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Research Paper

Effect of leaf pruning on energy partitioning and microclimate in an insect-proof screenhouse with a tomato crop

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An experiment was conducted to assess the effect of leaf pruning on energy partitioning and microclimate in a screenhouse with a tomato crop. The experiment was conducted in a flat-roof insect-proof screenhouse, 4 m in height with a floor area of 745 m^2, which was ventilated only through the roof. Measurements included global solar radiation inside and outside the screenhouse, net radiation, soil heat flux, transpiration, air velocity and air temperature and humidity. The results showed that leaf pruning in a tomato crop significantly affects energy partitioning in a screenhouse: it reduced transpiration at noon by more than 100%, increased soil heat flux by more than 200% and consequently increased sensible heat flux from crop to screenhouse air by nearly 70%. As a result of leaf pruning, air temperature increased slightly, but vapour-pressure deficit increased significantly. Furthermore, leaf pruning strongly reduced the gradients of temperature and vapour-pressure deficit in the air layer above the canopy at noon, resulting in a more homogeneous environment in the vertical direction. Finally, leaf pruning contributed to a higher air velocity within the canopy, especially at high wind speed.

1. Introduction

Leaf pruning is an important operation in which, by removing unwanted shoots and leaves and lowering the height of the plant, a larger percentage of nutrients can move to the fruit (Bihari & Narayan, 2009). Hence, pruning mature leaves located below the harvest-ripe fruit of high wire-supported greenhouse tomato (*Solanum lycopersicum* L.) has become common practice in many countries. The main reasons for leaf removal are to accelerate fruit ripening, expose the truss for easier harvest and prevent foliage diseases (Heuvelink, Bakker, Elings, Kaarsemaker, & Marcelis, 2005). Furthermore, Kim, Lee, Lee, Sim, and Kim (2014) indicated that tomato yield and quality can be improved by removing some of the leaves attached to the vine. Therefore, they investigated four leaf-removal methods and found that leaving only one leaf above the truss where harvesting begins was optimal under Korean greenhouse conditions.

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Nomenclature

Abbreviations

BAP	Before and after pruning
LAI	Leaf area index
VPD	Vapour pressure deficit

Symbols

L	Latent heat flux (W m^{-2})
N	Net radiation (W m^{-2})
S	Sensible heat flux (W m^{-2})
SO	Soil heat flux (W m^{-2})

Mature tomato leaf pruning may affect climatic conditions within the vegetative surroundings. Canopy transpiration, for example, depends mainly on leaf area together with vapour pressure deficit (VPD) and radiation (Jolliet & Bailey, 1992). Reducing leaf area and solar radiation interception by pruning may reduce canopy transpiration and thereby affect relative humidity and VPD within the canopy environment, as well as inside the whole greenhouse/screenhouse. Leonardi, Guichard, and Bertin (2000) found that during the summer, increased VPD (2.2 versus 1.6 kPa) negatively affected tomato growth and quality, whereas when more leaves were removed, the VPD effect on fruit soluble solids and water content was reduced. Another influence of mature leaf pruning is reduced leaf area index (LAI). Radiation, one of the most important factors influencing tomato yield, is intercepted by the canopy and exhibits a saturating response to LAI, with about 90% of the incident light intercepted at a LAI of 3.0 (Heuvelink, 1996). Thus it has been suggested that tomato yield may be optimised by controlling LAI through leaf pruning (Heuvelink et al., 2005). Starck (1983) observed that partial leaf pruning is compensated for by an increase in net assimilation rate of the remaining leaves, preventing fruit growth from being affected.

In addition to the physiological effects of pruning, there may also be effects on canopy microclimate due to the changes in its size, shape and density. Following leaf pruning in mango trees, air temperature near the canopy was found to increase, while the relative humidity decreased in comparison to the non-pruned canopy (Sharma & Singh, 2006). This was due to the change in evapotranspiration, and the fact that the mango trees were grown in a sort of protected environment. In another study (Impron, Hemming, & Bot, 2008), it was found that a canopy with high LAI will have a cooling effect due to the evaporative cooling effect of transpiration on the interior air temperature.

Ventilation rate in the canopy can be improved after pruning due to less resistance to air flow, which is good for plant health (Farquhar, Zhou, & Haslach, 2003). Furthermore, moderate humidity and air movement in the canopy may increase crop hardiness and fungal disease resistance (Huber & Gillespie, 1992). Bonato and Ridray (2007) suggested that leaf pruning has a strong influence on the development of mirids (*Macrolophus caliginosus*), which are natural predators of whitefly. Their results indicated that with delayed leaf pruning, mirid populations were 60% higher than with regular pruning, and the biological control of whiteflies was more efficient.

Thus, there have been studies on the effects of pruning on physiological, phytological and entomological aspects of crop growth. However, the effect of pruning on canopy microclimate has been mainly described qualitatively in the literature, and not documented quantitatively. This emphasises the need for further investigation into the quantitative influence of pruning on the microclimate of protected crops such as those in greenhouses/screenhouses. In particular, it raises the need to determine the effect of reduced LAI on microclimatic conditions such as air temperature, VPD, vertical temperature and humidity gradients, plant transpiration and air velocity. Furthermore, the effect of pruning on resource use in greenhouses/screenhouses (e.g. water consumption, nutrient consumption, cooling and humidification/dehumidification needs and on energy associated with that) is of interest to growers. This may enhance scientific knowledge and allow extension service workers and growers to improve greenhouse/screenhouse cultivation through a better operation of climate control and other systems.

2. Materials and methods

The experiments were conducted in a flat-roof screenhouse with sloping walls, 4 m in height and a crop floor area of 745 m^2, located at the Besor Experimental Station in southern Israel (31.27077N, 34.3893E, 75 m a.m.s.l). The experiments were done from 26 Sept. to 4 Oct. 2013. The screenhouse was covered with a semi-transparent 50-mesh insect-proof screen (porosity of 0.36, thread diameters of 0.25 $\pm$ 0.005 and 0.26 $\pm$ 0.009 mm and mesh sizes of 0.87 $\pm$ 0.01 and 0.23 $\pm$ 0.017 mm in the warp and weft directions, respectively). In an attempt to simulate large screenhouses, in which the effect of ventilation through the sidewalls is small, impermeable polyethylene sheets were mounted on the sidewalls of the screenhouse. As a result, air exchange between inside and outside took place only through the screen in the roof, similar to the situation found in very large commercial screenhouses.

Transplants of round tomato (4-week-old, cv. 1125) were hand-transplanted into the sandy loam soil beds, in stands of 2 plant m^{-2}. The plants were arranged in 24-m long double rows oriented roughly north–south and separated by about 1.8 m between the centres of adjacent double rows. Drip irrigation including chemical fertilisers in the irrigation water (fertigation) was used during growth. About 2 weeks after transplanting, plants were trained following the high-wire system with the wire at 3 m. About 90 d after transplanting (on 30 Sept. 2013), old leaves were pruned up to the lowest unripe fruit cluster and the whole plant was lowered. The LAIs before and after pruning and plant-height lowering were 3.9 and 0.7, respectively. The heights before and after pruning were 2.9 and 1.6 m, respectively.

A schematic view of the screenhouse and sensors used in the experiment is given in Fig. 1. Air temperature and relative humidity were measured by dry- and wet-bulb T-type thermocouples placed in aspirated boxes that were shielded against direct solar radiation. Vertical and horizontal distributions of temperature and humidity were measured at the