Cooling





How to avoid crops and animals from being affected by high temperatures

Technical Library

NETAFIM™

By Menahem Dinar

Cooling Greenhouses

Removing excessive heat and humidity appears to be one of the most difficult processes in greenhouse climate control.

The issue of heat accumulation is true for growing in moderate and hot climates, but also in "cold" climates; typical areas where cropping takes place in the cold season, but also in the summer.

The strategy of heat removal from the greenhouse will be determined according to climate conditions and financial aspects.

Basically, there are several possibilities for removing excess heat:

Ventilation - natural + forced ventilation

Shading

Evaporative cooling (pad & fan system or fogging) In addition, there are other means to cool down the temperature of the crop:

1. Air circulators
2. Misting

The effect of air circulation on leaf temperature is indirect and not very significant. The removal of humidity above the leaves will enhance transpiration, followed by reduced leaf temperatures.

The effect of misting on cooling air or crop temperatures could be very helpful in many cases. Misting as a means of cooling in the greenhouse: The misting technique has two main effects as a "cooling procedure" in the greenhouse:

- Effect on air temperature and humidity
- Effect on leaf temperature

Operation on misting by CoolNet™ could fulfill both.

Cooling air

The cooling effect of misting on the greenhouse climate will be through evaporative cooling processes. The small drops will evaporate and will absorb the heat immediately after system's operation, and will reduce air temperatures.

The operation of the system should be for short periods and at short intervals in order to be effective.

If the humidity in the greenhouse will be high, then the small drops will not evaporate and fall down to wet the leaves. Therefore, normally automatic control and operation will require a humidity and temperature sensor programmed to meet the required temperature and humidity.

Cooling the leaf

The effect of misting on reduced leaf temperatures could be a very useful tool, mainly to reduce leaf temperature on the upper part of the plant. Normally, those leaves are exposed to very high temperatures, and sometimes temporary wilting could occur, mainly when water cannot be uptaken by the roots, or cannot supply the high demand for transpiration.

The operation of misting for leaf wetting by CoolNet™, is normally done for longer periods than for air cooling purposes.

Operation for 20-40 seconds or even for 45 seconds with intervals of 20 minutes could serve this purpose well.

Set points of temperature and humidity should also be determined: normally temperatures of 28° -30°C and humidity of 65% -75% could serve as good starting set points.

CoolNet™

Netafim's new very fine mist sprayer, is a efficient means -at a low cost -for improving climatic conditions in greenhouse.

During the growing period, very high heat loads are a common problem, on events that interfere with the optimal development of plants. This phenomenon exists in nearly all-growing regions, and is especially pronounced in low greenhouses. At crops grown in high water drawing conditions, this phenomena is intensified, since the temperatures in the upper part of the greenhouse are very high, and in most cases, effect negatively the plants growing process..

Reducing the heat load in a greenhouse is one of the most difficult processes, and usually requires large capital investment.

- The mist is made of durable materials that are resistant to chemicals and acids (marked as Anti Acid – AA). This enables cleaning of the CoolNet™ by immersion in acid.
- The mister's color is a very light shade of gray – thus contributing to the return radiation inside the greenhouse.
- The CoolNet™ includes 4 nozzles assembled on a cross.
- Discharge capacity of each nozzle:
  7.5 l/h (at 4 bar). The cross CoolNet™ flow rate is 30 l/h (at 4 bar).
- Recommended operating pressure is 4 bar. The average drop size, at pressures of 4 bar, is 90 microns.
- Two types of AD valves (anti-drain)

High pressure

Opening at pressure of 4.0 bar

Closing at pressure of 1.8 bar

Orange colored pin

Medium pressure

Opening at pressure of 3.0 bar

Closing at pressure of 1.5 bar

Green colored pin

Operating principle of cooling

Adding humidity to the greenhouse reduction of temperatures – when the temperatures are high and the humidity is low, the **tiny water droplets** evaporate, and during this process, air temperatures are reduced.

Controlled wetting of leafs exposed to very high heat loads contribute to reducing the leaf's temperature: drops that wet the leafage, evaporate and significantly reduce the leaf's temperature.

System operating principles

- Short operation – the drops evaporate while still in the air – and main effect will be expressed in cooling of the greenhouse. (For example: Activating the system for 3 seconds every 10 minutes).
- When system activation is long – some of the drops will evaporate while still in the air, while others will wet and cool the leafage. (For example: Activating the system for 10 seconds every 15 minutes).
- Various combinations of duration and time intervals between spraying times will result in a combination of the two processes
- Air movement during mist operation will improve the greenhouse cooling process: therefore, ventilation of the air, such as opening side windows and/or opening roof windows or ventilation using ventilators, will enhance the cooling process.
- You must prevent leaves from remaining wet for long periods, and make sure that they dry between the wetting cycles
- If activation is manual, the grower must learn and calibrate operation timing. The shorter the activation time – a majority of the drops, or sometimes all of them, will evaporate before reaching the leafage.
- If the system is controlled by a computer, the set points will activate the system when two conditions are met: humidity is lower than 70% and the temperature is higher than 30°C.

Principles of System Placement and Installation

1. Try to install all CoolNet™ at the maximum possible height – but, of course, prevent wetting of the greenhouse parts.
2. Optimal (at a pressure of 4 atmospheres) will be stable with placement of CoolNet™ at spacing of 2.5 meters in a row, and 3 to 3.2 meters between rows.
3. Since numerous greenhouses are characterized by gable of 8 meters, the rows can be positioned at spacing of 2.5 – 3.0 – 2.5 meters across the rows. In these cases, the distance between CoolNet™ in a row should be 3.0 meters.
4. The CoolNet™ is usually connected to the distribution line using a line whose length is 30, 60 and 90 cm. Since positioning the CoolNet™ as high as possible is the preferred solution – a new unit was developed, that is 15 cm. long, that consists of a short stabilizer that is 5 cm. long, whose wall is thicker, in order to improve its stability.

Mayim & Hashkaya, October 1998

CASE STUDY 11

Cooling protection in greenhouses

The desirable climatic conditions in greenhouses derive from considerations concerning the growth rate, harvest, harvest quality, disease prevention, and so on. These desirable conditions are created by radiation, by temperature, and by the humidity within the greenhouse. The majority of crops benefit from high radiation, and therefore decreasing the heat by way of shading is not desirable. Maintaining the other two conditions (temperature and humidity in the greenhouse) as dependent on conditions within the surrounding environment (outside the greenhouse relative radiation, temperature and humidity) necessitates the controlling of two main parameters: the airflow through the greenhouse and the flow of water for steam. These flows are determined by calculating the balance between energy and the greenhouse's evaporation mass (8-4) and are expressed in the following equations:

Air flow (kg / sec m² - q)

Presuming a stable situation, and ignoring the flow of heat to the soil and to the crop, and supposing that the correct conditions in the greenhouse (temperature and relative humidity) are known, the air flux (q) may be calculated as follows:

$$q = \frac{I\tau\alpha - U(Ti - Ta)}{hi - ha}$$

When:

- I – solar irradiation (Wm^2)
- $\tau\alpha$ – greenhouse solar radiation transfer and absorption coefficient
- U – greenhouse heat transfer coefficient W/Cm^2
- Ti – inside temperature of the greenhouse in °C
- Ta – outside temperature in °C
- hi – thermal dynamics of air in the greenhouse kJ/kg
- ha – thermal dynamics of the surrounding air kJ/kg

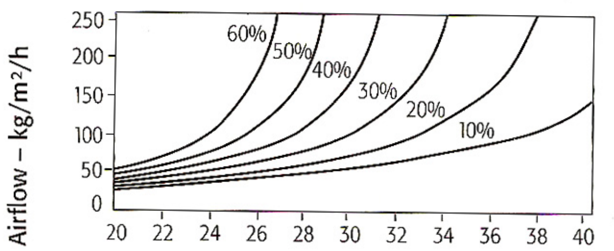

Figure 1: The airflow required to maintain the desired conditions (70%c-27°C) in relation to the temperature and humidity of the surrounding environment

Temperature of surrounding environment in °C

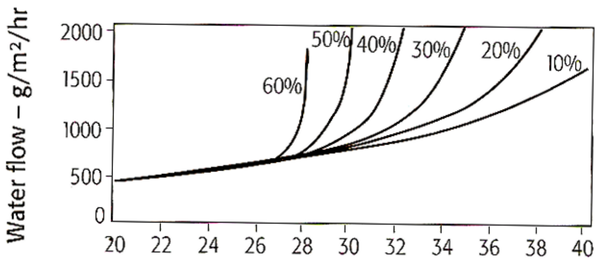

Figure 2: Rate of water evaporation required to maintain the desired conditions (70%C-27°C) in relation to the surrounding environment's temperature and humidity ratio.

Described of the Proposed System

A proposed system includes: softener, filters, tank, pump, pressure regulator, depressurizing valve, supply piping and nozzles. The tap water, treated by softener and filters, is supplied to a tank that is controlled by a ball cock. The water is directed to the supply piping by a high pressure pump. The water pressure at the point of exit from the pump is manually regulated by a pressure regulator. The water is supplied by the pipes to the nozzles. The nozzle housings comprise a valve (that opens at a pressure of 0.5 atmosphere) that prevents leaking while the system is not in operation.

When the system is not in operation, the electrically controlled pressure release valve opens for a short time. Opening this valve ensures fast depressurizing. Closing it at the correct time keeps the pipe full of water at a low pressure, which in turn ensures a fast pressure buildup when the system is switched back on. The speedy decrease and increase of pressure following a lower pressure than the correct range, restricts the creation of large drops (leaking) that cause foliage wetting.

Commercial systems of this type existed at the time that we started our work in this particular field. These systems were characteristically expensive. In order to reduce the cost of the proposed system, a survey on different nozzles was undertaken, which resulted in the pinpointing of nozzles of the following commercial companies: Delavan, and Spraying System. These nozzles demonstrated that they were more reliable and cheaper in comparison to the original nozzles that were installed in the commercial fog systems mentioned above. After that, a comparative test was held that showed that the performance of the nozzles was similar, from the aspects of the size of the drop, and their durability under wear and tear.

Experimental System

An experimental fog system was assembled in the greenhouse at the Schittin school in central Sapir. This greenhouse was divided into two parts, with each part being made up of two sections. Each part comprised the following, computer-controlled system: desert cooler, a north curtain overlapping with the desert cooler, a south curtain, side curtains (east and west), and fans on the south wall. The fog system was assembled in both parts with one central supply system (softener, filters, and pump), and electric taps that control the whole system separately; this setup was to test the fog system in comparison to the desert cooler, during intermittent operation of the two greenhouses (east and west). Due to the fact that the entrance of air, which is possible in this greenhouse, is done by opening the curtains (mainly on the north, west or east sides) the nozzles were distributed according to the following detail: double the density on the pipe closest to the north opening (18 nozzles to a line); all the remaining nozzles are distributed evenly throughout the whole greenhouse area (9 nozzles to a line), with two nozzles positioned at the end of each line next to the west (or east) opening.

In order to characterize the system's operations, a measurement system was set up. This system comprised air-conditioned cells for the measurement of temperature, humidity/dryness (unit). Three of the cells were positioned the length of the internal section in each of the greenhouses, and one cell characterized the surrounding environment. The measurements were collected by a data gathering system. The measurement system calibrates at the beginning of every day by making comparisons with measurements that were made manually on the igrometer machine, of the type "Asman" from "Casella". In addition, measurements of the speed of air through the ventilation apertures were taken.

By Yiftach Ben Asher and Mordecai Shomron

CASE STUDY 12

Leaf temperature in greenhouses

In an open field, it is possible to grow leafy crops in the summer as well. In greenhouses that are sealed against insects, the temperatures reach about 35–45°C at the hottest times of the day. These high temperatures damage the quality of the leaves by seriously scorching and discoloring them, and can even completely destroy the whole greenhouse crop.

In order to utilize greenhouses in summer, and to benefit from the favorable prices of leafy, insect-free crops, it is necessary to search for inexpensive ways to control the climate within them. Many growers spread shade nets over greenhouses where lettuce is grown in soil-less beds. It is probable that the decrease in the flow of radiation into the greenhouse caused by shading with nets, also has a negative effect on the crop, especially in summer. One of the difficulties of cooling the greenhouse by inexpensive means derives from the existing opposition to wetting the foliage due to a fear of leaf disease development.

The accepted cooling air, damaging the plant's self-cooling ability in the given temperatures. According to Jackson and Co.'s theory, in these conditions the difference in temperature between the plant foliage and the air is decreased, causing an accompanying increase in water distress methods are based on two approaches. One is to raise the humidity in the greenhouse by means of a humidity mattress and misting. The second is to use shading nets, to whitewash the greenhouse roof, and so on. The theoretical disadvantages of both these approaches are obvious.

The cooling raises the humidity in the greenhouse, thereby lessening the difference between the steam pressure (V.P.D.), the steam between the foliage, and the greenhouse air, damaging the plant's self-cooling ability in the given temperatures. According to Jackson and Co.'s theory, in these conditions the difference in temperature between the plant foliage and the air is decreased , causing an accompanying increase in water distress(CWSI).

Shading causes a decrease in the total level of radiation that reaches the plant, and as a result there is a decrease in the temperature difference between the foliage and the air, as in the case of increasing the humidity. According to the same theory, this is also accompanied by an increase in water distress. It may be concluded, therefore, that the field experiment showed that shaded lettuce plants were of a lower quality.

As a result, we chose to test the direct wetting cooling method. The theory behind the research is as follows:

1. Direct wetting decreases the average temperature of the leaf water-drop system due to the fact that part of the latent heat in the leaf is passed to the cold water drop.
2. The evaporation procedure of the water drop from the leaf-face causes cooling (cooling by evaporation). Utilization of a larger part of the total radiation as latent heat for steaming is on account of the energy utilized for heating the leaf. In the past, this method of cooling the foliage was not favored because it created ideal temperature and humidity conditions for the development of leaf diseases, an assumption that is correct for crops with extended growing periods, such as roses and tomatoes, but not for short-term crops (30–50 days) like lettuce.

The goals of the research are as follows:

3. To test the effectiveness of the direct wetting cooling method of lettuce foliage (in accordance with the harvested crop).
4. To measure the suitable "bottom line" in cooling lettuce.
5. To measure the degree of water distress (CWSI) in lettuce that is not cooled.

Conclusions

1. The degree of water distress (CWSI) is greatly affected by cooling. Without cooling, the CWSI was measured as 0.4 as opposed to 0ºC. It must be noted that in both methods of treatment (with and without cooling) there were optimal amounts of water but the greenhouse conditions (the high humidity and the speed of the wind restricted by the insect-proof net within the greenhouse) greatly slows the transpiration rate and reduces the plant's ability to cool itself by evaporation. In addition, wetting the foliage artificially with cold water contributes to a decrease in the average temperature of the leaf-drop system.
2. The lettuce crop is clearly affected by operating the misting system, with the plant weight being greater than the accepted non-cooled average. This also applies to a field sample harvested from commercial fields.
3. In addition to the results displayed in Tables 4 and 5, there are another two benefits brought about by using sprinklers for cooling:
4. A 30% increase in the rate of seedling survival.
5. An improvement in the quality of the crop: without cooling, a considerable percentage of the lettuce seedlings are disqualified from marketing, because of discoloring and drying of the foliage. With cooling, this phenomenon was unknown.

The three areas of damage to lettuce grown without cooling (mentioned above)—decrease in the size and quality of the crop and the successful survival of the seedlings—meant that in the years preceding the introduction of direct cooling, there was almost no lettuce grown in greenhouses during the summer months. Financial damage resulted from the need to market two plants instead of a single plant in the product packaging (plastic bag) which in itself contributed to an approximately 50% reduction in the crop per dunam. Further, the substantial percentage of lettuce seedling failure and of scorched plants resulted in the growers deciding not to grow lettuce in summer. However, with the help of cooling, more and more growers are beginning to grow summer lettuce.

By D. H. Willits, M. M. Peet, American Society of Agricultural Engineers, 2000

CASE STUDY 13

Intermittent application of water to an externally mounted greenhouse shade cloth to modify cooling performance

The cooling performance of an externally mounted, flat-woven, black-polypropylene shade cloth (manufacturers shade rating of 55%) was examined under both dry and wet conditions.

Wetting was accomplished by intermittently sprinkling the cloth with water when outside solar levels were greater than 400 W m-2 .

Compared to an unshaded greenhouse, the dry shade cloth reduced the rate of energy gain by about 26%, less than one-half the amount suggested by the shade rating. At the same time, electrical energy consumption was also reduced by about 8% due to reduced operation of the cooling equipment in the shaded house.

Under the wet cloth, the reduction in rate of energy gain improved to about 41%, of which 3.5% was attributable to the increased shading provided by the water-film. Air temperature rise along the house was reduced by 18% under the dry cloth and 40% under the wet cloth. Leaf temperature rise was reduced by only about 9% under the dry cloth: however, the value is misleading because leaf temperatures were reduced nearly uniformly along the house whereas air temperatures were reduced primarily at the exhaust end. Under wet shade, leaf temperature rise was reduced nearly 43% and electrical energy consumption by 21%.

Conclusions

The results of this study support the conclusion that dry, externally mounted, black plastic shade cloths cool significantly less (by any measure) than the amount predicted by their shade rating.

The reduction in rate of energy gain compared to an unshaded control was about 26.2%, less than half the manufacturer's shade rating of the cloth (55%).

A small savings in electrical energy consumption (8.4% in this study) may also be expected due to a decrease in the operational time of the cooling equipment. The results also suggest that reductions in leaf temperature can be expected to be greater than reductions in air temperature, with leaf temperatures being decreased almost uniformly along the house and air temperatures being reduced primarily at the exhaust end.

The results also support the conclusion that the application of water to external shade cloths can be expected increase cooling performance significantly.

NETAFIM™

Reductions in the rate of energy gain under wet shade (compared to an unshaded control) were found to be 41%, with only 3.3% of that attributable to increased shading from the water film. The remainder of the increase over the dry case is attributed to a reduction of cloth temperature due to evaporation of the water. Reduction of air and leaf temperature rise can be expected to be about the same as the reduction in the rate of energy gain. Leaf temperatures were again reduced more than air temperatures but, as with the dry case, the resulting leaf temperatures were more uniform along the house than were air temperatures.

Netafim™ Products

Supernet™

Regulated micro-sprinkler designed to cool from above the whole area or over each tree, mainly tree crops (orchards).

Recommended combinations:

Model	Pressure (bar)	Flow rate (l/hr)	Precipitation (mm/hr)	Distance between sprinklers (m)	Distance between laterals (m)
SR 030	2	30	10	Above each tree	
LR 070	2	70	6.1	3	4
LR 090	2	90	5.9	4	4

Gyronet™

Micro-sprinkler designed to cool from above the whole area or above each tree, mainly for tree crops (orchards).

Recommended combinations:

Model	Pressure (bar)	Flow rate (l/hr)	Precipitation (mm/hr)	Distance between sprinklers (m)	Distance between laterals (m)
SR 030	2	29	10	Above each tree	
LR 070	2	78	3	5	5
LR 120	2	134	3.5	6	6

CoolNet™

Very fine mist system, designed for evaporative cooling. Mainly for use in greenhouses and closed building. Can also be used in open areas.

Recommended combinations:

Model	Pressure (bar)	Flow rate (l/hr)	Precipitation (mm/hr)	Distance between sprinklers (m)
Cross body	4	30	3	3
Single body	4	7.5	1	1.5

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