

## Effects of the Passive Use of Nocturnal Radiative Cooling in Fresh Vegetable Cooling

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### [Summary]

Net radiation flux density of about 40 to 60 W/m<sup>2</sup> is obtained during the clear-sky night in autumn, and by the following morning, lettuces exposed to the atmosphere are cooled down to a temperature almost the same as that achieved by ordinary precooling. In a simple facility that provides shelter from wind or sunlight, this nocturnal radiative cooling effect may be enhanced. Using the net radiation flux density estimated from the temperature difference between the dry bulb temperature and the globe temperature as an index, it is possible to properly open and close the covering.

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### [Background and Objectives]

The authors attempt to identify the cooling effects when fresh vegetables are cooled by exposing them to an environment in which nocturnal radiative cooling is active, in order to save cooling energy by applying the passive use of natural cold thermal energy without using electric coolers. Another objective is to improve the effectiveness of using a simple covering for shelter from wind or sunlight to enhance the radiative cooling effect by developing a method that can appropriately control this covering to fit the ambient temperature and radiation environment.

### [Deliverables and Features]

1. Inside a tent made of two thick opaque covering materials (A and B), the upward value of net radiation flux just above the vegetables (substituted by a ball model) was about 30% of that in the outdoor turf observation field during the night. With a thin covering material (C) with its outer side coated with aluminum layer, the radiation flux was about 50% of that in outdoor. In a tent made of polyethylene film (D), the radiation flux was almost equal to that outside of the tent (Fig. 1).
2. A double pipe-structured house (4.0 m x 5.0 m and 5.0 m x 7.0 m) with its interior lined with a 0.1 mm thick transparent polyethylene film and its exterior lined with a 0.15 mm thick opaque film with one side coated with aluminum layer was set up at the National Institute for Rural Engineering as a nocturnal radiative cooling test facility. Each covering was designed to be rolled up by a manual winder (Fig. 2).
3. With both the inner and outer covering open, the cooling test commenced in the evening of late October when the net radiation flux reversed its direction upward. Lettuce with a temperature of about 20°C at the start of the test cooled down to about 7°C the next morning. The weather was fine that night, with a stable net radiation flux density of about 40 to 60 W/m<sup>2</sup> measured from 17:00 to 5:00 (Fig. 3).
4. When the wind is strong, the cooling effect of radiative cooling may be intensified by rolling down the inner covering to limit heat transfer between the surface of the vegetable and the ambient atmosphere. The body temperature of the vegetable that has been cooled at night may be prevented from rising for 2 to 3 hours before shipping by closing the outer covering early in the morning to shut off sunlight.

5. The difference between the dry bulb temperature and the globe temperature can be used to estimate the strength of radiative cooling without using a net radiometer (Fig. 4), showing that such a technique can serve as an index for appropriate control of the covering.

[Application and Points to Note]

When there is no wind and the humidity is low during a fair night in spring and fall, the nocturnal radiative cooling is very effective. On the other hand, the cooling effect decreases when the weather is cloudy or humidity is high because of the resulting intensification of downward sky radiation and when the wind velocity is high because of the resulting dominance of heat transfer with atmosphere. Therefore, automation of covering control by using the above index is expected to achieve more efficient use of radiative cooling.

[Supporting Data]

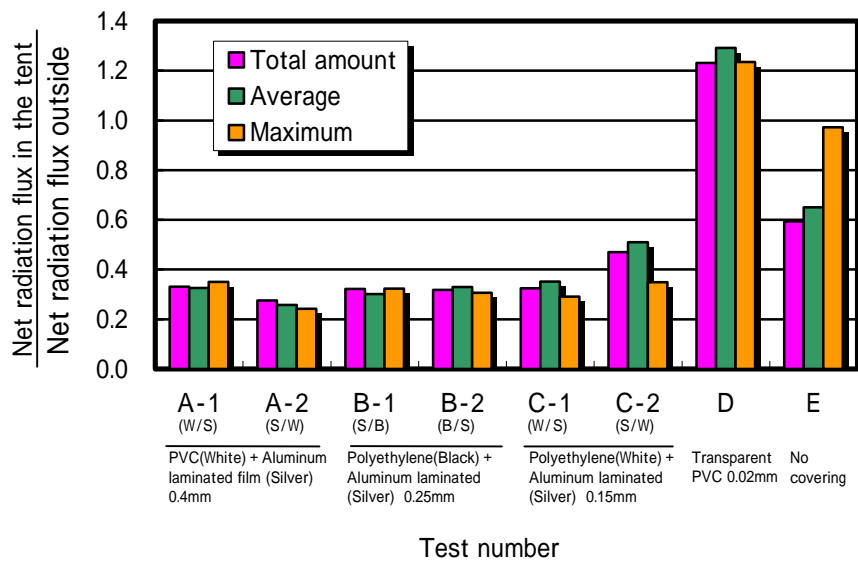


Fig. 1 Effect of covering material and covering arrangement on outgoing radiation in the tent (A to D represent the type of material, while 1 and 2 represent the difference of covering arrangement.)

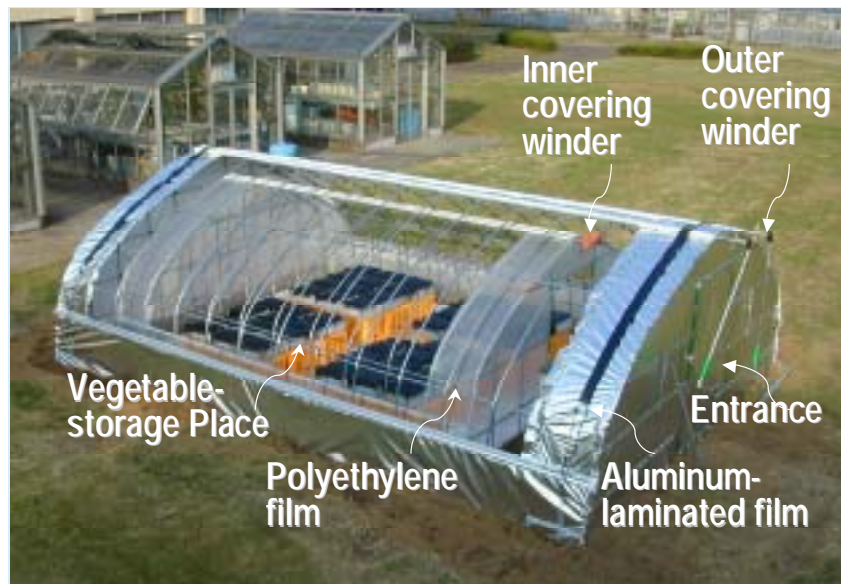


Fig. 2 Double pipe-structured house with capability of full opening/closing (when both the inner and outer covering are fully open)

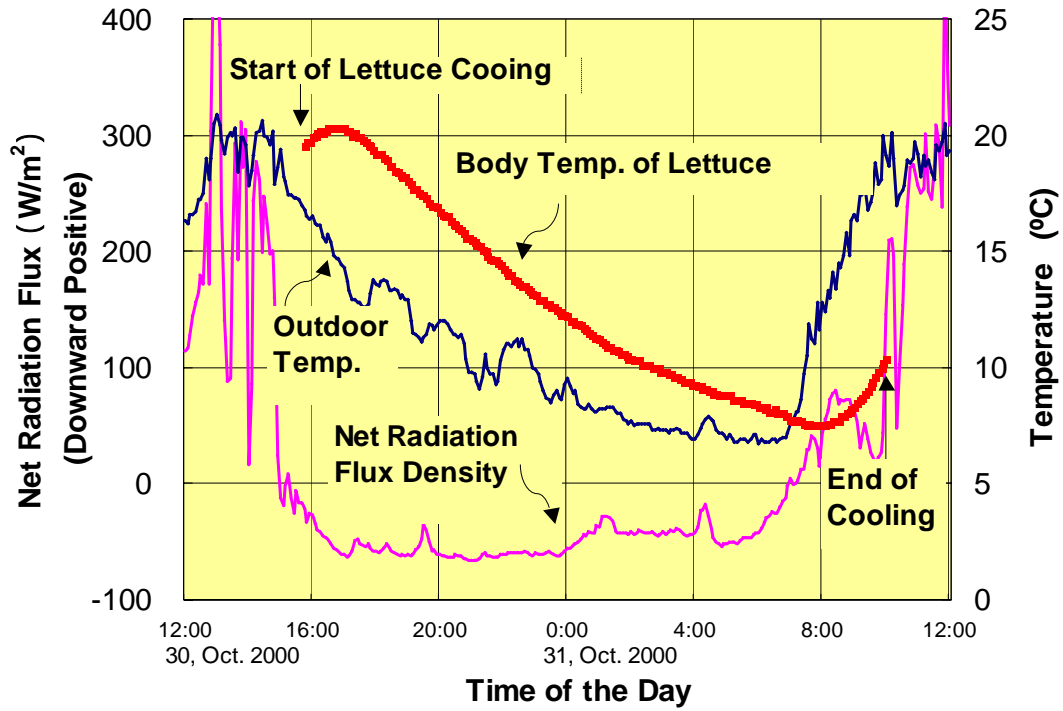


Fig. 3 Change in net radiation flux density in the house and cooling curve of lettuce at clear-sky night

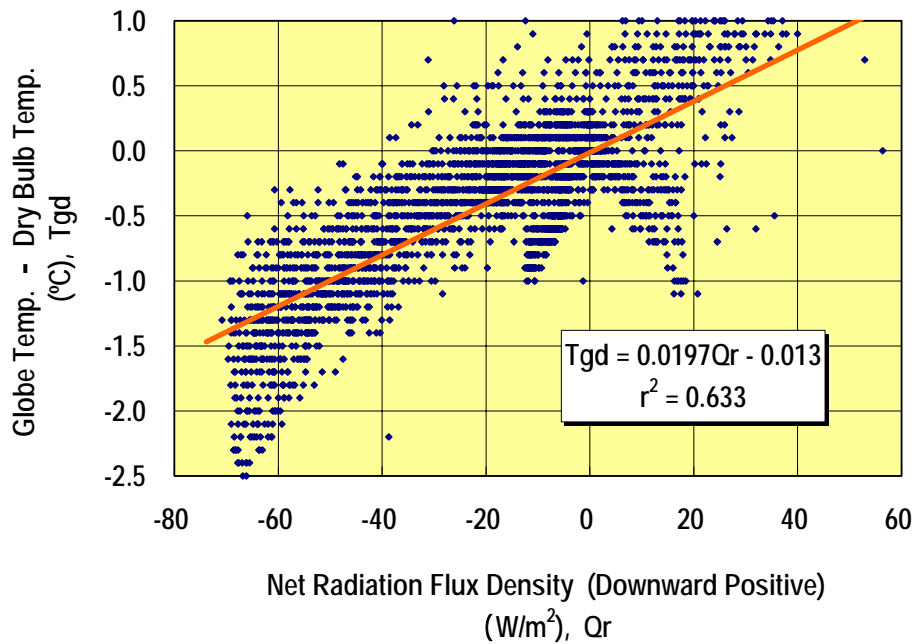


Fig. 4 Relationship of the net radiation flux density with the difference between the globe temperature and dry bulb temperature