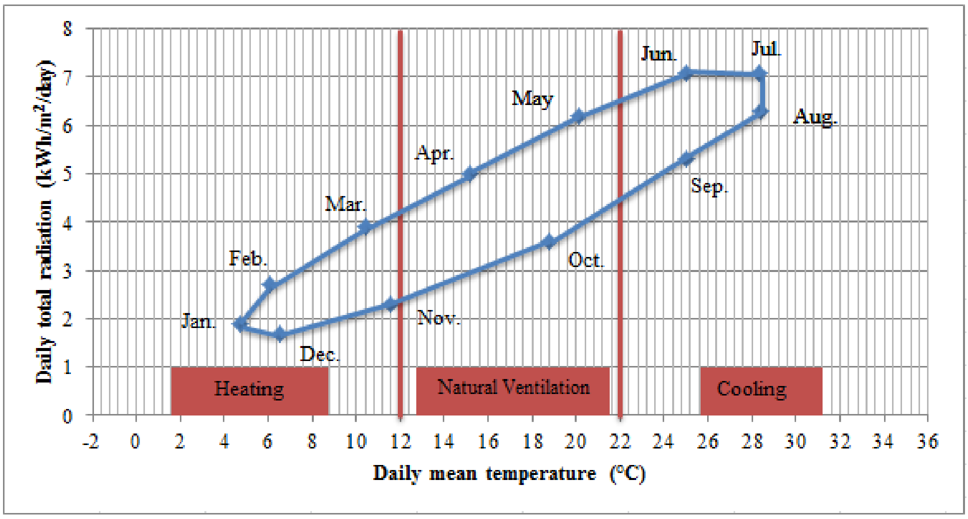

Fig.1: Climatic requirements of the study area

2.3. Structural properties of research greenhouses

Three greenhouses with spring roofs were used in the study. Ground area of the greenhouses directed in the North-South direction s 150 m^2 (7.5 m x 20 m), the height of gutter was 3 m and the height of ridge was 5 m.

The greenhouses made using galvanized steel were covered with a 350 µm thick 36-month UV+IR tempered PE plastic cover material.

2.4. Cooling systems used in the study

— **Fog+NV:** The system is composed of water softener, filter to prevent clogging of nozzles, water supply, pump, pressure regulator and fogging nozzles. Fogging heads with a diameter of 0.2 mm were placed at 1.25 m intervals to the long axis of the greenhouse at 45 degrees angle to obtain a uniform distribution pattern in the greenhouse. The system has been operated by electrically with a central water supply system depending on the relative humidity (RH) value of the greenhouse. Relative humidity in the greenhouse made of Fog+NV was kept at 70%.

— **FP:** A pad made of cardboard material with a height of 50 cm and size of 7.5 m^2 (50x50x10 cm) and the distributor honeycombs that ensure the proper distribution of water on the pad were placed to air inlet openings located at the short side of the greenhouse facing the north. Water was pumped to the pads by a water pump with a flow rate of 10 l min^{-1} [17] for 1 m of the pad. Water accumulated at the bottom of pad unit was returned back to the tank. A fan was installed at 3 m above the ground, opposite to the humidification pads in the greenhouse compartment (HP: 1.5, KW: 1.1, Volt: 380, HZ:50).

— **NV:** Total window area in the greenhouse with roof ventilation was 20% of the ground area. Upper doors of the greenhouse with natural ventilation system were opened and closed by a temperature sensor which functions below 15 °C and above 28 °C.

https://dx.doi.org/10.22161/ijhaf.2.6.1 ISSN: 2456-8635

2.5. Determination of the effectiveness of cooling systems

Effectiveness of the cooling systems used in greenhouses was calculated with Eq. 1 suggested by [18].

$$CE=((T_{out}-T_{in})/(T_{out}-T_{wb}))*100 \quad (1)$$

In equation; CE = System efficiency, %, T_{out} = Dry thermometer temperature of air outside the greenhouse, ºC, T_{in} = Dry thermometer temperature of air inside the greenhouse, ºC, T_{wb} = Wet thermometer temperature of air outside the greenhouse, ºC

2.6. Characteristics of the instruments used in measurement of meteorological data

Temperature and relative humidity values both inside and outside of the greenhouses were recorded every 30 minutes with data loggers during the plant growing periods.

2.7. Plant pattern and yield parameters in greenhouses

Tayfun F1 type tomato plant was used in the three periods of the greenhouse studies. Growing period of tomatoes planted as seedling in the greenhouse was 94 days for the 1st period (May 14 – August 11, 2011), 113 days for the 2nd period (March 22 - July 12, 2012) and 101 days for the 3rd period (August 03 – December 11, 2012). Four hundred twenty tomatoes seedlings were planted in the greenhouse at 40 cm in inter-row and intra-row spacings as double row and a 100 cm service path was left between two rows. Plant density in the greenhouse was 2.8 plants m^{-2}. Soils in 0-30 cm, 30-60 and 60-90 cm depth of greenhouse were heavy clayey textured and the class of irrigation water used in the greenhouse was C_2S_1. The plants in greenhouse were irrigated with 4 l/h drippers at 1 atmospheric pressure.

2.8. Measurements and analysis of plant and fruit

Plant parameters (stem diameter, plant height, number of leaves) were recorded weekly, whereas fruit analyzes (width, length, volume, weight, pH, hardness, titratable acid and water-soluble amount of dry matter) were determined when the fruits in the bunches reached the harvest maturity. Yield values obtained in each harvest were combined and total yield per plant was calculated at the end of the experiment. The marketable fruit percentage was classified according to [19]. Tomato fruits greater than 5.5 cm width were classified as the first grade, between 4.5-5.5 cm were the second grade, between 3.5-4.5 cm were the third grade and fruits smaller than 3.5 cm were the fourth grade. Accordingly, grade III and IV fruits were considered non-marketable.

2.9. Statistical Analysis of Data

Statistical analyses were performed using JUMP version 5.0.1 statistical software. The differences between treatments in terms of temperature and relative humidity values in the greenhouses, periodic plant growth observations, fruit quality and yield per plant values were interpreted by using the least significant difference (LSD) comparison test according to randomized experimental design.

III. RESULT AND DISCUSSION

3.1. Cooling Effectiveness

Climate requirements (15-28 °C temperature and 50-80 % relative humidity) of tomato plants in greenhouses have been taken into consideration for data interpretation. The systems started to be operated in cases where the temperature exceeded 28 °C and the natural ventilation was insufficient to reduce the internal temperature. An example of daily inside and outside temperatures, relative humidity, system efficiencies, and inside and outside temperature differences depending on outside relative humidity when the systems operating were presented in Table 1 and Fig. 2.

Table.1: Meteorological data measured inside and outside the greenhouses and system efficiencies.

Quantities	Min.	Mean	Max.
To (°C)	24.85	31.43	37.35
Fog+NV	23.40	28.33	32.32
Cooling Effect (%)	11.71	24.43	43.41
Δt (Tout-Tin, °C)	0.78	3.10	7.64
FP	20.27	24.48	27.74
Cooling Effect (%)	33.19	55.47	80.07
Δt (Tout-Tin, °C)	2.21	6.94	14.09
NV	29.01	35.67	40.90
Δt (Tout-Tin, °C)	-8.17	-4.25	-2.14
RHo%	16	35.76	58.00
Fog+NV	68	70.71	74
FP	45	57.71	68
NV	30	46.29	67

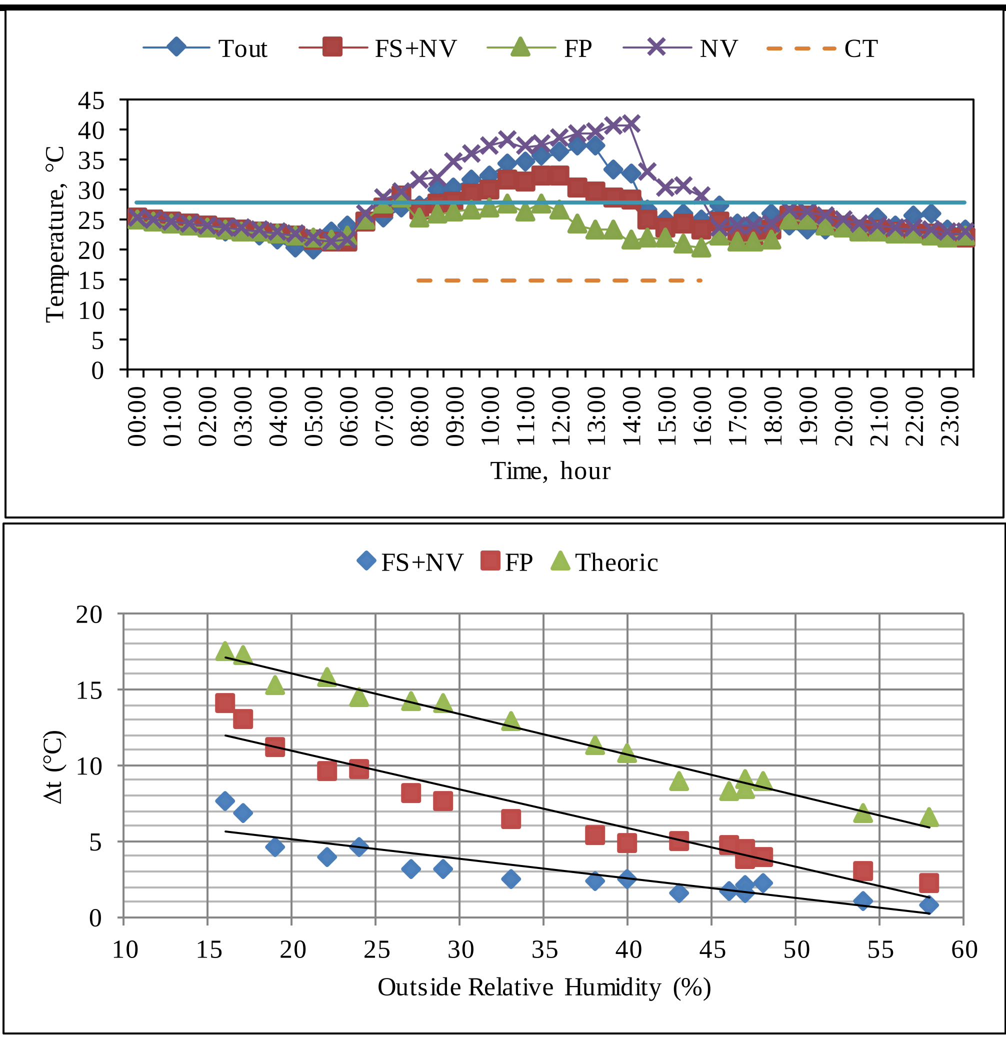

Fig.2: Temperature values measured inside and outside the greenhouses during a day and outside and inside temperature difference depending on outside relative humidity

The highest outside temperature measured during the day was 37.35 °C at 13:00 and the relative humidity was 16% while the inside temperatures reached to 29.71, 23.26 and 39.54 °C in Fog+NV, FP and NV greenhouses, respectively. The inside temperature in greenhouses were 7.72 and 14.09 °C lower in Fog+NV and FP treatments whereas inside temperature in NV was 8.17 °C higher compared to outside temperature. Temperature differences in Fog+NV and FP greenhouses were 7.64 °C and 14.09 °C when the outside relative humidity was 16% depending on outside and inside temperature differences. The temperature differences in Fog+NV and FP greenhouses were 0.78 °C and 2.21 °C when outside relative humidity of 58%. Accordingly, cooling efficiency in Fog+NV greenhouse ranged from 33 to 56-80% and in FP from 12 to 24-43%. The efficiency of appropriately designed evaporative cooling systems was reported as between 11.7 and 80% by different researchers [20,21,12]. The difference between inside and outside temperatures was reported between 5 and 9 °C in the fogging system [10,11,15], between 10 and 15 °C in the FP system [12,13,14] and 1.5 and 10.6 °C in NV greenhouses with a good ventilation [22, 23]. Dry air taken in the greenhouse with Fog+NV system was provided with natural ventilation, therefore efficiency of cooling system considerably depended on the air exchange, temperature difference and wind pressure. Since the cooling efficiency depends on the effectiveness of the natural ventilation, the temperatures during certain periods could not be maintained at the optimum temperature ranges of tomato plants requirements, and thus the temperature in the greenhouse increased to 32.32 °C. The cooling efficiency in the FP system reached 80% when the relative humidity of the outside air decreased to 16% during the day and the temperature in the greenhouse was 14.09 °C lower compared to the outside temperature. Temperature values recorded in FP system are within the ranges of optimum greenhouse indoor temperature values of tomato plants. In contrast to FP system, the temperature difference between outside and inside

https://dx.doi.org/10.22161/ijhaf.2.6.1 ISSN: 2456-8635

greenhouse increased up to 8.17 °C in the NV system. The temperatures recorded in the greenhouse with NV system were above the optimum values required for tomato plant, and therefore the growth and yield parameters of tomato plants were negatively affected. The lack of energy and labor costs in natural ventilation are the positive aspects of system. However, it is not possible to obtain the desired temperature decreases in the greenhouse during periods when the temperature increases and the efficiency of the system depends on the temperature difference and wind pressure. Since the efficiency of the system depends on the temperature difference and wind pressure, the desired temperature decreases in a greenhouse may not be possible during periods of high temperatures. Therefore, it would be more efficient to use natural ventilation in autumn and spring seasons.

3.2. Periodic plant growth observations

The effects of different cooling treatments on weekly stem diameter (SD), plant height (PH) and number of leaves (NL) were given in Table 2. The differences in SD, PH and NL between cooling systems were not statistically significant ($p<0.05$).

Table.2: Plant growth observations of treatments

Treatment	Stem diameter, (mm)			Plant height (cm)			Leaf number (number)		
	1st period	2nd period	3rd period	1st period	2nd period	3rd period	1st period	2nd period	3rd period
Fog+NV	16.20a	15.60a	9.84b	196.44a	196.89a	139.78c	32.33a	32.33a	23.89a
FP	13.67b	14.00b	12.00a	172.33b	176.22b	169.67a	28.44c	27.00c	25.44a
NV	14.24b	14.97ab	9.49b	180.89b	195.22a	154.89b	30.89b	30.67b	24.78a

*, The differences between the values indicated by the different letters are significant at $p<0.05$ level.

The body diameter changes in the greenhouses were between 13.67 and 14.24 mm at the first period, 14.00 to 15.60 mm at the second period, and between 9.49 and 12.00 mm at the third period. The plant height changes in greenhouses were between 172.33 and 196.44 cm at the first period, between 176.22 and 196.89 cm at the 2nd period, and between 139.78 and 169.67 cm at the 3rd period. The number of leaves changes were between 28.44 and 32.33 leaves at the first period, between 27.00 and 32.33 leaves at the 2nd period and between 23.49 and 25.44 leaves at the 3rd period. The results showed that the differences in temperature and relative humidity between the treatments had effect on SD, PH and NL values. The stem diameter of tomato plants has been reported between 8.90 and 16.50 mm, the PH was between 173.50-316.00 cm and the NL up to the first bunch was between 5.66-7.50 [24,25,26]. The SD, PH and NL values of tomato plants in Fog+NV treated greenhouse were significantly different ($p<0.05$) in the 1st and 2nd period of the experiment compared to the other treatments. The plant measurement values in NV treated greenhouse followed the values obtained in Fog+NV. The plants grown in NV greenhouses were affected by the high temperatures and the plants produced green parts instead of fruits. The tips of seedlings especially in Fog+NV and NV treated greenhouses dried in the third period of the experiment, due to the high outside temperatures (38 ° C) in the first week.

The plants started to grow with the emergence of new shoots after the 2nd week. The SD, PH and NL values of plants in which physiological structures deteriorated were affected by these temperatures till the end of the period. Therefore, plant growth parameters in the greenhouse treated by FP were greater, which was not because of the formation of green parts but the plants in the other greenhouses could not reveal their physiological characteristics due to the temperature stress. Negative effects of high temperatures on plants planted in August should be taken into account for good tomato cultivation.

3.3. Pomological characteristics of fruits

The effects of different cooling treatments on the width, length, volume, weight, pH, hardness, titratable acid (TA) and water-soluble solid content (SSC) of tomato fruits were shown in Table 3.

Table.3: Fruit quality and yield values

Measurement	Treatment	1st period	2nd period	3rd period
Width, mm	Fog+NV	53.50a	57.86b	54.61b
	FP	52.72a	63.24a	66.88a
	NV	45.66b	50.75c	47.76c
Fruit Length, mm	Fog+NV	39.81b	56.70b	41.96b
	FP	45.03a	61.04a	63.81a

	NV	36.24c	51.40c	35.38c
Volume, cm^3	Fog+NV	59.13b	91.27b	70.89b
	FP	66.42a	119.38a	133.11a
	NV	47.78c	68.89c	48.44c
Weight, g	Fog+NV	57.83b	85.60b	79.21b
	FP	72.92a	117.52a	134.27a
	NV	42.73c	65.37c	43.80c
pH	Fog+NV	4.34a	4.27b	4.23b
	FP	4.37a	4.23c	4.25a
	NV	4.39a	4.29a	4.24ab
Hardness of fruit pulp, kg cm^{-2}	Fog+NV	2.91c	3.43b	4.20b
	FP	3.74b	5.12a	4.16b
	NV	4.20a	3.20b	4.40a
TA, % Titratable acid content	Fog+NV	0.35a	0.48a	0.38a
	FP	0.33b	0.39b	0.34b
	NV	0.34ab	0.43b	0.35b
SSC, % Soluble solids content	Fog+NV	4.80a	4.88a	4.82a
	FP	4.61b	4.84b	4.18c
	NV	4.50b	4.86ab	4.32b

* The differences between the values indicated by the different letters are significant at p <0.05 level.

Pomological analysis of tomato fruits showed that pomological properties changed with cooling treatments. The width, volume and weight of tomato fruits obtained in FP treatment were higher than in other treatments. Average fruit weights in Fog+NV, FP and NV treatments in the first period were 57.83, 72.92 and 42.73 g, in the 2nd period 85.60, 117.52 and 65.37 g and in the 3rd period 79.21, 134.27 and 43.80 g, respectively. The results revealed that temperature and relative humidity differences between the treatments had significant effect on fruit quality and yield values. Tomato fruit width was reported between 56.44 and 58.67 mm, length 43.15 and 52.29 mm, volume 102.40 and 145.50 cm^3, weight 73.50 and 185.63 g, pH values 3.56 and 5.20, hardness 1.15 and 11.33 kg cm^{-2}, titratable acid values 0.30 and 0.56 and SSC 3.15 and 7.50 [24, 27, 25, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 26]. The results obtained in the current study are similar to the studies conducted by other researchers. However, high greenhouse inside temperatures during the flowering period of seedlings planted in the first period in May and high temperatures during the planting of seedlings in the third period in August had negative influence on seedlings, and caused to decrease in the yield. The results showed that planting the seedlings in the second period (March) was important to increase the yield and number of marketable fruits.

3.4. Marketable fruit and yield characteristics

Percentage and yield values of marketable fruits for the periods of experiments were given in Table 4.

Table.4: Marketable fruit and yield characteristics of the growing periods

Periods	Treatment	Total yield (g $plant^{-1}$)	Marketable (%)	Marketable yield (g $plant^{-1}$)
1	Fog+NV	1734.83b	67.20	1165.81
	FP	2187.51a	80.00	1750,00
	NV	1281.77c	60.00	769.06
2	Fog+NV	2568.11b	72.00	1849.04
	FP	3525.69a	81.60	2876.96
	NV	1961.13c	64.00	1176.68
3	Fog+NV	2376.30b	58.20	1383.00
	FP	4028.21a	85.20	3432.03
	NV	1314.07c	55.20	725.37

*, The differences between the values indicated by the different letters are significant at p <0.05 level.

Yield per plant, marketable fruit percentage and marketable fruit yield obtained in the 1st, 2nd and 3rd periods for Fog+NV treatment were 1734.83, 2568.11 and 2376.30 g plant^{-1}, 67.20, 72.00 and 58.20% and 1165.81, 1849.04 and 1383.00 g plant^{-1}, for FP treatment 2187.51, 3525.69 and 4028.21 g plant^{-1}, 80.00, 81.60 and 85.20% and 1750.00, 2876.96 and 3432.03 g plant^{-1}, for NV treatment 1281.77, 1961.13 and 1314.07 g plant^{-1}, 60.00, 64.00 and 55.20% and 769.06, 1176.68 and 725.37 g plant^{-1}, respectively. The difference in yield per plant was highly significant ($p<0.01$) between the treatments. The analyses showed a relationship between yield values and the cooling systems used in greenhouses. In addition, the FP system was superior in terms of the number of marketable fruits and yield per plant compared to the NV and Fog+NV systems. In a study comparing evaporative cooling and NET systems, the yield per plant was reported as 6300 and 6400 g plant^{-1}, the percentage of marketable fruit was 60.30 and 75.00% and the marketable yield was 3800 and 4500 g plant^{-1}, respectively [16]. The yield per plant in greenhouses cooled with the fan pad system and not cooled was found as 6619 and 3978 g plant^{-1}, the percentage of marketable fruits was 87.61 and 59% and the marketable yield was 5799 and 2349 g plant^{-1}, respectively [38]. In a greenhouse study conducted using the micro-fog system and non-cooling, yield per plant was 568 and 506 g plant^{-1}, the percentage of marketable fruit was 87.76% and 85.08%, and the marketable yield was 498.5 and 430.5 g plant^{-1} [39]. Although tomato yield varies depending on the characteristics of a variety, yield differences obtained in the same tomato variety is due to the difference in the cooling systems used in the experiment. Similar to the results reported in other studies, well designed evaporative cooling systems were efficient in reducing the inside temperature of the greenhouses during high temperatures and increase the total yield and marketable yield.

IV. CONCLUSION

Plant production using natural ventilation under high inside greenhouse temperatures (40 °C) in regions with Mediterranean climate is not possible. Therefore, evaporative cooling systems, in these periods, should be used in reducing greenhouse inside temperatures although costly compared to natural ventilation. Despite the success of evaporative cooling systems in reducing the greenhouse temperatures, humidity which cannot be controlled in the indoor environment may cause plant diseases and yield losses. Therefore, proper design of the systems is extremely important as in their use. In this study, the FP system was successful in reducing the inside temperatures (15 °C) compared to the outside temperatures depending on the relative humidity of the outside air. Contrary to FP system, since dry air intake and moist air discharge in Fog+NV treatment are depending on the wind and temperature differences, Fog+NV treatment was insufficient to reduce the inside temperatures needed for plant demand. Therefore, studies are needed to ensure the effectiveness of the system. Besides, the use of natural ventilation is considered more suited to autumn and spring seasons.

ACKNOWLEDGEMENTS

This study was a part of Ph.D. thesis of S. Boyaci (2014) and supported by the Scientific Research Project Coordination Unit of Kahramanmaraş Sütçü İmam University, Turkey.

REFERENCES

[1] A.A. Sapounas, Ch. Nikita-Martzopoulou, T. Bartzanas, and C. Kittas, 2008. Fan and Pad Evaporative Cooling System for Greenhouses: Evaluation of a Numerical and Analytical Model. Acta Hortic., 797: 131-137.

[2] J.J. Hanan, W.L. Holley, and K.L. Goldberry, 1978. Greenhouse Management. Advances Series in Agricultural Sciences, Springer-Verlag, pp.490.

[3] A.H. Abdelmageed, N. Gruda, and B. Geyer, 2003. Effect of High Temperature and Heat Shock on Tomato (*Lycopersicon esculentum* Mill.) Genotypes under Controlled Conditions. Conference on International Agricultural Research for Development, Göttingen, Germany, pp.1-7.

[4] K. Abak, S. Çürük, 1995. Adaptation to humid high temperature, pollen vitality and germination capabilities of some tomato genotypes under Cukurova Conditions, Adana, Turkey. Second National Horticulture Congress of Turkey, Adana, Turkey. (in Turkish).

[5] A. Sevgican, 2002. Undercover (greenhouse) vegetable farming. Publications of Ege University Faculty of Agriculture. No: 528-526. (in Turkish)

[6] S.R. Adams, K.E. Cockshull, C.R.J. Cave, 2001. Effects of temperature on the growth and development of tomato fruits. Ann. Bot. 88: 869–877.

[7] D. Morales, P. Rodriguez, J. Dell'Amico, E. Nicolas, A. Torrecillas and M.J. Sanchez-Blanco, 2003. High-temperature preconditioning and thermal shock imposition affects water relations, gas exchange and root hydraulic conductivity in Tomato. Biol. Planta. 47, 6–12.

[8] M. Peet, S. Sato, C. Cle´mente, and E. Pressman, 2003. Heat stress increases sensitivity of pollen, fruit and seed production in tomatoes (Lycopersicon

esculentum Mill.) to non-optimal vapor pressure deficits. Acta Hortic. 618: 209–215.

[9] V. Kleinhenz, K. Katroschan, F. Schütt, and H. Stützel, 2006. Biomass Accumulation and Partitioning of Tomato under Protected Cultivation in the Humid Tropics. Europ. J. Hort. Sci., 71 (4):173–182.

[10] A. Arbel, O. Yekutieli, and M. Barak, 1999. Performance of a Fog System for Cooling Greenhouses. Journal of Agricultural Engineering Research, (72): 129-136.

[11] H.H. Öztürk, 2003. Evaporative Cooling Efficiency of a Fogging System for Greenhouses. Turk. J. Agric. For., (27): 49-57.

[12] C. Kittas, T. Bartzanas, and A. Jaffrin, 2003. Temperature Gradients in a Partially Shaded Large Greenhouse Equipped with Evaporative Cooling Pads. Biosystems Engineering, 85 (1): 87-94.

[13] P.A. Davies, 2005. A Solar Cooling System for Greenhouse Food Production in Hot Climates. Solar Energy, (79): 661-668s.

[14] M. Fuchs, E. Dayan, and E. Presnov, 2006. Evaporative Cooling of a Ventilated Greenhouse Rose Crop Agricultural and Forest Meteorology, 138: 203–215.

[15] S. Li, and D.H. Willits, 2008. Comparing Low-Pressure and High-Pressure Fogging Systems in Naturally Ventilated Greenhouses. Biosystems Engineering, (101): 69-77.

[16] J.F.J., Max, J.H. Walter, U.N. Mutwiwa, and H.J. Tantau, 2009. Effects of Greenhouse Cooling Method on Growth, Fruit Yield and Quality of Tomato (*Solanum lycopersicum* L.) in a Tropical Climate. Scientia Horticulturae, 122: 179-186.

[17] ASAE, 1994. Plants: Greenhouses, Growth Chambers and Other Facilities. ASAE Fundamentals Handbook (SI), Michigan, 49085-9659 USA.

[18] R.W. Bottcher, G.R. Baughman, and D.J. Kesler, 1989. Evaporative Cooling Using a Pneumatic Misting System. Trans. ASAE, 32: 671-676.

[19] TS, 2004. TS 794 Notification on the Mandatory Implementation of Tomato Standard in Foreign Trade. (in Turkish)

[20] J.I. Montero, T.H.Short, R.B.Curry, and W.L. Bauerle, 1981. Influence of Evaporative Cooling Systems on Greenhouse Environment. ASAE, 81: 4027-4033.

[21] G.A. Giacomelli, 1993. Evaporative Cooling for Temperature Control and Uniformity. ISHS International Workshop on Cooling Systems for Greenhouses, Israel. pp. 152–160

[22] H. Harmanto, J. Tantau, and V.M. Salokhe, 2006. Optimization of Ventilation Opening Area of a Naturally Ventilated Net Greenhouse in a Humid Tropical Environment. Acta Hortic. 719, 165-172.

[23] M. Coelho, F. Baptista, V. Fitas da Cruz, and J.L., Garcia, 2006. Comparison of Four Natural Ventilation Systems in a Mediterranean Greenhouse. International Symposium on Greenhouse Cooling. Acta Hortic. 719, 157-164

[24] Ü. Şahin, A. Özdeniz, A. Zülkadir, and R. Alan, 1998. The Effects of Different Growing Media on Yield, Quality and Growth of Tomato (Lycopersicon esculentum Mill.) Grown and Irrigated by Drip Irrigation Method Under the Greenhouses Conditions. Tr. J. of Agriculture and Forestry (22): 71-79.

[25] H. Ünlü, 2001. Effects of Different Hanging Methods and Mulch Use in Open Pole Tomato Cultivation on Plant Growth, Yield and Yield Components. Master Thesis. Süleyman Demirel University, Isparta, Turkey. (in Turkey)

[26] E. Çolpan, 2011. The Effects of Potassium Applications on Yield and Yield Components of Pool Tomatoes (*Lycopersicon Esculentum* L. Var. Lightning). Master Thesis. Selçuk University. Konya, Turkey. (in Turkish)

[27] E. Gomez, J. Costa, M. Amo, A. Alvarruiz, M. Picazo, and E.J. Pardo, 2001. Physicochemical and Colorimetric Evaluation of Local Varieties of Tomato Grown in Spain. Journal of the Science of Food and Agriculture, 81: 1101-1105.

[28] A. Raffo, C. Leonardi, V. Fogliano, P. Ambrosino, M. Salucci, L. Gennaro, R. Bugianesi, F. Giuffrida, and G. Quaglia, 2002. Nutritional Value of Cherry Tomatoes (*lycopersicon esculantum* Cv. Naomi F1) Harvested at Different Ripening Stages. Agricultural and Food chemistry, 50: 6550-6556.

[29] I. Martínez-Valverde M.J. Perıago, G. Provan, and A. Chesson, 2002, Phenolic Compounds, Lycopene and Antioxidant Activity in Commercial Varieties of Tomato (Lycopersicum esculentum). J Sci Food Agr, 82: 323-30.

[30] F. Şen, A. Uğur, M.K. Bozokalfa, D. Eşiyok, and K. Boztok, 2004. Determination of Yield, Quality and Storage Properties of Some Greenhouse Tomato Cultivars. Ege Univ. Journal of Agricultura Faculty, 41 (2): 9-17.

[31] D. Kaur, R. Sharma, A.A. Wani, S. Gill, and D.S. Sogi, 2006. Physicochemical Changes in Seven Tomato (*Lycopersicon esculantum*). Cultivars during Ripening. İnternational Journal of Food Properties, 9: 747-757.

[32] R. Toor, and G.P. Savage, 2006. Effect of Semi-Drying on the Antioxidant Components of Tomatoes. Food Chemistry, 94: 90-97.

[33] A. Özbahçe, and H. Padem, 2007. The Determination of Some Processing Tomato Varieties Having Suitable Superior Yield and Technological Properties in Isparta Ecological Conditions. Süleyman Demirel University, Journal of Institute of Science and Technology, 11(2), 128-133.
[34] N. Turhan, 2007. Determination of Some Chemical Properties of Tomato Varieties Grown in Erzurum Prince and Its Districts. Master Thesis. Erzurum, Turkey. (in Turkish)
[35] A. Bozköylü, 2008. Comparison of Chemical and Organic Fertilization in Soilless Tomato Cultivation. Master Thesis. Adana, Turkey. (in Turkish)
[36] Y. Tüzel, H. Duyar, G.B. Öztekin, and A. Gül, 2009. Effects of tomato rootstocks on plant growth, temperature sum requirements, yield and quality in different planting dates. Ege Üniv. Agric Fac. Journ., 46 (2): 79-92. (in Turkish).
[37] K. Ulukapı, N. Ercan, and A.N. Onus, 2009. Effects of Different Training Systems and Planting Densities on Yield and Quality of M19 F1Tomato Cultivar. Akdeniz Univ. Journal of Agricultural Fac., 22(2): 233-238.
[38] M.M. Maboko, C.P. Du Plooy, and I. Bertling, 2010. Performance of Tomato Cultivars in Temperature and Non- Temperature Controlled Plastic Tunnels. Acta Hortic. 927, 405-411.
[39] D. Zhang, Z. Zhang J. Li, Y. Chang, Q. Du, and T. Pan, 2015. Regulation of Vapor Pressure Deficit by Greenhouse Micro-Fog Systems Improved Growth and Productivity of Tomato via Enhancing Photosynthesis during Summer Season. PLoS ONE, 10(7):1-16.