

Thermal infrared hot spot effect of crop canopy: A realistic simulation approach

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In the visible and near infrared (VIS/NIR) region, hot spot effect has been extensively studied for various vegetation canopies. The peak and width of the hotspot reflectance are two typical features related to leaf size and leaf area index. After few experiments reporting significant variations (2-5 deg C) of hot spot variations in the solar principal, hot spot effects in thermal infrared (TIR) were explored by a few scientists. Smith and Ballard (2001) first performed theoretical calculations of TIR hot spot over homogeneous canopy using a 3-D model. For simple homogeneous canopies, they also predict canopy thermal infrared hot spot variations of 2 deg C at the surface with respect to nadir viewing. Similar to VIS/NIR, the dependence of hot spot on leaf size is weak as long as the ratio of leaf size to canopy height is maintained, and the angular width of the hot spot increases as the ratio of leaf diameter to canopy height increases. Atmospheric effects minimize but do not eliminate the TIR hot spot at satellite altitudes. Chen et al. (2002) concluded that the hot spot effect is more difficult than that in VIS/NIR because of the complex energy balance processes.

In this paper, we present here a simulation analysis of thermal hot spot effect over row-planted canopies. Through coupling an energy balance model, Cupid, and a 3-D thermal emission directionality model, TRGM, various conditions which can not be performed in reality are designed to find out the underlying principle of the thermal hot spot effect. We investigated in detail the row structure, LAI, component temperature distribution and microclimate variations and identify their influences on the canopy hotspot effects. The results show that there are typically four types of directional emission shape in principle plane. For each type, there is a local peak around solar direction, which can be defined by a hot spot size and hot spot width. The row direction and row width effect on the hot spot effect is significant. Hot spot size increases as the LAI increases from 0 to 1.5 and then decreases with LAI. Component temperature differences, especially the difference between sunlit soil and shadowed soil, affect the hot spot significantly. When difference increases, hot spot size increases. Wind speed and solar radiation are the most sensitive environmental factor to the hot spot. For the winter wheat canopies, during the growth stage (mainly in April), the maximum hot spot size of wheat canopies is around 0.8 deg C. Finally, the relationship between hot spot and LAI, row structure and component temperature difference is derived and discussed.

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