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Review

The effect of screened openings on greenhouse microclimate

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Abstract

The use of screens to reduce insect entry into greenhouses has become a common practice in many countries. The screens act as a mechanical barrier that prevents migratory insects from reaching the plants, and thus reduce the incidence of direct crop damage and of insect-transmitted virus diseases. As a consequence, the need for pesticide application is reduced; growers can follow international mandatory regulations, and can use biological control agents as well as insect pollinators. The exclusion of very small insects is achieved by installing fine-mesh screens across the greenhouse openings. Since the porosity (ratio between open and total areas) of these screens is usually low, they impede ventilation and reduce light transmission. Therefore, it is important to determine their resistance to airflow and their optical characteristics, in addition to characterizing their effectiveness against insect entry. Studies in wind tunnels have shown that screens that generated a higher pressure drop for a given incident air velocity caused higher temperature and humidity within a greenhouse. The fine-mesh insect-proof screens reduce the discharge coefficient of the openings, and thus reduce the mean air velocity and turbulence level at the openings. The screens generate small eddies and increase the spectral decay rate of the turbulent flow, and, furthermore, they reduce the air velocities within the greenhouse, which results in higher temperature and humidity gradients there. These problems may be addressed by increasing the area of the openings in naturally ventilated greenhouses or by using forced ventilation. When ventilation does not provide the desired air temperature, artificial cooling systems, such as fan and pad or fogging systems, need to be applied to maintain conditions favorable to plant growth. The present review examines the current literature on the use of insect-proof screens in greenhouses. It summarizes methods for characterizing the pressure drop through screens and screened openings, and examines the effect of screens on the microclimates of greenhouses and screenhouses. Differences among the various studies are discussed and directions for further research are suggested.

Keywords: Screens; Discharge coefficient; Porous media; Microclimate; Ventilation; Insects

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1. Introduction

Insect exclusion is considered a first step in developing an integrated approach to greenhouse pest management. The pests not only damage the crop by direct feeding but may also transmit phytopathogenic organisms (Bethke and Paine, 1991). The exclusion is obtained by installing fine-mesh screens, which act as mechanical barriers, on the greenhouse openings. The main purpose of the screens is to prevent migratory insects from reaching the plants. Hence, the use of screens facilitates considerable reduction of pesticide application. Although the application of screens has proved cost-effective for both growers and consumers (Taylor et al., 2001) it created a problem since screens impede ventilation and in some cases reduce light transmission (Bethke et al., 1994; Klose and Tantau, 2004). Since ventilation and light are essential for satisfactory crop growth, as good ventilation limits the increase in internal temperature and humidity and light is essential for photosynthesis, there has been a worldwide effort to improve the performance of screens with regard to these parameters.

To exclude very small insects, e.g. *thrips*, screens with very small mesh size are needed. Berlinger et al. (2002) indicated that the rate of penetration by insects is directly proportional to the mesh size of the screen. However, Bethke and Paine (1991) postulated that an insect's ability to pass through any barrier cannot be predicted solely from its thoracic width and the mesh size; they showed that the hole geometry, or the way in which holes were formed, is an important factor in insect exclusion.

The average sizes of some of the most common pests that attack greenhouse crops (Bethke and Paine, 1991; Bethke, 1994) and the maximum sizes of the openings in a screen to exclude the insects (Ross and Gill, 1994; Bailey, 2003) are given in Table 1. Generally, most physical control methods such as screens are environmentally safe, fit well into integrated pest management strategies (release of biocontrol agents), allow pollination by bumble bees, and reduce the use of chemical controls. Thus, the screens contribute to the protection of the environment through the reduction in pesticide application. To be effective, all greenhouse openings, including the entrance, must be totally covered by screens.

Several authors have studied the flow-resistance characteristics of various screening materials. In those studies, the resistance to airflow caused by the screens was determined, either by using equations derived for free and forced fluid flow through porous materials (Miguel et al., 1997, 1998; Miguel and Silva, 2000) or by means of a ‘‘coefficient of discharge’’ obtained from Bernoulli's equation (Brundrett, 1993; Kosmos et al., 1993; Munoz et al., 1999; Teitel et al., 1999). When the screens are installed on greenhouse openings they change the airflow through the openings and as

Table 1
The average sizes of some of the most common pests that attack greenhouse crops and the maximum sizes of the openings in a screen that can exclude these insects (Bethke and Paine, 1991; Bethke, 1994; Ross and Gill, 1994; Bailey, 2003)

Common name	Scientific name	Thorax (micrometer)	Mesh size (micrometer)
Western flower *thrips*	*Frankliniella occidentalis*	184.4 (male), 245.5 (female)	190
Silverleaf whitefly	*Bemisia argentifolii*	239	240
Greenhouse whitefly	*Trialeurodes vaporariorum*	288	290
Melon aphid	*Aphis gossypii*	355 (female)	340
Sweet potato whitefly	*Bemisia tabaci*	215.8 (male), 261.3 (female)	462
Serpentine leaf miner	*Liriomyza trifolii*	562.5 (male), 653.8 (female)	610